38/502/FDIS

FINAL DRAFT INTERNATIONAL STANDARD
PROJET FINAL DE NORME INTERNATIONALE

	Project number Numéro de projet	**IEC 61869-9 Ed. 1.0**
	IEC/TC or SC CEI/CE ou SC **38**	Secretariat / Secrétariat **Italy**
☒ Submitted for parallel voting in CENELEC Soumis au vote parallèle au CENELEC	Distributed on / Diffusé le **2016-02-12**	Voting terminates on / Vote clos le **2016-03-25**

Also of interest to the following committees Intéresse également les comités suivants 13 - 17C - 57 - 85 - 95 - 115	Supersedes document Remplace le document 38/438A/CDV; 38/453A/RVC

Horizontal standard
Norme horizontale

☐ Other TC/SCs are requested to indicate their interest, if any, in this FDIS to the TC/SC secretary
Les autres CE/SC sont requis d'indiquer leur intérêt, si nécessaire, dans ce FDIS à l'intention du secrétaire du CE/SC

Functions concerned
Fonctions concernées

☐ Safety Sécurité	☐ EMC CEM	☐ Environment Environnement	☐ Quality assurance Assurance de la qualité

CE DOCUMENT EST UN PROJET DIFFUSÉ POUR APPROBATION. IL NE PEUT ÊTRE CITÉ COMME NORME INTERNATIONALE AVANT SA PUBLICATION EN TANT QUE TELLE.

OUTRE LE FAIT D'ÊTRE EXAMINÉS POUR ÉTABLIR S'ILS SONT ACCEPTABLES À DES FINS INDUSTRIELLES, TECHNOLOGIQUES ET COMMERCIALES, AINSI QUE DU POINT DE VUE DES UTILISATEURS, LES PROJETS FINAUX DE NORMES INTERNATIONALES DOIVENT PARFOIS ÊTRE EXAMINÉS EN VUE DE LEUR POSSIBILITÉ DE DEVENIR DES NORMES POUVANT SERVIR DE RÉFÉRENCE DANS LES RÈGLEMENTATIONS NATIONALES.

LES RÉCIPIENDAIRES DU PRÉSENT DOCUMENT SONT INVITÉS À PRÉSENTER, AVEC LEURS OBSERVATIONS, LA NOTIFICATION DES DROITS DE PROPRIÉTÉ DONT ILS AURAIENT ÉVENTUELLEMENT CONNAISSANCE ET À FOURNIR UNE DOCUMENTATION EXPLICATIVE.

THIS DOCUMENT IS A DRAFT DISTRIBUTED FOR APPROVAL. IT MAY NOT BE REFERRED TO AS AN INTERNATIONAL STANDARD UNTIL PUBLISHED AS SUCH.

IN ADDITION TO THEIR EVALUATION AS BEING ACCEPTABLE FOR INDUSTRIAL, TECHNOLOGICAL, COMMERCIAL AND USER PURPOSES, FINAL DRAFT INTERNATIONAL STANDARDS MAY ON OCCASION HAVE TO BE CONSIDERED IN THE LIGHT OF THEIR POTENTIAL TO BECOME STANDARDS TO WHICH REFERENCE MAY BE MADE IN NATIONAL REGULATIONS.

RECIPIENTS OF THIS DOCUMENT ARE INVITED TO SUBMIT, WITH THEIR COMMENTS, NOTIFICATION OF ANY RELEVANT PATENT RIGHTS OF WHICH THEY ARE AWARE AND TO PROVIDE SUPPORTING DOCUMENTATION.

Title

IEC 61869-9: Instrument Transformers - Part 9: Digital interface for instrument transformers

ATTENTION VOTE PARALLÈLE CEI – CENELEC	**ATTENTION IEC – CENELEC PARALLEL VOTING**
L'attention des Comités nationaux de la CEI, membres du CENELEC, est attirée sur le fait que ce projet finale de Norme internationale est soumis au vote parallèle. Les membres du CENELEC sont invités à voter via le système de vote en ligne du CENELEC.	The attention of IEC National Committees, members of CENELEC, is drawn to the fact that this final draft International Standard (DIS) is submitted for parallel voting. The CENELEC members are invited to vote through the CENELEC online voting system.

Copyright © 2016 International Electrotechnical Commission, IEC. All rights reserved. It is permitted to download this electronic file, to make a copy and to print out the content for the sole purpose of preparing National Committee positions. You may not copy or "mirror" the file or printed version of the document, or any part of it, for any other purpose without permission in writing from IEC.

® Registered trademark of the International Electrotechnical Commission

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

INSTRUMENT TRANSFORMERS –

Part 9: Digital interface for instrument transformers

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 61869-9 has been prepared by IEC technical committee 38: Instrument transformers.

This first edition replaces the corresponding specific requirements previously contained in IEC 60044-8, published in 2002.

The text of this standard is based on the following documents:

FDIS	Report on voting
38/XX/FDIS	38/XX/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61869 series, published under the general title *Instrument transformers*, can be found on the IEC website.

This publication contains an attached file in the form of a .xml file. This file is intended to be used as a complement and does not form an integral part of the publication.

This International Standard contains specific requirements for electronic low power instrument transformers (LPIT) having a digital output.

This Part 9 is to be read in conjunction with, and is based on, IEC 61869-1:2007, *General Requirements* and IEC 61869-6:2016. However, the reader is encouraged to use its most recent edition.

This Part 9 follows the structure of IEC 61869-6 and IEC 61869-1 and supplements or modifies their corresponding clauses/subclauses.

When a particular clause/subclause of Part 6 is not mentioned in this Part 9, that clause/subclause applies. When this standard states "addition", "modification" or "replacement", the relevant text in Part 6 is to be adapted accordingly.

When a particular clause/subclause of Part 1 is not mentioned in Part 6, that clause/subclause applies. When part 6 states "addition", "modification" or "replacement", the relevant text in Part 1 is to be adapted accordingly.

For additional clauses, subclauses, figures, tables, annexes or note, the following numbering system is used:

– clauses, subclauses, tables, figures and notes that are numbered starting from 901 are additional to those in Part 1;
– additional annexes are lettered 9A, 9B, etc.

An overview of the planned set of standards at the date of publication of this document is given below. The updated list of standards issued by IEC TC38 is available at the website: www.iec.ch

<table>
<tr><th colspan="2">PRODUCT FAMILY STANDARDS</th><th>PRODUCT STANDARD IEC</th><th>PRODUCTS</th><th>OLD STANDARD IEC</th></tr>
<tr><td rowspan="13">61869-1
GENERAL REQUIREMENTS FOR INSTRUMENT TRANSFORMERS</td><td rowspan="4"></td><td>61869-2</td><td>ADDITIONAL REQUIREMENTS FOR CURRENT TRANSFORMERS</td><td>60044-1
60044-6</td></tr>
<tr><td>61869-3</td><td>ADDITIONAL REQUIREMENTS FOR INDUCTIVE VOLTAGE TRANSFORMERS</td><td>60044-2</td></tr>
<tr><td>61869-4</td><td>ADDITIONAL REQUIREMENTS FOR COMBINED TRANSFORMERS</td><td>60044-3</td></tr>
<tr><td>61869-5</td><td>ADDITIONAL REQUIREMENTS FOR CAPACITOR VOLTAGE TRANSFORMERS</td><td>60044-5</td></tr>
<tr><td rowspan="9">61869-6
ADDITIONAL GENERAL REQUIREMENTS FOR LOW POWER INSTRUMENT TRANSFORMERS</td><td>61869-7</td><td>ADDITIONAL REQUIREMENTS FOR ELECTRONIC VOLTAGE TRANSFORMERS</td><td>60044-7</td></tr>
<tr><td>61869-8</td><td>ADDITIONAL REQUIREMENTS FOR ELECTRONIC CURRENT TRANSFORMERS</td><td rowspan="3">60044-8</td></tr>
<tr><td>61869-9</td><td>DIGITAL INTERFACE FOR INSTRUMENT TRANSFORMERS</td></tr>
<tr><td>61869-10</td><td>ADDITIONAL REQUIREMENTS FOR LOW POWER PASSIVE CURRENT TRANSFORMERS</td></tr>
<tr><td>61869-11</td><td>ADDITIONAL REQUIREMENTS FOR LOW POWER VOLTAGE TRANSFORMERS</td><td>60044-7</td></tr>
<tr><td>61869-12</td><td>ADDITIONAL REQUIREMENTS FOR COMBINED ELECTRONIC INSTRUMENT TRANSFORMERS AND COMBINED STAND ALONE INSTRUMENT TRANSFORMERS</td><td></td></tr>
<tr><td>61869-13</td><td>STAND ALONE MERGING UNIT</td><td></td></tr>
<tr><td>61869-14</td><td>ADDITIONAL REQUIREMENTS FOR DC CURRENT TRANSFORMERS</td><td></td></tr>
<tr><td>61869-15</td><td>ADDITIONAL REQUIREMENTS FOR DC VOLTAGE TRANSFORMERS FOR DC APPLICATIONS</td><td></td></tr>
</table>

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

The National Committees are requested to note that for this publication the stability date is 2019.

THIS TEXT IS INCLUDED FOR THE INFORMATION OF THE NATIONAL COMMITTEES AND WILL BE DELETED AT THE PUBLICATION STAGE.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

General

This standard is a product family standard for instrument transformers. It provides an application of the standard series IEC 61850, which details layered substation communication architecture in the world of instrument transformers.

By providing tutorial material such as examples and explanations, it also provides access for instrument transformer, protective relay and meter experts to concepts and methods applied in the IEC 61850 series.

Compared to instrument transformers, digital communication technology is subject to on-going changes which are expected to continue in the future. Significant experience with electronics integrated directly into instrument transformers has yet to be gathered on a broader basis, as this type of equipment is not widely spread in the industry and a change of paradigm has not yet occurred.

Position of this standard in relation to the IEC 61850 series

The IEC 61850 series is a standard intended to be used for communication networks and systems for power utility automation. The most important parts of this series define:

a) information models for the substation automation system;
b) these information models include both the models of the instrument transformers and other process equipment (like circuit-breakers and disconnectors), and the models of the substation automation system (like protection relays and meters). The models are defined in IEC 61850-7-3 and IEC 61850-7-4;
c) the communication between intelligent electronic devices (IEDs) of the substation automation system. The abstract models are defined in IEC 61850-7-2 and the mappings on communication stacks are defined in IEC 61850-8-1 and IEC 61850-9-2;
d) a configuration language used to describe the configuration aspects of the substation automation system is described in IEC 61850-6;
e) conformance testing of the communication interfaces of the IEDs of the power utility automation system including their data models. The conformance testing is defined in IEC 61850-10.

Typically, in a traditional system, IEDs like bay level controllers or protection relays interface directly through analogue signals to instrument transformers. In that case, the data models of the instrument transformers are implemented in these bay level devices. However, this is not the only realization. In the case where electronics are integrated directly into electronic LPIT, the above-mentioned data models should be implemented within the instrument transformer and the instrument transformer needs to support a communication interface. The part of an electronic LPIT that does this is known as the merging unit.

IEC 61850, being a system oriented standard series, leaves many options open in order to support present and future requirements of all sizes of substations at all voltage levels.

To reduce the engineering amount required to achieve interoperability for the digital interface between instrument transformers and equipment that uses the digital signal (like protective relays, meters or bay level controllers), this standard specifies additional constraints on implementing a digital communication interface.

The IEC 61869-9 standard:

– replaces the IEC 60044-8 digital solution;

– provides a product standard for instrument transformers with a digital interface according to the IEC 61850 series; similar to what IEC 62271-3 offers for switchgear;
– includes backward compatibility for the UCA International Users Group *Implementation Guideline for Digital Interface to Instrument Transformers Using IEC 61850-9-2*;
– uses IEC 61588 based time synchronization in accordance with IEC PAS 61850-9-3, with an option for 1PPS (pulse per second).

Overview of the digital interface for instrument transformers

An illustrative general block diagram of an instrument transformer with digital output is shown in Figure 901. It shows multiple current and/or voltage information coming from the secondary converters (SC in Figure 901) and fed into a common block labelled “merging unit”. The merging unit performs all the data processing (sampling, analogue to digital conversion, scaling, message formatting, etc.) necessary to produce a time-coherent output data stream according to this standard. For the purposes of this standard a merging unit is a physical unit (hardware subsystem) used to assemble and transmit digital output data frames.

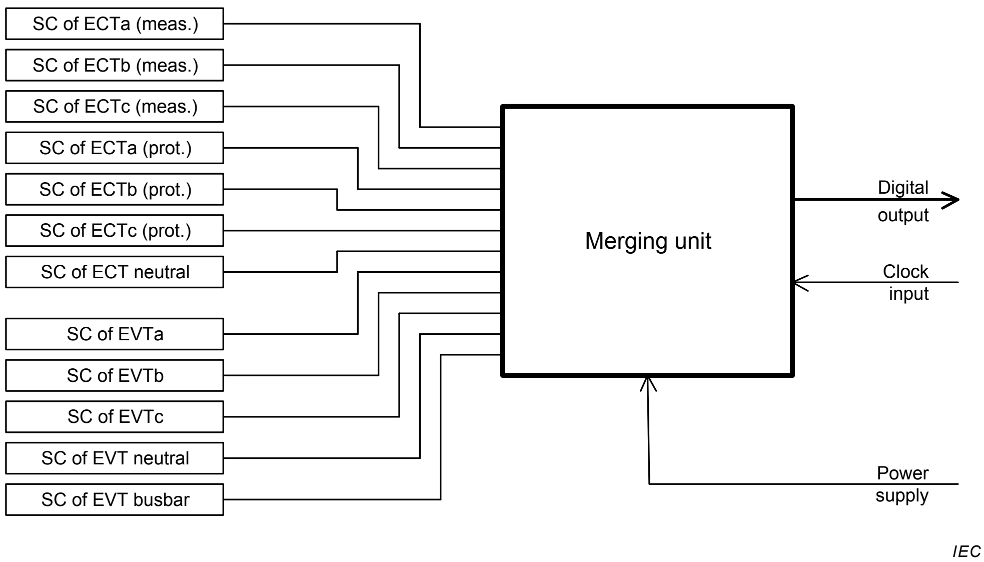


Figure 901 – General block diagram of an electronic LPIT with digital output

A merging unit is modelled as one or more logical devices that contain multiple logical nodes as illustrated in Figure 902.

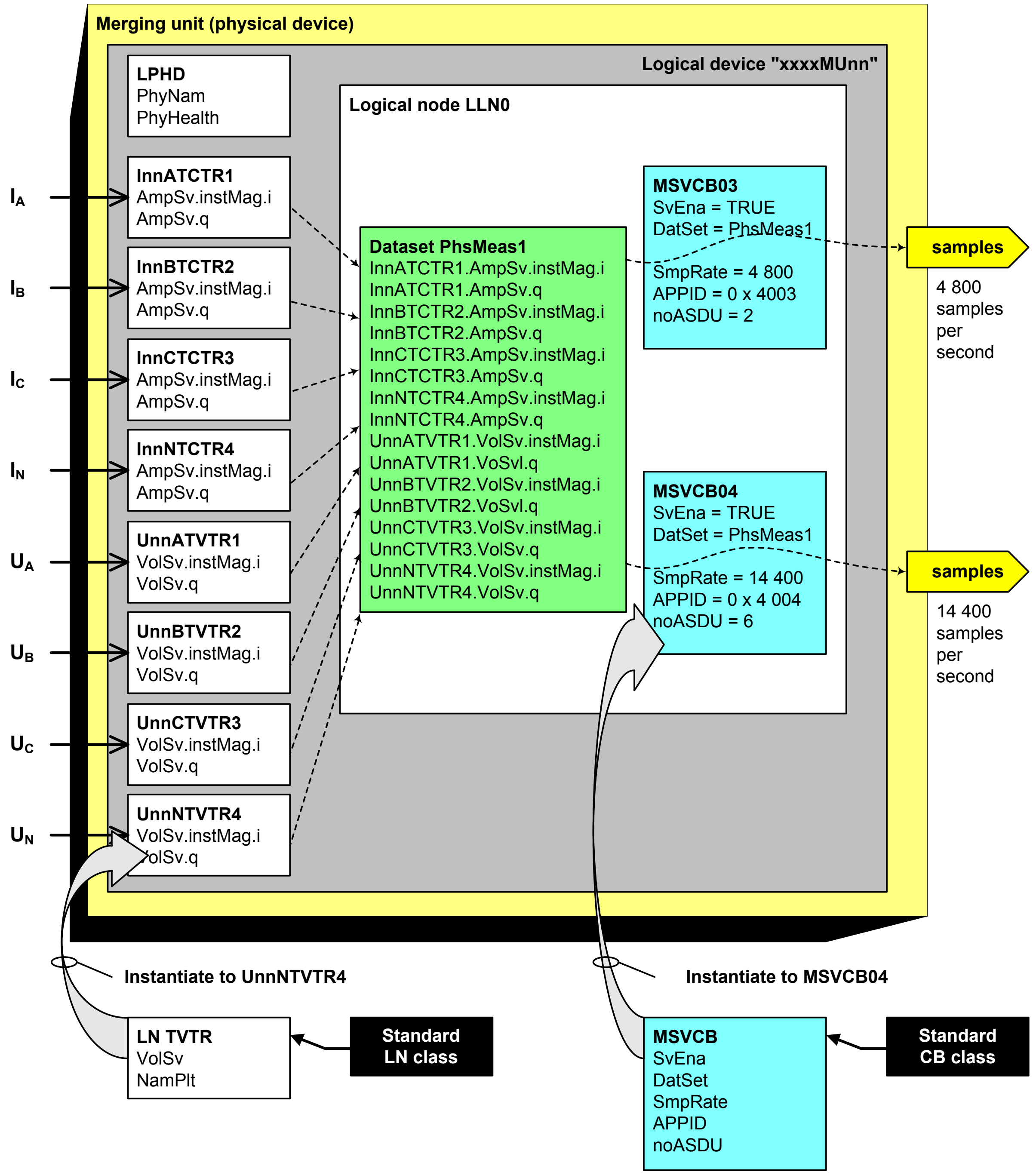


Figure 902 – General illustration of the objects within a merging unit (example)

Current and voltage measurements in the example merging unit in Figure 902 are modelled per IEC 61850-7-1 by using the following logical nodes:

- Class **TCTR** per IEC 61850-7-4, instantiated individually for each of the three current transformer phases, and for the neutral current measurement.
- Class **TVTR** per IEC 61850-7-4, instantiated individually for each of the three voltage transformer phases, and for the neutral voltage measurement.
- Logical node zero **LLN0** containing instances of the sampled value control blocks (MSVCB03 and MSVCB04 in this example) controlling simultaneous publishing of IEC 61850-9-2 data streams (in this example one with 4 800 samples per second and 2 samples per frame yielding a frame rate of 2 400 per second, the other with 14 400 samples per second and 6 samples per frame also yielding a frame rate of

2 400 per second), and a dataset that controls the content of the sampled value digital output messages.

Applicable sample rates, time synchronization, control blocks and dataset are defined in this standard.

Physical realization of the above concepts may vary with the applied technology determining which parts are necessary for the realization of an actual instrument transformer. One such realization showing an electronic LPIT with built-in digital data output is shown in Figure 903 and further described in the relevant product specific standards in the IEC 61869 series (Part 7, Part 8, Part 12, Part 14, Part 15).

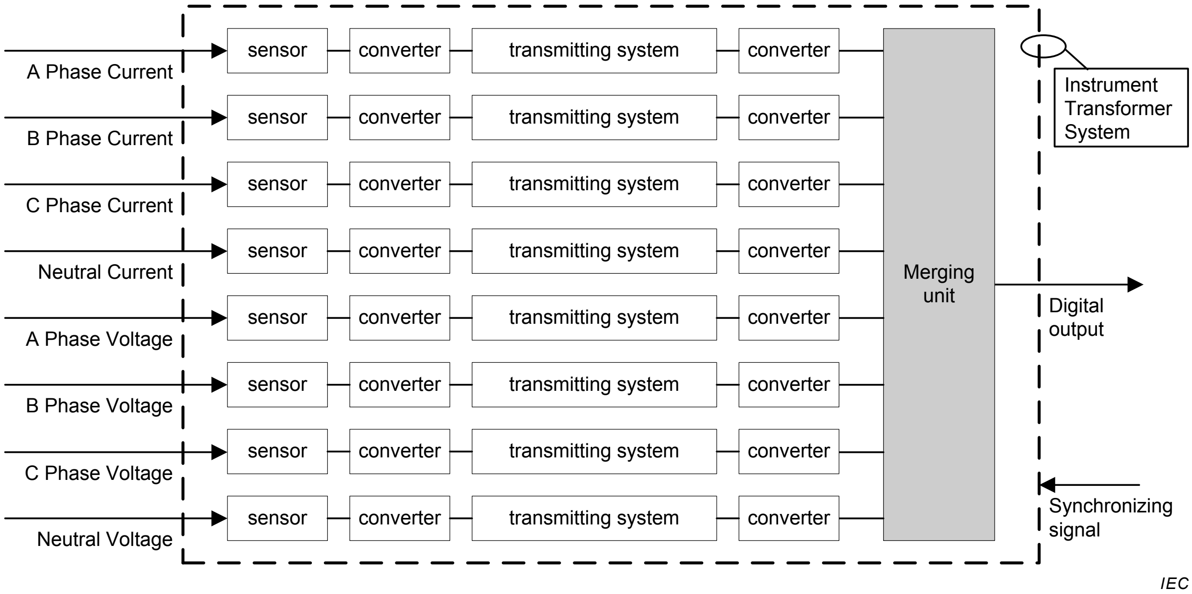
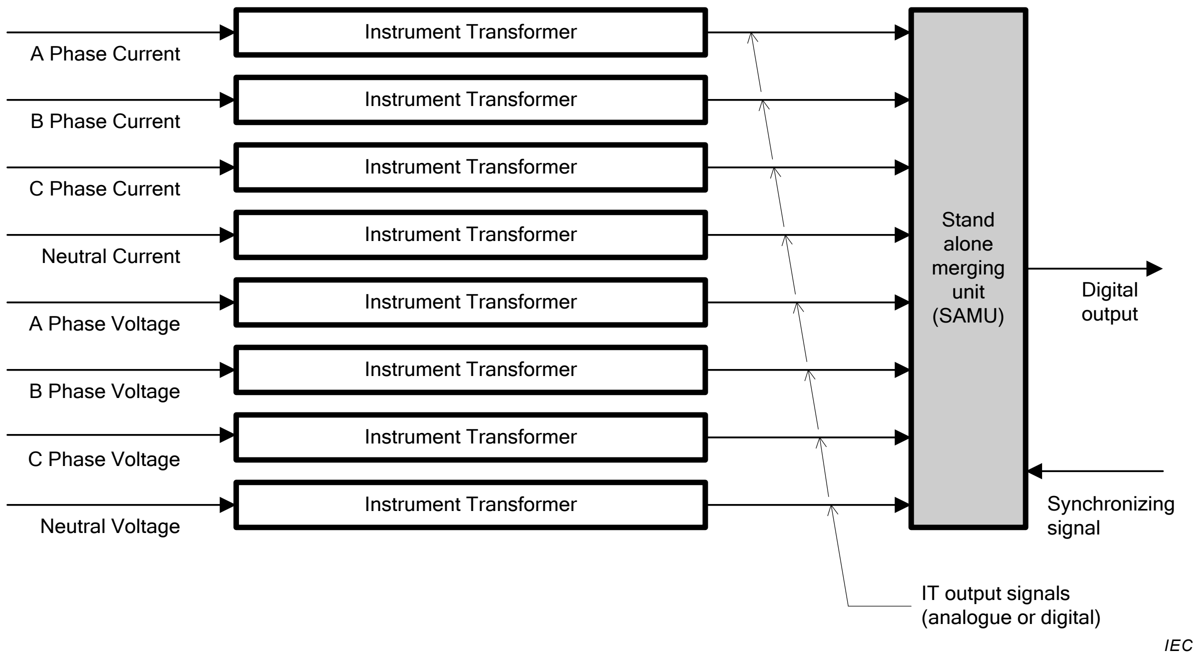


Figure 903 – Electronic LPIT with digital output (concept example)

It is not absolutely necessary that all parts shown in Figure 903 be included. For clarity, power supplies are not shown here. An instrument transformer may be implemented in a single physical unit or in multiple physical units. For example, there may be a separate physical unit for each phase containing the primary voltage and/or current sensors, primary converters and primary insulation, with all secondary converters and the merging unit in a separate physical unit located in the control house. The number of primary inputs and their type (voltage or current) in a single instrument transformer may be other than shown here.

For comparison, an illustrative general block diagram of an installation using a stand-alone merging unit (SAMU) is shown in Figure 904. Unlike the merging unit in an instrument transformer, a SAMU is a separate product covered in IEC 61869-13. It accepts as inputs the outputs of instrument transformers, said outputs conforming to the specifications of one of the product standards in the IEC 61869 series. The number of inputs and their type (voltage or current) may be other than shown in Figure 904. Output produced by a SAMU and output produced by an electronic LPIT with built in merging unit should in principle be indistinguishable from each other (excluding the fact that SAMU output will typically have lower accuracy due to cascading the separately given instrument transformer and SAMU accuracy specifications).



An example will be presented in IEC 61869-13[1], as soon as this standard will be available.

Figure 904 – Standalone merging unit

[1] Under consideration.

INSTRUMENT TRANSFORMERS –

Part 9: Digital interface for instrument transformers

1 Scope

This part of IEC 61869 is a product family standard applicable to instrument transformers with digital output. The product standard is composed of IEC 61869-1 and IEC 61869-6, in addition to this standard and the relevant product specific standards in the IEC 61869 series (Part 7, Part 8, Part 12, Part 13, Part 14, and Part 15).

This standard defines requirements for digital communications of instrument transformer measurements. It is based on the IEC 61850 series, UCA international users group document *Implementation guideline for digital interface to instrument transformers using IEC 61850-9-2*, and the relevant parts of IEC 60044-8 that are replaced by this standard. It includes additional improvements including the IEC 61588 network based time synchronization.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Clause 2 of IEC 61869-6:2016 is applicable with the following additions:

IEC 61588:2009, *Precision clock synchronization protocol for networked measurement and control systems*

IEC 61850-6:2009, *Communication networks and systems for power utility automation – Part 6: Configuration description language for communication in electrical substations related to IEDs*

IEC 61850-7-1:2011, *Communication networks and systems for power utility automation – Part 7-1: Basic communication structure – Principles and models*

IEC 61850-7-2:2010, *Communication networks and systems for power utility automation – Part 7-2: Basic information and communication structure – Abstract communication service interface (ACSI)*

IEC 61850-7-3:2010, *Communication networks and systems for power utility automation – Part 7-3: Basic communication structure – Common data classes*

IEC 61850-8-1:2011, *Communication networks and systems for power utility automation – Part 8-1: Specific communication service mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3*

IEC 61850-9-2:2011, *Communication networks and systems for power utility automation – Part 9-2: Specific communication service mapping (SCSM) – Sampled values over ISO/IEC 8802-3*

IEC PAS 61850-9-3:2015, *Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation*

IEC 61850-10:2012, *Communication networks and systems for power utility automation – Part 10: Conformance testing*

IEC 61869-6:2016, *Instrument transformers – Part 6: Additional general requirements for low-power instrument transformers*

UCA (International Users Group), *Implementation guideline for digital interface to instrument transformers using IEC 61850-9-2*

3 Terms and definitions

3.5 Terms and definitions related to other ratings

For the purposes of this document, the terms and definitions in IEC 61869-6:2016 apply, with the following additions:

3.5.901
rated holdover time
rated duration over which the merging unit continues to send samples maintaining the sample timing required for the measuring accuracy class following loss of the time signal

3.5.902
processing delay time
t_{pd}
difference between the time encoded by the field SmpCnt in a digital output message and the time this message appears at the digital output

3.5.903
maximum processing delay time
longest processing delay time (t_{pd}) under all rated operating conditions

3.5.904
free running mode
operating mode where sampled values issued by the merging unit are not synchronised to an external clock to the degree required to meet the measuring accuracy class phase error limit

Note 1 to entry: The values are based on an internal clock oscillator.

3.7 Index of abbreviations

Index of abbreviations of IEC 61869-6:2016 is extended by the addition of the following:

9-2LE	The sampled value protocol defined by UCA International Users Group document *Implementation Guideline for Digital Interface to Instrument Transformers using IEC 61850-9-2*, modification Index R2-1 dated 2004-07-07
ASDU	Application Service Data Unit
ACSI	Abstract Communications Service Interface
SCSM	Specific Communication Service Mapping
SAV	Common data class defined in IEC 61850-7-3:2010, 7.4.4 for modelling sampled values.
TCTR	Logical node defined in IEC 61850-7-4:2010, 5.15.4 for modelling sampled values from current transformers
TVTR	Logical node defined in IEC 61850-7-4:2010, 5.15.20 for modelling sampled values from voltage transformers

SCL System Configuration description Language according to IEC 61850-6:2009, Clause 4

ICD IED Capability Description file according to IEC 61850-6:2009, 5.3

IED Intelligent Electronic Device

SAS Substation Automation System

MU Merging Unit

SAMU Stand Alone Merging Unit

EMC ElectroMagnetic Compatibility

4 Normal and special service conditions

Clause 4 of IEC 61869-1:2007 applies.

5 Ratings

5.6 Rated accuracy class

Accuracy classes for electronic LPIT with digital output are defined in the applicable IEC 61869 series product standards Part 7, Part 8, Part 12, Part 13, Part 14, and Part 15. Accuracy class specifications apply end-to-end, representing all errors introduced between the instrument transformer primary and the properly time-stamped message created at the digital output.

Accuracy specifications directly incorporate all errors associated with time synchronization. Time synchronization requirements are as described in 6.904.

With regard to accuracy classes, instrument transformers with digital output shall be classified in two groups:

- measuring instrument transformers,
- protection instrument transformers.

To make best use of the dynamic range enabled by the 32-bit message format specified in this standard, all protection instrument transformers and protection capable SAMU channels shall be specified with dual accuracy class ratings. Dual rating is intended to precisely document the measuring and protection accuracy class applicable to a given channel.

The dual rating requirement acknowledges the fact that protection rated instrument transformers are commonly also used for measurement and indication purposes. It establishes a proven, well understood method for documenting this performance.

The protection instrument transformer accuracy class shall be given as a slash "/" symbol separated pair, with measuring accuracy class taking the first position and the protection accuracy class followed by the accuracy limit factor K_{ALF} at the end. Dual specification shall be reported on the digital instrument transformer nameplate.

Rating examples:

0,2S 0,2S class measuring instrument transformer (not rated for protection)

0,2S/5P20 5P20 protection instrument transformer meeting class 0,2S measuring accuracy class requirements

5.901 Performance requirements

Electronic LPIT with digital output shall meet all the requirements defined in IEC 61869 specific product standards Part 7, Part 8, Part 12, Part 13, Part 14, and Part 15. This requirement therefore extends to the merging unit component which is an integral part of the instrument transformer apparatus, and is therefore subject to the same environmental and EMC conditions.

Depending on the device conformance class defined in 6.903.13, the merging unit component may be exposed to various levels of Ethernet network traffic. Although it is impossible to foresee all operating environments, the following recommendations are provided based on real life field experience:

- merging unit behaviour should be well defined under all operating conditions;
- if present, the test signal generating capability should be disabled by default;
- all data included in the same ASDU (including quality bits) should be mutually consistent and represent the same time instant as required by the applicable accuracy class specification;
- data shall be synchronized to a common time reference as described in 6.904.

Merging units should have well defined behaviour under all operating conditions. This especially applies during power-up, power-down and self-diagnostic system failure indications (as required by IEC 61869-6:2016, 6.604). While the merging unit output (data stream) may become unavailable at any time (through component failure), when present, quality bits within the stream should faithfully represent the electronic LPIT operating state in accordance with the built-in self-check, diagnostic capabilities or external alarm inputs (when present). Quality bits are used by protective relays, and are relied upon to prevent protective scheme mal-operation.

For example, when powering up, an optical current transformer may need to activate thermoelectric coolers, perform carefully controlled laser start-up, and wait until the system has stabilized to allow operation within stated accuracy. During this process, merging unit (digital) output should be disabled. If data output is enabled, all affected data values should be tagged as ‘invalid’, and detailed quality set to either ‘failure’ or ‘inaccurate’ in accordance with 6.903.9. The same requirement applies during power-down (loss of power) and self-diagnostic system activation (i.e. DSP subsystem failure). The merging unit should guarantee no un-flagged bad sampled value data is output.

Built in test signal generating capability is generally encouraged, but should be considered at the substation system level. It should be disabled by default. This applies to shipping and to all active power system installations. When present, test values shall be accompanied by the associated test bit activation as described in 6.903.9.

External Ethernet traffic received by the merging unit should not interfere with the sampled value transmission. This requirement applies regardless of the type of traffic, destination address range or the receive channel loading (100 % loading and full duplex communications are assumed).

A data consistency requirement applies to all data values within the same ASDU. Quality bit updates should be atomic (shall be updated at the same time and shall be consistent with the SV data point they describe), and are not allowed to lag behind their associated data values. For example; the outOfRange quality bit should be set as soon as clipping occurs, and it should stay set until the input value is back within clipping limits and output returns within the accuracy class. While the outOfRange bit is true, the associated data value should be reported as being at some value between the clipping limit and the actual input value. The output behaviour, while the input is outside the clipping limits, should be monotonic, with the output value not allowed to change sign without a corresponding change at the device input (no polarity inversion).

6 Design and construction

6.901 Technological boundaries

6.901.1 Interface point

An electronic LPIT with built in merging unit has two signal interface boundaries, plus an auxiliary power supply interface. The first signal boundary is the instrument transformer high voltage primary, while the second is the merging unit's digital output connector interface. The merging unit output connector should also define the split of responsibility between the electronic LPIT manufacturer and the system integrator. Additional interface boundaries such as interfaces between the primary and secondary converter are considered to be integral parts of the electronic LPIT. Additional interface points, such as 1PPS time synchronization input, may also be present in some installations.

The cables and connections that are internal to the electronic LPIT assembly including connections between a merging unit and the primary side sensor are outside the scope of this standard. The system integrator should supply all cables and connections that form part of the connection to the substation automation system (SAS). Where any cables or connections are run external to enclosures, they should be supplied with suitable mechanical protection.

6.901.2 Digital output interface

A fibre optic digital transmission system 100BASE-FX (1 300 nm, multimode, full duplex, two strand fibre optic cable) according to ISO/IEC 8802-3:2001 is recommended, but future technologies including 1 Gbit/s (1000BASE-LX) can be used (see IEC TR 61850-90-4).

NOTE 901 Individual optical cable strands with BFOC/2,5[2] (also known as ST type) connectors are still widely used, calling for individual fibre labelling (Rx, Tx fibres). Going forward duplex LC[3] connectors shown in Figure 905 are the preferred solution as these eliminate the Rx/Tx cross connection cabling issues. When required (backward compatible installations) conversion between the ST, FC and LC connector types can be accomplished with widely available fibre-optic patch cord cables.

Figure 905 – Duplex LC connector

6.901.3 Human-machine interface

Due to the wide variety of possible merging unit implementations, human-machine interface (HMI) requirements are kept to the absolute minimum, and are limited only to devices that can be visually inspected by the operator during normal operation. There are no limits on the maximum complexity of the HMI.

All devices which can be visually inspected by the operator shall have the means to indicate:

- the device is turned ON (powered);

---

2 As specified in IEC 61754-2:1996, *Fibre optic connector interfaces – Part 2: Type BFOC/2,5 connector family.*

3 As specified in IEC 61754-20:2002, *Fibre optic connector interfaces – Part 20: Type LC connector family.*

- the device is in service
- alarm conditions and/or failure;
- the communication link status;
- it is in a test condition.

All indications and their exact behaviour shall be clearly stated in the manufacturer's product documentation.

6.902 Electrical requirements

6.902.1 Frequency response requirements

Instrument transformers with digital output shall comply with the frequency response and accuracy requirements on harmonics specified in IEC 61869-6:2016, Annex 6A. For electronic LPIT with built in digital output, this requirement applies between the instrument transformer primary, and the instrument transformer digital output.

6.902.2 Maximum processing delay time requirement

Processing delay time (t_{pd}) is defined in 3.5.902 as the difference between the time encoded by the message field SmpCnt and the time the message appears at the digital output.

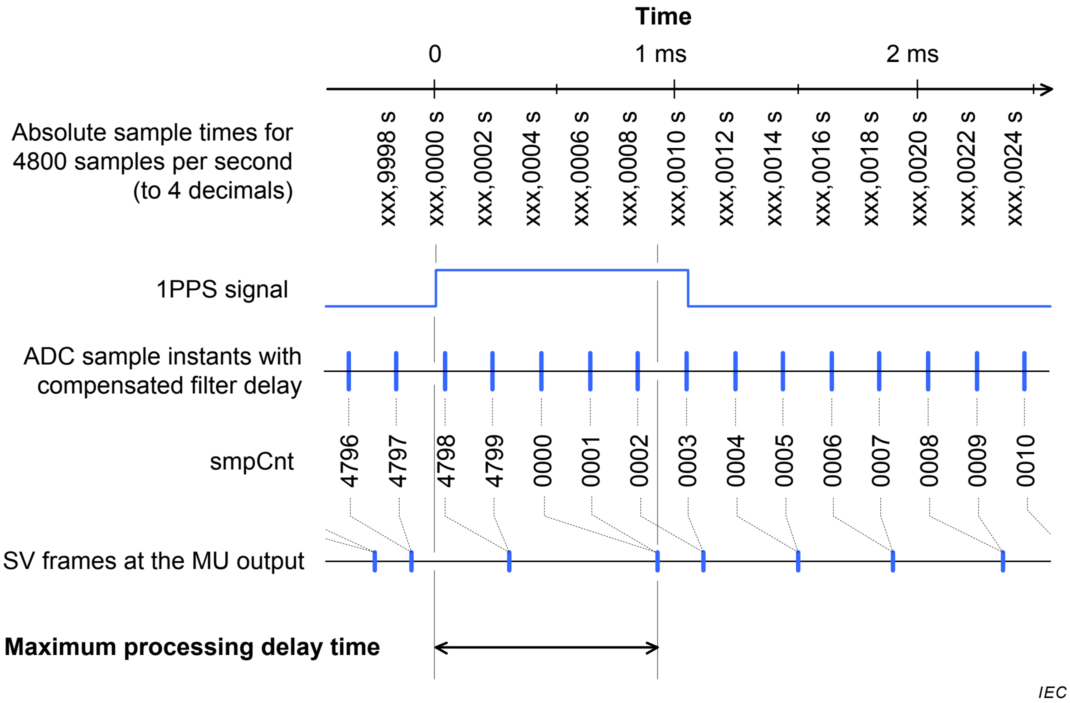


Figure 906 – Maximum processing delay time

The time of the message appearing on the digital output shall be measured at the message timestamp point (Figure 907) using the external clock supplied to the device synchronization input.

Maximum processing delay time is the longest processing delay time under rated operating conditions. It is measured in accordance to 7.2.901, and illustrated in Figure 906. In this example, the sample with smpCnt 0000, which encodes a time of xxx,0000, reaches the MU output at time xxx,0009, so the processing delay time for this sample is 0,9 ms. As there is no longer processing delay time in this example, 0,9 ms is also the maximum processing delay time.

The maximum processing delay time shall be specified by the manufacturer and shall be within the limits specified in Table 901.

Table 901 – Maximum processing delay time limits

Application class	Maximum processing delay time limit
Quality metering applications	10 ms
Protective and measuring applications	2 ms
Time critical low bandwidth d.c. control applications	100 μs
High bandwidth d.c. control applications	25 μs

The maximum processing delay time limit is measured at the merging unit output and does not include external delays contributed by the process bus network components or network congestion. External delays are application dependent and are critical for correct system operation. External network delays are the responsibility of the system integrator (network design engineer) and are outside of the scope of this standard.

The maximum processing delay time shall remain compliant with this standard, regardless whether the device is in the holdover mode or synchronized to an external time reference.

Per definition, maximum processing delay time cannot be measured when the device is free running. Due to complexity associated with precise high voltage and high current measurements, delay time in the free running mode is not separately verified. However, no significant processing delay time change shall be observed during the transition from the holdover to the free running mode in accordance to 7.2.901.

With merging units, in contrast to instrument transformers with analogue output, the main impact of delay time is that it adds to the relay's fault detection time. With analogue outputs, the delay time is also important in estimating primary phase angles. With digital output, the sample time encoded within the message rather than the time of signal receipt is used in estimating the primary phase angle. Thus, phase error is a result of differences between the encoded sample time and the time that the sample corresponds to on the power system primary, and is independent of delay time. Phase error limits specified in the applicable product standards (Part 7, Part 8, Part 12 and Part 13) ensure correspondence of the encoded sample time and the time that the sample corresponds to on the power system primary. Instrument transformers for d.c. applications (Part 14 and Part 15) meet phase error limits specified in IEC 61869-6:2016, 6A.4.3.

For high performance systems it is recommended that maximum delay time be kept to a minimum.

A precise definition of the timestamping point in the frame for 100BASE-FX physical layer encoding is shown in Figure 907.

It is adopted from http://standards.ieee.org/findstds/interps/1588-2008.html interpretation #26. and will be incorporated in the next revision of IEEE 1588 / IEC 61588 standards.

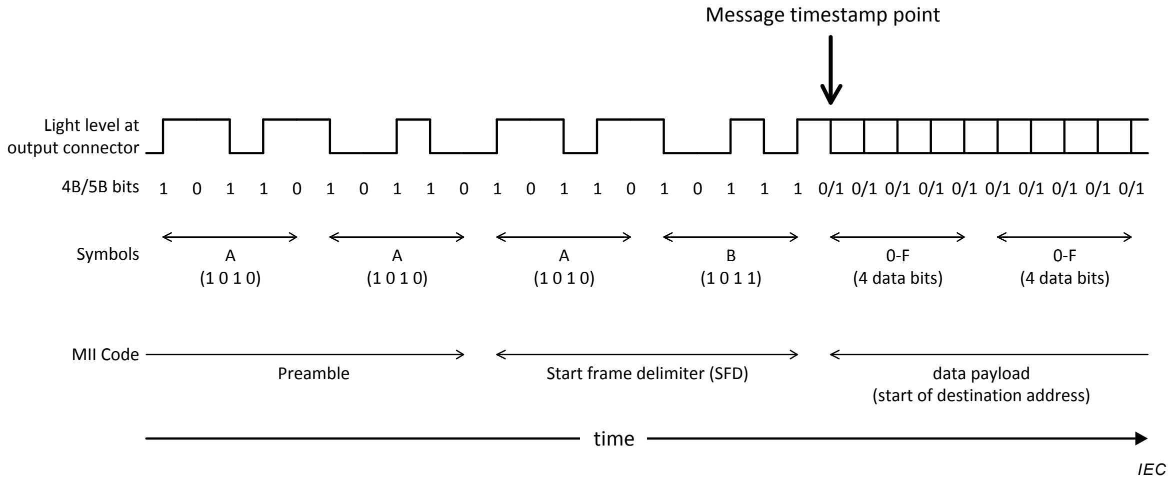


Figure 907 – Output message timestamp point

6.903 Specification of the communications profile

6.903.1 General

The IEC 61869-9 communications profile is a carefully selected subset of the IEC 61850 series. It uses IEC 61850-9-2:2011 for sampled values specific communication service mapping (SCSM). It uses IEC 61850-8-1 for client/server and peer-to-peer SCSM. The abstract communications service interface (ACSI) is as defined in IEC 61850-7-2. The logical nodes are as defined in IEC 61850-7-4. Common data classes and constructed attribute classes are as defined in IEC 61850-7-3.

6.903.2 Variants

To facilitate interoperability, only a limited variability is permitted for naming, message structure, sample rate, analogue signal content and scaling. The permitted variants are described in the device nameplate using the following notation, introduced here as an easy way to describe merging unit capabilities in a human readable text format:

$$\mathrm{F}\,f\,\mathrm{S}\,s\,\mathrm{I}\,i\,\mathrm{U}\,u$$

where

- f is the digital output sample rate expressed in samples per second;
- s is the number of ASDUs (samples) contained in a sampled value message;
- i is the number of current quantities contained in each ASDU;
- u is the number of voltage quantities contained in each ASDU.

Device nameplate documents device capability (range of supported variants) with active configuration separately specified in the merging unit configuration file (Annex 9C).

Variant notation examples:

F4000S1I4U4	describes the 9-2LE MSVCB01 sampled values with 50 Hz nominal system frequency.
F12800S8I4U4	describes the 9-2LE MSVCB02 sampled values with 50 Hz nominal system frequency.
F4800S2I8U0	describes sampled values with 4 800 samples per second, two ASDU (samples) per message, 8 currents, and no voltages.

Instrument transformers/SAMU claiming compliance to this standard shall be configurable to implement one of the preferred rates defined in Table 902 and at least one of the following backward compatible configurations:

- F4000S1I4U4
- F4800S1I4U4
- F5760S1I4U4

Merging units may also implement variants with other numbers of currents and voltages. The minimum number of current plus voltage quantities allowed is 1. The maximum number of quantities allowed on a 100 Mbit/s network is:

- for general measuring and protection: 24 quantities maximum
- for quality metering: 8 quantities maximum
- for d.c. control applications: 24 quantities maximum.

The maximum limitations are introduced to ensure fair network access and prevent blocking caused by excessively long Ethernet frames. No specific limits are defined for 1 Gbit/s and faster networks. DC instrument transformer outputs may require point to point connection and Gigabit Ethernet links.

6.903.3 Digital output sample rates

The standard sample rates (f in the variant notation) are indicated in Table 902.

Table 902 – Standard sample rates

Digital output sample rates Hz	**Number of ASDUs per frame**	**Digital output publishing rate** frames/s	**Remarks**
4 000	1	4 000	For use on 50 Hz systems backward compatible with 9-2LE guideline.
4 800	1	4 800	For use on 60 Hz systems backward compatible with 9-2LE guideline, or 50 Hz systems backward compatible with 96 samples per nominal system frequency cycle.
4 800	2	2 400	Preferred rate for general measuring and protective applications, regardless of the power system frequency.
5 760	1	5 760	For applications on 60 Hz systems backward compatible with 96 samples per nominal system frequency cycle.
12 800	8	1 600	Deprecated, only for use on 50 Hz systems.
14 400	6	2 400	Preferred rate for quality metering applications, regardless of the power system frequency including instrument transformers for time critical low bandwidth d.c. control applications.
15 360	8	1 920	Deprecated, only for use on 60 Hz systems.
96 000	1	96 000	Preferred rate for instrument transformers for high bandwidth d.c. control applications.

Sampling rates with variants F4000S1I4U4, F4800S1I4U4, F12800S8I4U4 and F15360S8I4U4 are identical to the sample rates recommended by UCA international users group document Implementation Guide line for Digital Interface to Instrument Transformers using IEC 61850-9-2 (commonly referred to as 9-2LE) and are retained for backward compatibility purposes. Going forward, preference is given to 4 800 Hz, 14 400 Hz and 96 000 Hz with 2, 6 and 1 ASDUs respectively, which are marked “preferred” in Table 902. Specified sample rates are constant and are normally synchronized to an external time source. Power system frequency tracking (if required by an application) is performed by the subscriber.

6.903.4 Logical devices

The merging unit shall implement one or more logical devices. Logical devices shall be as specified in IEC 61850-7-2:2010, 5.3.2.

Each logical device product-related name (LDName) shall be formatted according to:

*xxxx*MU*nn*

where

xxxx is the configurable IED name of the merging unit per IEC 61850-6:2009, 8.5.3.

MU*nn* is the logical device instance name, the attribute “inst” of the element LDdevice in the IED section of the ICD file. *nn* shall be a decimal number that makes the instance identifier of the logical device unique within the physical device.

NOTE 902 The combination of the IED name and the LD instance number makes the logical device unique within the system.

6.903.5 Logical nodes LPHD

LPHD logical nodes shall be as specified in IEC 61850-7-4:2010, 5.3.2, except that the LPHD logical nodes shall be extended by the addition of the nameplate data objects defined in Table 903. The value of dataNs data attributes of these extended data objects shall be “IEC 61869-9:2016”. The data attributes of these extended data objects shall be read-only.

The LPHD data object PhyNam shall conform to the DPL common data class definition in IEC 61850-7-3:2010, 7.8.2, except that attributes PhyNam.vendor, PhyNam.model, PhyNam.serNum, PhyNam.hwRev, PhyNam.swRev and PhyNam.d are mandatory and read-only.

For attribute PhyNam.serNum, where the manufacturing date is not implicit in the serial number, the date of manufacture shall be included.

Table 903 – Extensions to the LPHD class

LPHD class extensions for nameplate information				
Data object name	**Common data class**	**Explanation**	**T**	**M/O/C**
NamVariant	VSD	a semicolon separated list of the variant codes supported, the codes being as defined in 6.903.2, e.g. “F4800S1I4U4;F14400S6I4U4;F4800S2I0-24U0-24”		M
NamHzRtg	VSD	a semicolon separated list of the nominal frequencies (f_R) supported, in hertz, e.g. “dc; 50; 60”		M
NamAuxVRtg	VSD	a semicolon separated list or hyphenated range of rated auxiliary power supply voltages (U_{ar}) in volts, with indication of ac or dc where applicable, e.g. “80-300 dc;100-250 ac”		O
NamHoldRtg	VSD	the rated holdover time in seconds, e.g. “10”		M
NamMaxDlRtg	VSD	the maximum processing delay time in microseconds, e.g. “1500”		M
Key M = Mandatory O = Optional C = Conditional				

6.903.6 Logical nodes LLN0

LLN0 logical nodes shall be as specified in IEC 61850-7-4.

6.903.7 Logical nodes TCTR

TCTR logical nodes shall be as specified in IEC 61850-7-4, except that the TCTR logical nodes shall be extended by the addition of the nameplate data objects defined in Table 905 and in Table 903. The value of dataNs data attributes of these extended data objects shall be "IEC 61869-9:2016". The data attributes of these extended data objects shall be read-only.

Each TCTR name (LNName) shall be formatted during engineering phase according to:

I *nn p* TCTR *n*

where

nn is the instance number of the current measurement point (01-99) that makes the current measurement identification (Inn) unique within the bay. This value is part of the substation section of the SCL description and is defined during the engineering process.

p is the phase identification of the primary current, either A, B, C, or N for AC instrument transformers. For d.c. instrument transformers, pending support for d.c. systems in the IEC 61850 series of standards, use A for pole 1, B for pole 2, and N for earth return. This value should correspond to the SubEquipment phase attribute in the substation section of the SCL description if any.

n is the attribute "inst" of the element LN in the substation and IED sections of the ICD file. It binds the TCTR described in the substation section to the TCTR described in the IED section. *"n"* shall be a decimal number (1 through 99) that makes the instance identifier of the TCTR unique within the logical device, and is in general fixed by the manufacturer.

As an example, a TCTR name might be:

I02ATCTR4

The above name is for current measurement point number 02, phase A, with current transformer core connected to TCTR instance 4 as illustrated in Figure 908. This is only one example illustrating substation modelling defined in IEC 61850-7-1 and substation configuration language rules defined in IEC 61850-6.

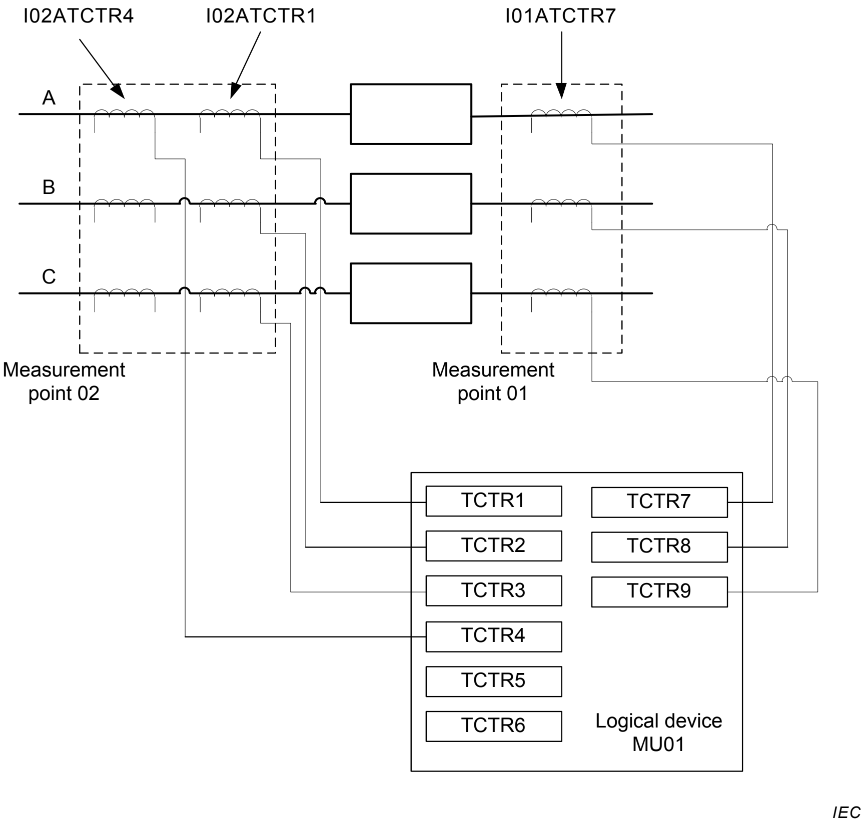


Figure 908 – TCTR naming example

The TCTR data object NamPlt shall conform to the LPL common data class definition in IEC 61850-7-3:2010, 7.8.3.

The TCTR data object AmpSv shall conform to the SAV common data class definition in IEC 61850-7-3:2010, 7.4.4, except that attributes AmpSv.instMag.i, AmpSv.sVC.scaleFactor, AmpSv.sVC.offset, AmpSv.units.multiplier and AmpSv.units.SIUnit are mandatory and read-only with values specified in Table 904:

Table 904 – AmpSv object attribute values

Attribute	Value
AmpSv.units.SIUnit	5 (code for ampere)
AmpSv.units.multiplier	0
AmpSv.sVC.offset	0
AmpSv.sVC.scaleFactor	0,001
AmpSv.instMag.i	count (of milliampere)

Table 905 – Extensions to the TCTR class

TCTR class extensions with nameplate information				
Data object name	**Common data class**	**Explanation**	**T**	**M/O/C**
NamAccRtg	VSD	the accuracy class rating in the format described in 5.6, e.g. “0,5S/5P20”		M
NamARtg	VSD	a semicolon separated list of the rated primary currents (I_{Pr}) in amperes, e.g. “200;400;800”		M
NamClipRtg	VSD	the ratio of the clipping limit of the instantaneous current to the rated primary current multiplied with a square root of two, e.g. “20”		M
Key M = Mandatory O = Optional C = Conditional				

6.903.8 Logical nodes TVTR

TVTR logical nodes shall be as specified in IEC 61850-7-4:2010, except that the TVTR logical nodes shall be extended by the addition of the nameplate data objects defined in Table 907 and in Table 903. The value of dataNs data attributes of these extended data objects shall be “IEC 61869-9:2016”. The data attributes of these extended data objects shall be read-only.

Each TVTR name (LNName) shall be formatted during engineering phase according to:

U *nn p*TVTR *n*

where

nn is the instance number of the voltage measurement point (01-99) that makes the voltage measurement identification (Unn) unique within the bay. This value is part of the substation section of the SCL description.

p is the phase identification, either A, B, C, AB, BC, CA or N for a.c. instrument transformers. For d.c. instrument transformers, pending support for d.c. systems in the IEC 61850 series, use A for pole 1, B for pole 2, and N for earth return. This value should correspond to the SubEquipment phase attribute in the substation section of the SCL description if any.

n is the attribute “inst” of the element LN in the substation and IED sections of the ICD file. It binds the TVTR described in the substation section to the TVTR described in the IED section. "*n*" shall be a decimal number (1 through 99) that makes the instance identifier of the TVTR unique within the logical device, and is in general fixed by the manufacturer.

As an example, a TVTR name might be:

U01ATVTR1

The TVTR attribute NamPlt shall conform to the LPL common data class definition in IEC 61850-7-3:2010, 7.8.3.

The TVTR data object VolSv shall conform to the SAV common data class definition in IEC 61850-7-3:2010, 7.4.4, except that attributes VolSv.instMag.i, VolSv.sVC.scaleFactor, VolSv.sVC.offset, VolSv.units.multiplier and VolSv.units.SIUnit are mandatory and read-only with values specified in Table 906.

Table 906 – VolSv object attribute values

Attribute	Value
VolSv.units.SIUnit	29 (code for volt)
VolSv.units.multiplier	0
VolSv.sVC.offset	0
VolSv.sVC.scaleFactor	0,01
VolSv.instMag.i	count (of centivolt)

Table 907 – Extensions to the TVTR class

TVTR class extensions with nameplate information				
Data object name	**Common data class**	**Explanation**	**T**	**M/O/C**
NamAccRtg	VSD	the accuracy class rating in the format described in 5.6, e.g. “0.5/3P”		M
NamVRtg	VSD	the rated primary voltage (U_{Pr}) in volts, e.g. for rating of 300000/sqrt(3) we will have “173000”		M
NamClipRtg	VSD	the ratio of the clipping limit of the instantaneous voltage to the rated primary voltage multiplied with a square root of two, e.g. “2”		M
Key M = Mandatory O = Optional C = Conditional				

6.903.9 Quality

The constructed attribute quality where used in the SAV common data class shall be as specified in IEC 61850-7-3:2010, 7.4.4, and as further constrained by this subclause 6.903.9.

The quality attribute refers to the quality of the sampled value independently of any error in the sample time instant. The quality of sample timing is communicated in the SmpSynch attribute defined in 6.904.4 below. For instance when in the free-run mode, wherein sample time error is arbitrarily large, sample quality may still be good and sampled values perfectly usable by subscribers that are not sensitive to the phase difference between these samples and samples from other instrument transformers.

The quality of each sampled value in each ASDU shall be as represented by its quality value in that ASDU. For example, if a channel having previously been accurate becomes inaccurate, the first inaccurate value shall have in the same ASDU as its inaccurate attribute set.

The validity attribute shall be invalid and all other attributes of the quality attribute shall be their default value when the quantity is not provided, e.g. when a single phase bus voltage is being transmitted in a legacy format with a 4 TCTR, 4 TVTR dataset, the unused phases shall be tagged as invalid.

The validity attribute shall be set to questionable and the outOfRange attribute shall be true as soon as clipping occurs, and they shall stay set till the input value is again within clipping limits and the output value accuracy has recovered. This mechanism allows the subscribing applications to use the clipping information where appropriate (for example for recording or time overcurrent function).

The validity attribute shall be set to questionable when the inaccurate attribute is true.

The failure attribute shall be true when an instrument transformer supervision function has detected an error condition other than the loss of synchronism indicating that the sampled value is unusable, e.g. to indicate internal hardware failure.

The inaccurate attribute shall be true when an instrument transformer supervision function has detected an error condition other than the loss of synchronism indicating that the sampled value does not meet the nameplate measuring accuracy class, but may be useable.

Notwithstanding IEC 61850-7-3:2010, 6.2.2, the sampled value shall at all times be the merging unit's best estimate of the primary value. Subscriber applications shall individually choose how to use values marked questionable.

The overflow, badReference, oscillatory, oldData, inconsistent and operatorBlocked flags shall be set to false.

The source attribute shall be set to process.

The test attribute shall be set in accordance with IEC 61850-7-3.

6.903.10 Dataset(s)

The datasets shall be as specified in IEC 61850-7-2:2010, 10.1.3.4, and as further constrained by this subclause 6.903.10.

Each dataset name (DSName) shall be formatted according to:

PhsMeas*x*

where

x is the is the instance number of the dataset (1-99). "*x*" shall be a decimal number that makes the dataset name unique within LLN0, and is in general fixed by the manufacturer.

The dataset name PhsMeas1 may only be used for a dataset whose members in order are:

InnATCTR1.AmpSv.instMag.i
InnATCTR1.AmpSv.q
InnBTCTR2.AmpSv.instMag.i
InnBTCTR2.AmpSv.q
InnCTCTR3.AmpSv.instMag.i
InnCTCTR3.AmpSv.q
InnNTCTR4.AmpSv.instMag.i
InnNTCTR4.AmpSv.q
UnnATVTR1.VolSv.instMag.i
UnnATVTR1.VolSv.q
UnnBTVTR2.VolSv.instMag.i
UnnBTVTR2.VolSv.q
UnnCTVTR3.VolSv.instMag.i
UnnCTVTR3.VolSv.q
UnnNTVTR4.VolSv.instMag.i
UnnNTVTR4.VolSv.q

Dataset members shall consist of AmpSv.instMag.i (current sampled value) or VolSv.instMag.i (voltage sampled value) attributes, each followed immediately by the corresponding AmpSv.q or VolSv.q (quality) attribute. The number of current sampled values and the number of voltage sampled values shall match the number of each specified by the variant code for the dataset.

All AmpSv members (current sampled values) shall precede any VolSv members (voltage sampled values).

By default, where multiple current or multiple voltage members for a common measurement point exist, they shall be adjacent and in the sequence: A, AB, B, BC, C, CA, N.

6.903.11 Multicast sampled value control block(s)

The multicast sampled value control blocks shall be as specified in IEC 61850-7-2:2010, 19.2.1, and as further constrained by this subclause 6.903.11.

Each multicast sampled value control block name (MsvCBName) shall be formatted according to:

MSVCB*xx*

where

xx is the instance number (01-99) of the multicast sampled value control block. Instance number “*xx*” shall be a decimal number that makes the dataset name unique within the LLN0, and is in general fixed by the manufacturer.

For backward compatibility with legacy products, in the control blocks MSVCB01, MSVCB02, and high bandwidth d.c. control applications with sample rate equal to 96 kHz, the SmpMod attribute shall have a value of ‘0’ (samples per nominal period). For all other applications, SmpMod shall have a value of ‘1’ (samples per second).

The value of attribute MsvID shall be unique within the substation. It is recommended that this field be short to preserve communications bandwidth (recommend making it equal to hexadecimal character representation of APPID: 4000 to 7FFF).

NOTE 903 Some legacy devices restrict the length of this field to be between 10 and 34 characters.

The SmpRate attribute shall have a value matching the sample rate in the variant code for the control block. For control blocks MSVCB01 SmpRate attribute shall be 80, and for MSVCB02 it shall be 256. For other control blocks, the value in the variant code is used directly with exception of the d.c. control block for 96 kHz whose value is 9 600. Use of 9 600 samples per nominal period, implying a nominal frequency of 10 Hz, is a workaround to the maximum value the SmpRate attribute can encode.

The OptFlds.refresh-time attribute shall be false.

The OptFlds.reserved (OptFlds.samplesynchonised in IEC 61850-9-2:2012 attribute shall be true.

The OptFlds.sample-rate attribute shall be false.

The OptFlds.data-set-name attribute shall be false.

The OptFlds.security attribute as per IEC 61850-9-2:2011 shall be false.

The smpMod attribute shall not be present in the SV message.

The noASDU attribute shall have a value matching the number of ASDUs in the applicable variant code defined in 6.903.2.

6.903.12 Configuration of the merging unit

Table 908 summarizes the parameters that need to be configurable.

Table 908 – Configuration parameters of the merging unit

Parameter		Value Range	Details
LDName		xxxxMUnn	xxxx is the configurable IED name of the merging unit per IEC 61850-6:2009, 8.5.3. MUnn is the attribute **Inst** of the **LDevice** per IEC 61850-6:2009, 8.5.3.
MSVCBxx.SvEna		TRUE/FALSE	Repeated for each MSVCB implemented.
MSVCBxx.MsvID		see details	Should be unique within the substation. It is recommended that this field be short; set to match the hexadecimal APPID representation. NOTE Some legacy devices restrict the length of this field to 10…34 characters.
DstAddress			
	Addr	see comment	If DstAddress is a multicast address, the address shall be 01-0C-CD-04-xx-xx, where xx-xx needs to be configured. If DstAddress is a unicast address, the address shall be the Ethernet address of the SV subscriber.
	PRIORITY	0…7	
	VID	0…4095	
	APPID	0x4000…0x7FFF	The value 0x4000 is the default value, indicating lack of configuration. It is strongly recommended to have unique, source orientated SV APPID within a system, in order to enable a filter on the link layer. The configuration of APPID should be enforced by the configuration system.

6.903.13 Rated conformance classes

6.903.13.1 General

The standards of the IEC 61850 series specify a large set of communication models and services. Not all of these are used in merging units. Many of these support additional capabilities such as configuration and supervision of a merging unit.

NOTE 904 Communication services are used to access and exchange data residing in logical nodes via a serial communication network according to the IEC 61850 series.

Therefore, not all of the models or services defined in the IEC 61850 series need to be implemented in all merging units. The services that are required to be implemented are defined in terms of conformance classes within this subclause 6.903.13.1. The conformance classes are defined using the abstract communication service interface (ACSI) conformance statements specified in 6.903.13.2 through 6.903.13.6, which in turn are based on those in IEC 61850-7-2:2010, Annex A. The conformance classes may be summarized as follows:

– class a: the minimal set of services required to transmit MU data using sampled values;

– class b: class a capabilities plus the minimal set of services required to support GOOSE messages;

– class c: class b capabilities plus services required to implement the IEC 61850 series' information model with self-descriptive capabilities;

– class d: class c capabilities plus services for file transfer, buffered and unbuffered reporting.

NOTE 905 The communication services within the IEC 61850 series are defined using an abstract modelling technique (abstract communication service interface or ACSI). Abstract means that the definition is a high level description of what the services provide. The lower levels upon which the abstract level is implemented are specified in specific communication service mappings (SCSM).

NOTE 906 Logical nodes and services within the IEC 61850 series provide means to retrieve comprehensive information about the information model and the services that operate on the information models, i.e. about themselves. This capability is called self-description.

NOTE 907 File transfer can be used to transmit information such as configuration information via the communication network.

NOTE 908 Logging and reporting are communication facilities within the IEC 61850 series which can be used for the transmission of, for example, a sequence of events, from a merging unit to a human-machine interface for the purpose of maintenance of a substation.

6.903.13.2 ACSI basic conformance statement

The basic conformance statement shall be as defined in Table 909.

Table 909 – Basic conformance statement

		Conformance classes			
		a	**b**	**c**	**d**
Client-server roles					
B11	Server side (of TWO-PARTY-APPLICATION-ASSOCIATION)	–	–	M	M
B12	Client side (of TWO-PARTY-APPLICATION-ASSOCIATION)	–	–	–	–
SCSMs supported					
B21	SCSM: IEC 61850-8-1 used	–	C1	M1	M1
B22		–	–	–	–
B23	SCSM: IEC 61850-9-2 used	M	M	M	M
B24	SCSM: other	–	–	–	–
Generic substation event model (GSE)					
B31	Publisher side	–	M	M	M
B32	Subscriber side	–	O	O	O
Transmission of sampled value model (SVC)					
B41	Publisher side	M	M	M	M
B42	Subscriber side	O	O	O	O
Key M – Mandatory O – Optional C1 – SCSM related to GOOSE is mandatory M1 – SCSM: IEC 61850-8-1 other than its time synchronization model (STNP) is mandatory. The time synchronization SCSM shall be as specified in 6.904.					

6.903.13.3 ACSI models conformance statement

The ACSI models conformance statement shall be as defined in Table 910.

Table 910 – ACSI models conformance statement

Model		Conformance class			
		a	**b**	**c**	**d**
M1	Logical device	–	–	M	M
M2	Logical node	–	–	M	M
M3	Data	–	–	M	M
M4	Data set	–	–	M	M
M5	Substitution	–	–	O	O
M6	Setting group control	–	–	O	O

Model		Conformance class			
		a	b	c	d
Reporting					
M7	**Buffered report control**	–	–	–	M
M7-1	sequence-number	–	–	–	M
M7-2	report-time-stamp	–	–	–	M
M7-3	reason-for-inclusion	–	–	–	M
M7-4	data-set-name	–	–	–	M
M7-5	data-reference	–	–	–	M
M7-6	buffer-overflow	–	–	–	M
M7-7	entryID	–	–	–	M
M7-8	BufTim	–	–	–	M
M7-9	IntgPd	–	–	–	M
M7-10	GI	–	–	–	M
M7-11	conf-revision	–	–	–	M
M8	**Unbuffered report control**	–	–	–	M
M8-1	sequence-number	–	–	–	M
M8-2	report-time-stamp	–	–	–	M
M8-3	reason-for-inclusion	–	–	–	M
M8-4	data-set-name	–	–	–	M
M8-5	data-reference	–	–	–	M
M8-6	BufTim	–	–	–	M
M8-7	IntgPd	–	–	–	M
M8-8	GI	–	–	–	M
M8-9	conf-revision	–	–	–	M
Logging					
M9	Log control (LCB)	–	–	–	O
M9-1	IntgPd	–	–	–	O
M10	Log	–	–	–	O
Control					
M11	Control	–	–	O	O
GSE					
M12	GOOSE	–	M	M	M
M13	GSSE	–	–	–	–
SVC					
M14	Multicast SVC	M	M	M	M
M15	Unicast SVC	O	O	O	O
Miscellaneous					
M16	Time	M	M	M	M
M17	File transfer	–	–	O	M
Key M = Mandatory O = Optional					

6.903.13.4 ACSI service conformance statement

The ACSI service conformance statement shall be as defined in Table 911 (depending on the statements in Table 909 and Table 910.

Table 911 – ACSI service conformance statement

Services		Conformance classes			
		a	b	c	d
Server (IEC 61850-7-2:2010, Clause 7)					
S1	ServerDirectory	–	–	M	M
Application association (IEC 61850-7-2:2010, Clause 8)					
S2	Associate	–	–	M	M
S3	Abort	–	–	M	M
S4	Release	–	–	M	M
Logical device (IEC 61850-7-2:2010, Clause 9)					
S5	LogicalDeviceDirectory	–	–	M	M
Logical node (IEC 61850-7-2:2010, Clause 10)					
S6	GetLogicalNodeDirectory	–	–	M	M
S7	GetAllDataValues	–	–	M	M
Data object (IEC 61850-7-2:2010, Clause 11)					
S8	GetDataValues	–	–	M	M
S9	SetDataValues	–	–	O	O
S10	GetDataDirectory	–	–	M	M
S11	GetDataDefinition	–	–	M	M
Data set (IEC 61850-7-2:2010, Clause 13)					
S12	GetDataSetValues	–	–	M	M
S13	SetDataSetValues	–	–	O	O
S14	CreateDataSet	–	–	O	O
S15	DeleteDataSet	–	–	O	O
S16	GetDataSetDirectory	–	–	M	M
Setting group control (IEC 61850-7-2:2010, Clause 16)					
S18	SelectActiveSG	–	–	O	O
S19	SelectEditSG	–	–	O	O
S20	SetEditSGValue	–	–	O	O
S21	ConfirmEditSGValues	–	–	O	O
S22	SetEditSGValue	–	–	O	O
S23	GetSGCBValues	–	–	O	O
Reporting (IEC 61850-7-2:2010, Clause 17)					
Buffered report control block (BRCB)					
S24	Report	–	–	C4	C4
S24-1	data-change (dchg)	–	–	O	O
S24-2	q-change (qchg)	–	–	O	O
S24-3	data-update (dupd)	–	–	O	O
S25	GetBRCBValues	–	–	C4	C4
S26	SetBRCBValues	–	–	O	O
Unbuffered report control block (URCB)					

Services		Conformance classes			
		a	b	c	d
S27	Report	–	–	C5	C5
S27-1	data-change (dchg)	–	–	O	O
S27-2	q-change (qchg)	–	–	O	O
S27-3	data-update (dupd)	–	–	O	O
S28	GetURCBValues	–	–	C5	C5
S29	SetURCBValues	–	–	O	O
Logging (IEC 61850-7-2:2010, Clause 17)					
Log control block					
S30	GetLCBValues	–	–	C6	C6
S31	SetLCBValues	–	–	O	O
Log					
S32	QueryLogByTime	–	–	C6	C6
S33	QueryLogAfter	–	–	C6	C6
S34	GetLogStatusValues	–	–	C6	C6
C4 – Mandatory if M8 (buffered reporting) is supported C5 – Mandatory if M7 (unbuffered reporting) is supported C6 – Mandatory if M9 (logging) is supported					
Generic substation event model (GSE)					
GOOSE (IEC 61850-7-2:2010, Clause 18)					
S35	SendGOOSEMessage	–	M	M	M
S36	GetGoReference	–	–	O	O
S37	GetGOOSEElementNumber	–	–	O	O
S38	GetGoCBValues	–	–	O	O
S39	SetGoCBValues	–	–	O	O
GSSE (IEC 61850-7-2:2010, Clause 18)					
S40	SendGSSEMessage	–	–	–	–
S41	GetGsReference	–	–	–	–
S42	GetGSSEElementNumber	–	–	–	–
S43	GetGsCBValues	–	–	–	–
S44	SetGsCBValues	–	–	–	–
Transmission of sampled value model (SVC) (IEC 61850-7-2:2010, Clause 19)					
Multicast SVC					
S45	SendMSVMessage	M	M	M	M
S46	GetMSVCBValues	–	–	O	O
S47	SetMSVCBValues	–	–	O	O
Unicast SVC					
S48	SendUSVMessage	O	O	O	O
S49	GetUSVCBValues	–	–	O	O
S50	SetUSVCBValues	–	–	O	O
Control (IEC 61850-7-2:2010, Clause 20)					
S51	Select	–	–	O	O
S52	SelectWithValue	–	–	O	O
S53	Cancel	–	–	O	O

Services		Conformance classes			
		a	b	c	d
S54	Operate	–	–	M	M
S55	Command-Terminate	–	–	O	O
S56	TimeActivated-Operate	–	–	O	O
File transfer (IEC 61850-7-2:2010, Clause 23)					
S57	GetFile	–	–	–	M
S58	SetFile	–	–	–	O
S59	DeleteFile	–	–	–	O
S60	GetFileAttributeValues	–	–	–	M
Key M = Mandatory O = Optional					

6.903.13.5 A-Profile conformance statement

The A-Profile conformance statement shall be as defined in Table 912.

Table 912 – PICS for A-Profile support

Services		Conformance classes			
		a	b	c	D
A1	Client/Server A-Profile per IEC 61850-8-1:2011, 6.2.2 and IEC 61850-9-2:2011, 5.2.2	–	–	M	M
A2	GOOSE/GSE management A-Profile per IEC 61850-8-1:2011, 6.3.2	–	M	M	M
A3	GOOSE A-Profile per IEC 61850-8-1:2011, 6.3.2	–	M	M	M
A4	TimeSync A-Profile per IEC 61850-8-1:2011, 6.4.2	N1	N1	N1	N1
A5	Security for client/server A-Profile	–	–	–	–
A6	Security for GOOSE/GSE management A-Profile	–	–	–	–
A7	SV A-Profile per IEC 61850-9-2:2011, 5.3.2	M	M	M	M
Key M = Mandatory N1 = Time synchronization requirements shall be as specified in 6.904. Time synchronization using SNTP is optional in this standard.					

6.903.13.6 T-Profile conformance statement

The T-Profile conformance statement shall be as defined in Table 913.

Table 913 – PICS for T-Profile support

Services		Conformance classes			
		a	b	c	d
T1	TCP/IP T-Profile per IEC 61850-8-1:2011, 6.2.2 and IEC 61850-9-2:2011, 5.2.3	–	–	M	M
T2	SV T-Profile per IEC 61850-9-2:2011, 5.3.3	M	M	M	M
T3	GOOSE T-Profile per IEC 61850-8-1:2011, 6.3.3	–	M	M	M
T4	GSSE T-Profile	–	–	–	–
T5	TimeSync T-Profile per IEC 61850-8-1:2011, 6.4.3	–	–	O	O
Key M = Mandatory O = Optional					

6.904 Synchronization

6.904.1 General

The ability of instrument transformers with digital output to meet their published accuracy specification depends on time synchronization. Merging units shall have the capability to accept an external synchronizing signal, so that their sampling can be synchronized both to other merging units and to an external time reference. The preferred synchronization method is Precision Time Protocol specified in IEC 61588:2009 (PTP, also known as 1588.) with profile subset specified in IEC PAS 61850-9-3.

The merging unit may use a one pulse per second (1PPS) input as specified herein instead of (or as an optional alternative to) PTP for legacy applications. In either case, the accuracy of the time signal (mean error from absolute time) is expected to be better than ± 1 μs for accuracy characterisation.

Phase error when in service will suffer depending on the degree that delivered time deviates from this ideal. IEC 61850-5:2013, Table 3 defines applicable time synchronization classes (typically classes T4 and T5 for synchronized sampling).

The merging unit shall contain an internal clock that is synchronized by the synchronizing signal. A sample counter (SmpCnt) shall be used to identify the samples within the present second and to code their sample times. The sample counter increments from zero to the nominal number of samples per second less one, then repeats. Sample times are those instants where the internal clock's fraction of a second equals the sample counter's count divided by the nominal sample rate. That means; when synchronized, the sample counter shall be zero at the top of the second mark.

The sample counter field SmpCnt defined in IEC 61850-9-2:2011, 8.5.2 is an unsigned sixteen bit integer (INT16U) representing values between 0 and 65 535. When used for high bandwidth d.c. control applications with sample rate of 96 kHz, the sample counter field shall naturally overflow back to zero, 65 536 samples after the top of the second mark; and shall continue counting up to: 30 463 (96 000 – 65 536 − 1 = 30 463), correctly representing the lower 16 bit of an internal 17 bit counter representation. Subclause 6.904.7 defines additional details governing SmpCnt behaviour during time adjustments.

6.904.2 Precision time protocol synchronization

This subclause 6.904.2 applies only to merging units claiming precision time protocol (PTP) synchronization.

Merging unit ports used for sample value transmission shall be capable of receiving time synchronization messages compliant with IEC PAS 61850-9-3.

A synchronizing signal received with the PTP clockClass 6 or 7 shall be sourced by a global area clock. A synchronizing signal received with any other clockClass shall be sourced by a local area clock.

6.904.3 1PPS synchronization

This subclause 6.904.3 applies only to merging units claiming 1PPS synchronization.

Merging units shall accept the following 1PPS signal on a dedicated clock input port:

Signal type	optical on graded index 62,5/125 μm glass fibre
Clock rate	one pulse per second
Change of second	on the rising edge from low to high
Pulse duration t_h	10 μs to 500 ms
Rise and fall times, 10 to 90%	up to 200 ns
Jitter	±2 μs maximum
Optical wavelength	820 nm to 860 nm
Maximum receiving power	–12 dBm (while high)
Minimum receiving power	–24 dBm (while high)
Connector	BFOC/2,5 (recommended, but future technology may be used).

Optionally, the merging unit may compensate for transmission delays in the time network by applying a user configurable time offset to the 1PPS signal.

Figure 909 shows the shape of the 1PPS signal graphically.

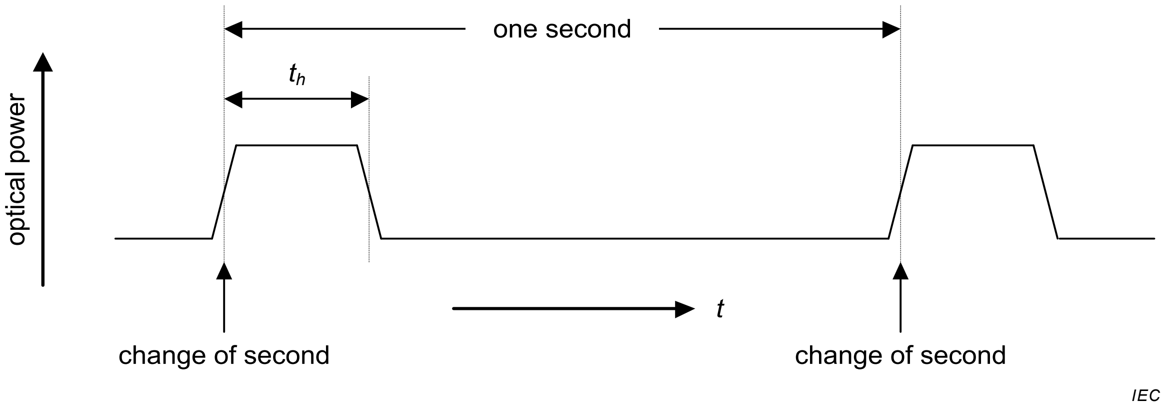


Figure 909 – 1PPS signal waveform at the merging unit clock input

The 1PPS signal does not contain information on the clock that is the source of the synchronizing signal. It shall therefore always be interpreted as a global area clock. This enables the newly manufactured merging units to be used in legacy installations built in accordance to UCA international users group Implementation Guide line for Digital Interface to Instrument Transformers using IEC 61850-9-2. Use of legacy MUs (1PPS mode) in new systems built in accordance with this standard needs to be analyzed on a case by case basis.

6.904.4 Sample value message SmpSynch attribute

Applications that are sensitive to the phase angle difference between different merging units require that the sampled values from those merging units be synchronized with each other. Such applications include protection, control, metering, and synchrophasors. Sampled values are synchronized to each other when each is synchronized to the same time source. The SmpSynch attribute defined IEC 61850-9-2:2011, Table 14, provides information on the time source used to assist sample value subscribers in determining whether sampled values are synchronized to each other.

While sampled values are synchronized to a global area clock to the degree required to meet the measuring accuracy class phase error limit, the value of the "SmpSynch" attribute in the SV messages shall be 2. A global area clock is a source that provides time that is traceable to the international standards laboratories maintaining clocks that form the basis for the International Atomic Time (TAI) and Universal Coordinated Time (UTC) timescales. Examples of these are Global Positioning System (GPS), NTP, and National Institute of Standards and Technology (NIST) timeservers. All sampled values synchronized to any global area clock are synchronized to each other.

While sampled values are synchronized to a local area clock to the degree required to meet the measuring accuracy class phase error limit, the value of the "SmpSynch" attribute in the SV messages shall be 1. If the unique identifier of the specific local area clock is known "SmpSynch" attribute can be set to that value. A local area clock is a source that provides time that advances at essentially the correct rate but which may have a time offset from global area clocks and other local area clocks. A specific local area clock unique identifier is a number from 5 to 254. All sampled values synchronized to the same local area clock are synchronized to each other, but may not be synchronized to sampled values synchronized to some other clock. The meaning of unspecified local area clock code (SmpSynch == 1) depends on the design of the time distribution network. In some cases the time distribution network design ensures that a set of merging units can only receive synchronization from the same local area clock, in which case they are synchronized to each other. In other cases, time network design allows different merging units to receive from different local area clocks, in which case they cannot be presumed to be synchronized. Merging units may optionally have a setting specifying the unique local area clock identifier (5 to 254) to use should the identifier not be received via the time signal.

While sampled values are not synchronized to a global or local area clock to the degree required to meet the measuring accuracy class phase error limit, the value of the "SmpSynch" attribute in the SV messages shall be 0. A merging unit may be in the not synchronized state due to:

- the synchronizing signal having never been received;
- the synchronizing signal being interrupted and the merging unit operating beyond its hold-over duration specification;
- lock to the synchronizing signal not acquired;
- other condition that results in the samples not being synchronized with an external clock to the degree required by the measuring accuracy class phase error limit.

6.904.5 Holdover mode

When the external synchronization signal is lost, the merging unit shall go into a holdover mode. For the duration of the holdover period the merging unit shall continue to send samples maintaining the sample timing required for the measuring accuracy class. During holdover, the "SmpSynch" attribute in the SV messages shall remain unchanged, and the "SmpCnt" attribute in the SV messages shall increment and wrap as if a synchronization signal were present.

The minimum holdover duration shall be 5 s under stable temperature conditions.

When the synchronization signal resumes before holdover timeout, the sampled value messages shall continue as if the synchronizing signal were continuous.

6.904.6 Free-running mode

While a merging unit is in the not synchronized state (i.e. when free-running), sampled values shall be sent with sampling rate whose maximum deviation from its nominal sampling rate is no more than $\pm 100 \times 10^{-6}$.

While free-running, the "SmpSynch" attribute in the SV messages shall be zero, and the "SmpCnt" attribute in the SV messages shall increment and wrap as if a synchronization signal were present.

Regardless of whether the merging unit is synchronized to an external time source or not, all sampled values from the same merging unit shall be synchronized to each other.

6.904.7 Time adjustments

When the synchronization signal is restored after an interruption, when a transfer is made between different external clock sources, and when the external clock executes a time adjustment, there may be an offset between the time tracked before the event and the time tracked after the event. In this case a time adjustment of the merging unit local clock that controls sample times is required.

The time adjustment shall be accomplished as follows. The sampling shall jump from the old time to the new time between consecutive samples. The sample interval over jumps shall be no more than one and a half times the nominal interval and no shorter than one half times the nominal interval. SmpCnt is discontinuous over the jump for time adjustments larger than are accommodated by an off-nominal sample interval, but is always continuous for samples immediately prior to the adjustment and continuous for samples immediately following the adjustment, see Figure 910.

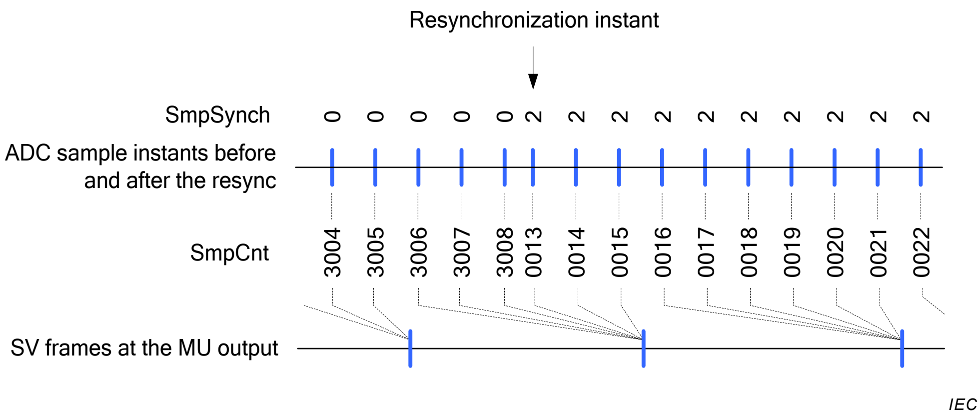


Figure 910 – Time adjustment example (6 ASDU example)

The values of SmpCnt and SmpSynch in ASDUs shall in all cases correspond to the time scale and source used for the samples in that ASDU. In particular, the sample following a jump shall have the adjusted values of both SmpCnt and SmpSynch.

Receiving applications using sampled value data during the synchronization state change (free running to synchronized) are expected to cope with this transition. Time adjustments greater than one half of the nominal interval cause discontinuity in SmpCnt and a change in SmpSynch.

The manufacturer shall state in the protocol implementation extra information for testing (PIXIT) the maximum time required to achieve synchronization on merging unit power up and on resynchronization.

7 Tests

7.2 Type tests

7.2.6 Test for accuracy

7.2.6 of IEC 61869-6:2016 applies with the following addition:

Annex 9D provides sample circuits for performing accuracy tests for instrument transformers having digital output.

For protection classes, accuracy tests shall be performed over one period of power frequency signal; e.g. 20 ms for a 50 Hz system.

For measuring classes, accuracy tests may be performed over several power frequency cycles, or several measurements may be averaged. If the comparison is not over one period of power frequency signal, the details of the test arrangement and timing and/or bandwidth of test system shall be provided in the accuracy test report.

7.2.901 Digital output conformance tests

IEC 61850-10:2012, Clause 6 dealing with conformance and IEC 61850-10:2012, Clause 8 performance tests are applicable.

7.2.902 Maximum processing delay time test

Maximum processing delay time limit compliance (defined in 6.902.2) shall be verified by measuring the processing delay time of individual sample value frames as presented to the merging unit digital output.

Since frequency and phase response requirements defined in sections 5.6 and 6.902.1 form part of the merging unit accuracy specification, it can be assumed that the time coded within each sampled value message adequately corresponds to the sampling point on the primary, or in the case of SAMUs, on the SAMU input.

The maximum processing delay time is measured by determining the difference between the instant the message timestamp point appears at the merging unit output, and the sample time represented by the SmpCnt field within the message.

The test shall be performed for a minimum of 1 min. Time measurement uncertainty shall be smaller than the difference between the upper limit of the maximum processing delay time specified in 6.902.2 and the maximum measured value of the processing delay times.

For sampled value messages containing multiple samples (NoASDU > 1), the maximum processing delay time measurement shall be performed with respect to the first (oldest) SmpCnt field.

NOTE 909 No analogue signals (voltage or current) are required to complete this test.

This method requires external time synchronization. The same time source that synchronizes the merging unit is used in the measurement of the sampled value frame output time. The SmpCnt field is decoded as the fractional part of the present second as follows:

$$St = SmpCnt/f_s$$

where

St is the sample time, and

f_S is the nominal number of samples per second

(Example: SmpCnt = 0x0000 corresponds to the start of the second)

For 96 kHz rate; the equation becomes:

$$St = \begin{cases} SmpCnt/f_s & after\ top\ of\ second \\ (SmpCnt + 65\,536)/f_s & after\ SmpCnt\ overflow \end{cases}$$

NOTE 910 Above equation addresses the fact SmpCnt overflows, reaching zero twice in one second. SmpCnt transition from 30 463 to zero denotes the real start of the second.

To observe the transition from the holdover to the free running mode the following test shall be performed.

– Start operating in the synchronized state; allow sufficient time for the device to stabilize.
– Remove the synchronization input to the device under test.
– Observe SmpSynch attribute and wait until it changes to zero (holdover period).
– Perform the maximum processing delay test for 1 s starting from the instant SmpSynch attribute changes to zero.
– Verify that the maximum processing delay measured in this test does not change by more than ±100 μs from the value measured during the 1 min synchronized state test.

This test may not be practical for devices with holdover mode exceeding 24 h. Such devices are exempt from this test and are expected to ensure compliance by design.

7.2.903 Loss of synchronization tests

Verify under worst-case conditions that on loss of synchronizing signal, the merging unit continues to send samples maintaining the sample timing required for the measuring accuracy class for the published duration of the holdover period. Verify that over this period, the SmpSynch attribute in the SV messages remains unchanged, and the SmpCnt attribute in the SV messages increments and wraps as if synchronization signal was present.

Verify that before the sample timing fails to meet the requirements for the measuring accuracy class declared, the SmpSynch attribute changes to zero.

Verify both on power up without a synchronizing signal present and after a time interval appropriate to the specific merging unit under test following synchronization signal cessation, the sampling rate maximum deviation from nominal is no more than $\pm 100 \times 10^{-6}$.

For merging units supporting PTP, verify that SmpSynch follows transitions between a global clock and at least two local area clocks. Verify that when transferring, time adjustments proceed as specified in this standard.

7.2.904 1PPS test

For merging units supporting 1PPS, verify jitter compliance by observing the output is within specified tolerance and SmpSynch remains non-zero with nominal primary input and 1PPS input signal alternately 2 μs early and 2 μs late.

Verify that without a valid 1PPS signal present SmpSynch is equal to 0.

Verify that with a valid 1PPS signal present SmpSynch is equal to 2.

Annex 9A
(informative)

Dynamic range considerations

Figures 9A.1 and 9A.2 show how the INT32 representation with the fixed scaling defined in this standard can be used to satisfy the complete dynamic range required by the majority of power system applications. Two nomograms illustrate the relationship between the dynamic range required by various instrument transformer accuracy classes and the dynamic range offered by a signed 32 bit integer INT32 data representation.

The LSB values defined in this standard are:

– Current: LSB = 1 mA (instantaneous value)

– Voltage: LSB = 10 mV (instantaneous value)

– One bit is used for the sign (+ or -)

The required bit-range has been determined as shown in the example below for a current measurement according to class 0.1 and application of protection and disturbance recording. The LSB value is chosen to be around 4 times less than the minimum voltage or current error allowed.

Example:

Instrument transformer with 100 A rated current.

100 A r.m.s. corresponds to 141 421 mA peak for pure sinusoidal signals.

141 421 $\cong 2^{17}$represents the approximate numerical expression for the rated current in this example.

– The maximum current error tolerated for an ECT according to class 0,1 at 5 % of its rated current equals to 0,4 %.

– The tolerated error thus becomes 0,000 2 I_{rated}. The value of 0,000 2/4 equals 0,000 05 and approximately corresponds to 2^{-14}.

– The highest current value at accuracy limit is in this case 65 $I_{\text{rated}} \times 2 = 130\ I_{\text{rated}}$. $130 \cong 2^{7}$.

– We get the minimal binary peak value as: $2^{17} \times 2^{-14} = 2^{3}$ which is acceptable since $2^{3} > 2^{0}$.

– The max binary value becomes $2^{17} \times 2^{7} = 2^{24}$ which is acceptable since $2^{24} < 2^{31}$.

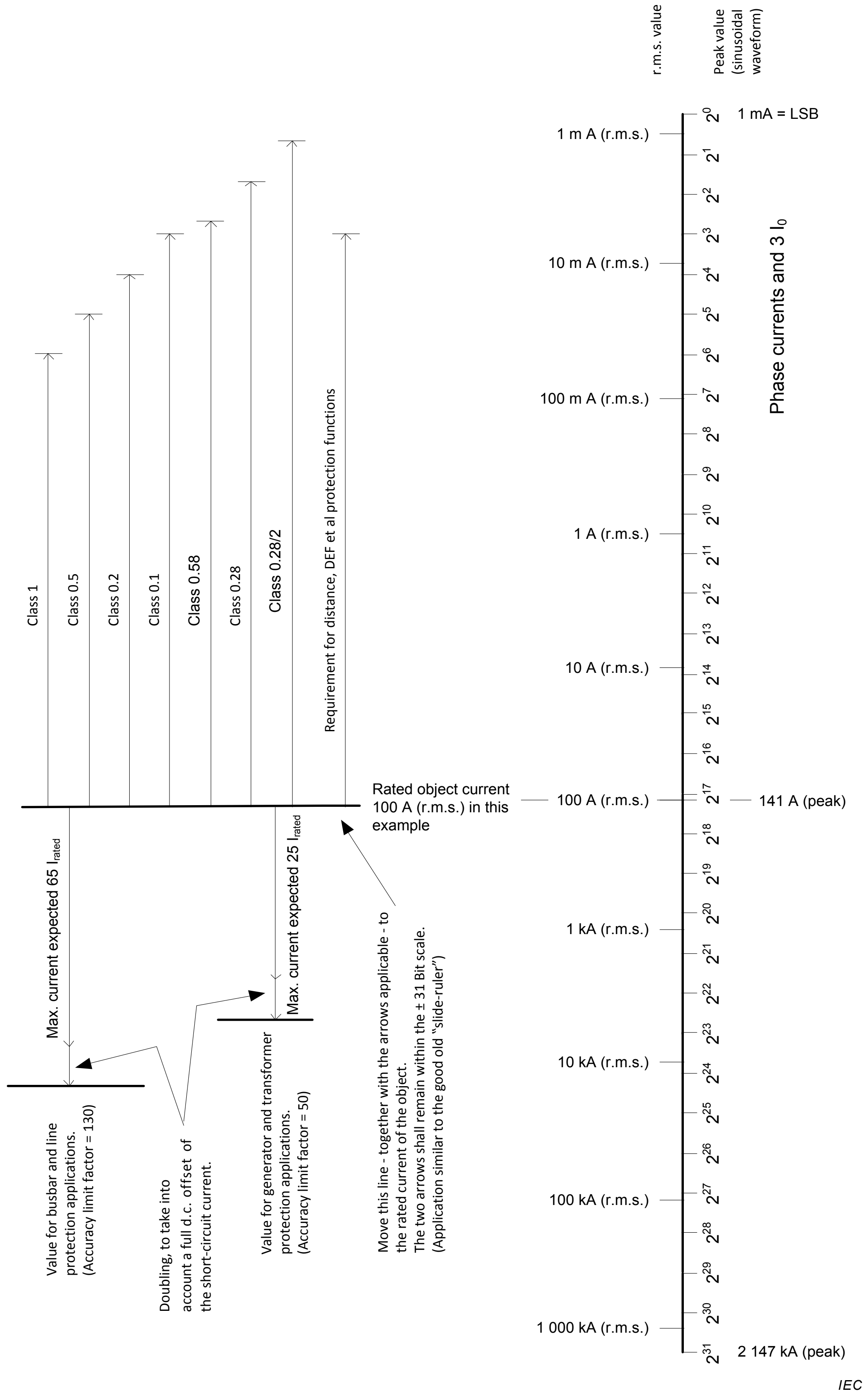


Figure 9A.1 – Nomogram for current

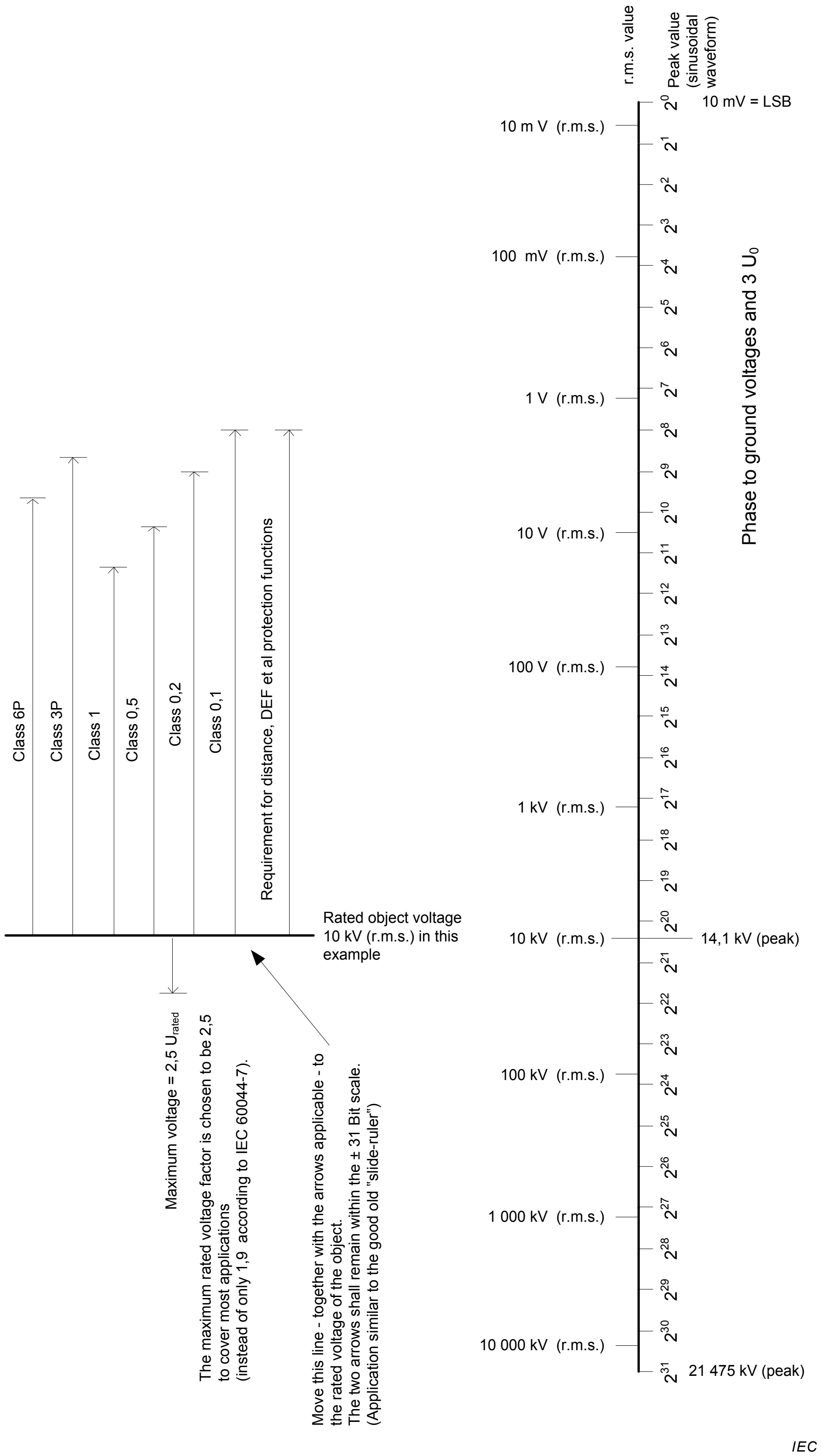


Figure 9A.2 – Nomogram for voltage

Annex 9B
(informative)

Time synchronization and management example

Figure 9B.1 shows a typical example of the signal processing and the individual sources of delay that make up the total delay time from the power system primary to the application algorithm. The time source may be either the 1PPS signal shown or precision time protocol (PTP).

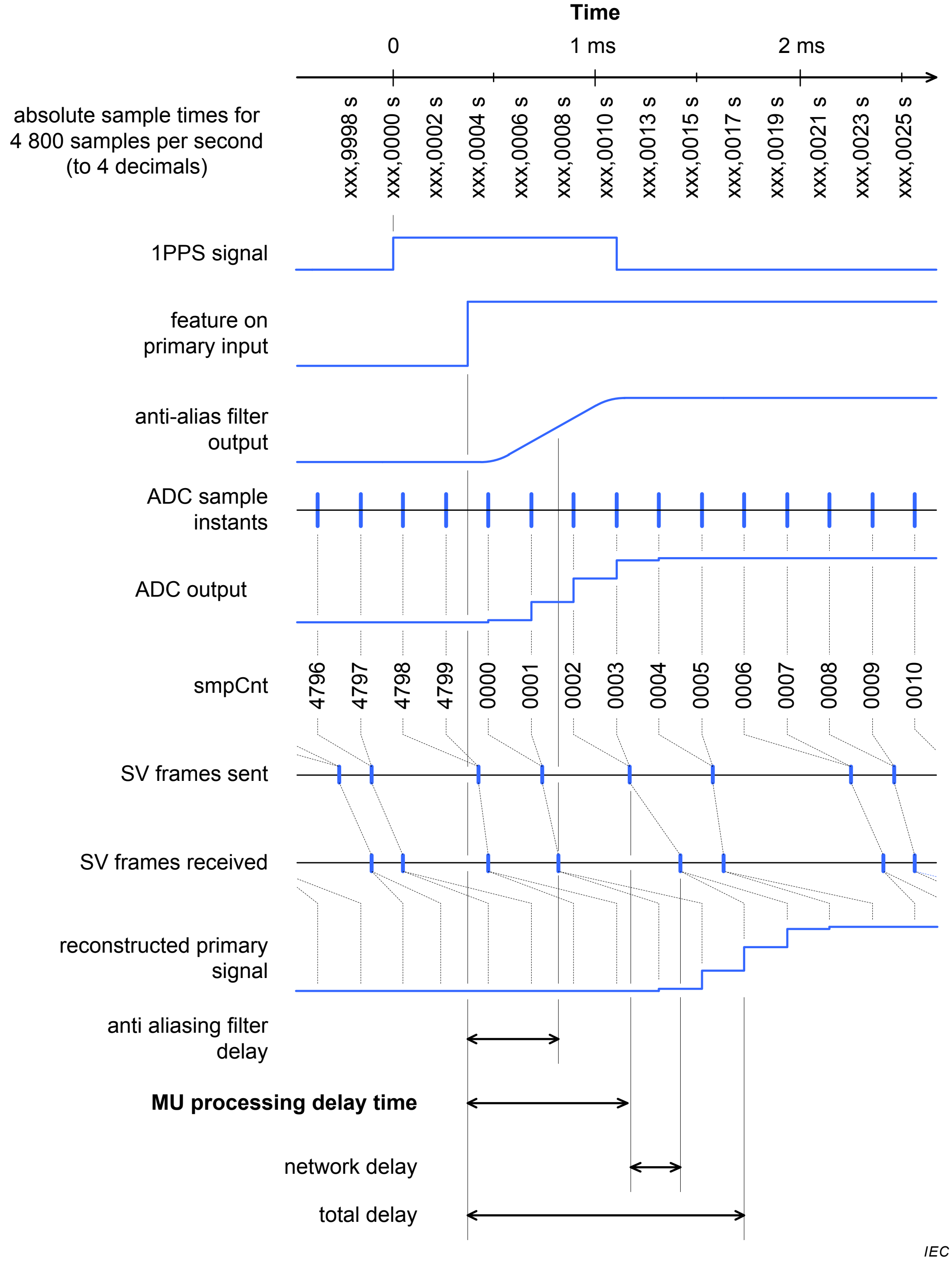


Figure 9B.1 – Sampled value signal processing example showing 2ASDUs per message (F4800S2I4U4 example)

Major delay time components in this example are:

– transport delay between the instrument transformer primary and secondary converters (when present)
– the anti-aliasing filtering of the primary input that introduces time delay prior to the analogue to digital converter;
– the analogue to digital converter that introduces a constant conversion delay (not shown);
– the message assembly and processing within the instrument transformer that may introduce a variable delay between the time the digital sample is acquired and when the sampled value packet becomes available at the MU digital output.

The sum of these delays forms the bulk of the instrument transformer processing delay time.

Because there is a variable component to the delay time, the worst-case delay time shall be considered when evaluating conformance to the maximum processing delay time requirement.

Where 1PPS is used for synchronization, additional offset may also be used to compensate for different 1PPS propagation delays contributed by the 1PPS delivery system (e.g. an exceptionally long fibre run).

The merging unit processing delay time does not include any delays that occur after the sampled value packet leaves the merging unit output (such as the process bus network delays). Such delays depend on the network speed, switching capabilities, and configuration. They can be separately calculated and will depend on the particular application. Responsibility for the overall system performance is left with the system integrator.

Annex 9C
(informative)

Example merging unit ICD file

The ICD (IED Capability Description) file in Substation Configuration Language (SCL) format below describes the capabilities of an example merging unit with variant codes (see 6.903.2) F4000S1I4U4 (9-2LE for 50 Hz), F4800S1I4U4 (9-2LE for 60 Hz), F4800S2I3U3 (preferred for protection and measuring applications with 3 currents and 3 voltages), F14400S6I3U3 (preferred for quality metering with 3 currents and 3 voltages) and F4800S2I1U0 (demonstration of a stream with only one current, no voltages), conformance class a (see 6.903.13), and PTP time synchronization (see 6.904.2). In practice, a file of this kind may be generated by the merging unit manufacturer or by the merging unit manufacturer's configuration tool, and passed to the system configuration tool.

Please note this ICD text is given only as an example. Refer to the SCL schema published in IEC 61850-6.

File ICD_example.xml


```xml
<?xml version="1.0" encoding="utf-8"?>
<SCL xmlns="http://www.iec.ch/61850/2003/SCL"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.iec.ch/61850/2003/SCL SCL.xsd" version="2007"
revision="B">

  <Header id="ICD file as supplied by the manufacturer for a hypothetical
IEC 61869-9 instrument transformer" version="1.0" revision="12" toolID="XML
Notepad"/>

  <Substation name="TEMPLATE" desc="Binds the TCTR and TVTR instances in the IED
section to particular phases of particular CTs/VTs in the station">
    <VoltageLevel name="TEMPLATE">
      <Bay name="TEMPLATE">
        <ConductingEquipment name="Inn" type="CTR">
          <SubEquipment name="A" phase="A">
            <LNode iedName="TEMPLATE" ldInst="MU01" lnClass="TCTR" lnInst="1"/>
          </SubEquipment>
          <SubEquipment name="B" phase="B">
            <LNode iedName="TEMPLATE" ldInst="MU01" lnClass="TCTR" lnInst="2"/>
          </SubEquipment>
          <SubEquipment name="C" phase="C">
            <LNode iedName="TEMPLATE" ldInst="MU01" lnClass="TCTR" lnInst="3"/>
          </SubEquipment>
          <SubEquipment name="N" phase="N">
            <LNode iedName="TEMPLATE" ldInst="MU01" lnClass="TCTR" lnInst="4"/>
          </SubEquipment>
        </ConductingEquipment>
        <ConductingEquipment name="Unn" type="VTR">
          <SubEquipment name="A" phase="A">
            <LNode iedName="TEMPLATE" ldInst="MU01" lnClass="TVTR" lnInst="1"/>
          </SubEquipment>
          <SubEquipment name="B" phase="B">
            <LNode iedName="TEMPLATE" ldInst="MU01" lnClass="TVTR" lnInst="2"/>
          </SubEquipment>
          <SubEquipment name="C" phase="C">
            <LNode iedName="TEMPLATE" ldInst="MU01" lnClass="TVTR" lnInst="3"/>
          </SubEquipment>
```

```
          <SubEquipment name="N" phase="N">
            <LNode iedName="TEMPLATE" ldInst="MU01" lnClass="TVTR" lnInst="4"/>
          </SubEquipment>
        </ConductingEquipment>
      </Bay>
    </VoltageLevel>
  </Substation>

  <Communication>
    <SubNetwork name="NONE" type="8-MMS">
      <BitRate unit="b/s" multiplier="M">100</BitRate>
      <ConnectedAP iedName="TEMPLATE" apName="S1">
        <SMV ldInst="MU01" cbName="MSVCB01" desc="9-2LE SV stream (F4000S1I4U4 and
F4800S1I4U4)">
          <Address>
            <P type="MAC-Address">01-0C-CD-04-00-00</P>
            <P type="VLAN-ID">000</P>
            <P type="VLAN-PRIORITY">4</P>
            <P type="APPID">4000</P>
          </Address>
        </SMV>
        <SMV ldInst="MU01" cbName="MSVCB03" desc="preferred stream for apps
needing measuring or protective class (F4800S2I3U3)">
          <Address>
            <P type="MAC-Address">01-0C-CD-04-00-01</P>
            <P type="VLAN-ID">000</P>
            <P type="VLAN-PRIORITY">4</P>
            <P type="APPID">4003</P>
          </Address>
        </SMV>
        <SMV ldInst="MU01" cbName="MSVCB04" desc="preferred stream for apps
needing quality metering class (F14400S6I3U3)">
          <Address>
            <P type="MAC-Address">01-0C-CD-04-00-02</P>
            <P type="VLAN-ID">000</P>
            <P type="VLAN-PRIORITY">4</P>
            <P type="APPID">4004</P>
          </Address>
        </SMV>
        <SMV ldInst="MU01" cbName="MSVCB05" desc="demonstration of a stream with
one quantity (F4800S2I1U0)">
          <Address>
            <P type="MAC-Address">01-0C-CD-04-00-03</P>
            <P type="VLAN-ID">000</P>
            <P type="VLAN-PRIORITY">4</P>
            <P type="APPID">4005</P>
          </Address>
        </SMV>
        <PhysConn type="Connection">
          <P type="Type">FOC</P>
          <P type="Plug">ST</P>
        </PhysConn>
      </ConnectedAP>
    </SubNetwork>
  </Communication>

  <IED name="TEMPLATE" desc="Hypothetical instrument transformer with digital
output according to IEC 61869-9">
    <AccessPoint name="S1">
      <Server>
        <Authentication none="true"/>
```

```
        <LDevice inst="MU01">
          <LN0 lnType="LN0" lnClass="LLN0" inst="">
            <DataSet name="PhsMeas1" desc="9-2LE dataset for SV streams
F4000S1I4U4 and F4800S1I4U4">
              <FCDA ldInst="MU01" lnClass="TCTR" lnInst="1" doName="AmpSv" fc="MX"
daName="instMag.i"/>
              <FCDA ldInst="MU01" lnClass="TCTR" lnInst="1" doName="AmpSv" fc="MX"
daName="q"/>
              <FCDA ldInst="MU01" lnClass="TCTR" lnInst="2" doName="AmpSv" fc="MX"
daName="instMag.i"/>
              <FCDA ldInst="MU01" lnClass="TCTR" lnInst="2" doName="AmpSv" fc="MX"
daName="q"/>
              <FCDA ldInst="MU01" lnClass="TCTR" lnInst="3" doName="AmpSv" fc="MX"
daName="instMag.i"/>
              <FCDA ldInst="MU01" lnClass="TCTR" lnInst="3" doName="AmpSv" fc="MX"
daName="q"/>
              <FCDA ldInst="MU01" lnClass="TCTR" lnInst="4" doName="AmpSv" fc="MX"
daName="instMag.i"/>
              <FCDA ldInst="MU01" lnClass="TCTR" lnInst="4" doName="AmpSv" fc="MX"
daName="q"/>
              <FCDA ldInst="MU01" lnClass="TVTR" lnInst="1" doName="VolSv" fc="MX"
daName="instMag.i"/>
              <FCDA ldInst="MU01" lnClass="TVTR" lnInst="1" doName="VolSv" fc="MX"
daName="q"/>
              <FCDA ldInst="MU01" lnClass="TVTR" lnInst="2" doName="VolSv" fc="MX"
daName="instMag.i"/>
              <FCDA ldInst="MU01" lnClass="TVTR" lnInst="2" doName="VolSv" fc="MX"
daName="q"/>
              <FCDA ldInst="MU01" lnClass="TVTR" lnInst="3" doName="VolSv" fc="MX"
daName="instMag.i"/>
              <FCDA ldInst="MU01" lnClass="TVTR" lnInst="3" doName="VolSv" fc="MX"
daName="q"/>
              <FCDA ldInst="MU01" lnClass="TVTR" lnInst="4" doName="VolSv" fc="MX"
daName="instMag.i"/>
              <FCDA ldInst="MU01" lnClass="TVTR" lnInst="4" doName="VolSv" fc="MX"
daName="q"/>
            </DataSet>
            <DataSet name="PhsMeas2" desc="dataset for preferred SV streams
F4800S2I3U3 and F14400S6I3U3">
              <FCDA ldInst="MU01" lnClass="TCTR" lnInst="1" doName="AmpSv" fc="MX"
daName="instMag.i"/>
              <FCDA ldInst="MU01" lnClass="TCTR" lnInst="1" doName="AmpSv" fc="MX"
daName="q"/>
              <FCDA ldInst="MU01" lnClass="TCTR" lnInst="2" doName="AmpSv" fc="MX"
daName="instMag.i"/>
              <FCDA ldInst="MU01" lnClass="TCTR" lnInst="2" doName="AmpSv" fc="MX"
daName="q"/>
              <FCDA ldInst="MU01" lnClass="TCTR" lnInst="3" doName="AmpSv" fc="MX"
daName="instMag.i"/>
              <FCDA ldInst="MU01" lnClass="TCTR" lnInst="3" doName="AmpSv" fc="MX"
daName="q"/>
              <FCDA ldInst="MU01" lnClass="TVTR" lnInst="1" doName="VolSv" fc="MX"
daName="instMag.i"/>
              <FCDA ldInst="MU01" lnClass="TVTR" lnInst="1" doName="VolSv" fc="MX"
daName="q"/>
              <FCDA ldInst="MU01" lnClass="TVTR" lnInst="2" doName="VolSv" fc="MX"
daName="instMag.i"/>
              <FCDA ldInst="MU01" lnClass="TVTR" lnInst="2" doName="VolSv" fc="MX"
daName="q"/>
              <FCDA ldInst="MU01" lnClass="TVTR" lnInst="3" doName="VolSv" fc="MX"
daName="instMag.i"/>
```

```
              <FCDA ldInst="MU01" lnClass="TVTR" lnInst="3" doName="VolSv" fc="MX"
daName="q"/>
            </DataSet>
            <DataSet name="PhsMeas3" desc="dataset for SV stream F4800S2I1U0">
              <FCDA ldInst="MU01" lnClass="TCTR" lnInst="4" doName="AmpSv" fc="MX"
daName="instMag.i"/>
              <FCDA ldInst="MU01" lnClass="TCTR" lnInst="4" doName="AmpSv" fc="MX"
daName="q"/>
            </DataSet>
            <SampledValueControl name="MSVCB01" datSet="PhsMeas1" confRev="1"
smvID="xxxxMU0101" smpRate="80" smpMod="SmpPerPeriod" nofASDU="1"
multicast="true">
              <SmvOpts sampleSynchronized="true" refreshTime="false"
sampleRate="false" dataSet="false" security="false"/>
            </SampledValueControl>
            <SampledValueControl name="MSVCB03" datSet="PhsMeas2" confRev="1"
smvID="4003" smpRate="4800" smpMod="SmpPerSec" nofASDU="2" multicast="true">
              <SmvOpts sampleSynchronized="true" refreshTime="false"
sampleRate="false" dataSet="false" security="false"/>
            </SampledValueControl>
            <SampledValueControl name="MSVCB04" datSet="PhsMeas2" confRev="1"
smvID="4004" smpRate="14400" smpMod="SmpPerSec" nofASDU="6" multicast="true">
              <SmvOpts sampleSynchronized="true" refreshTime="false"
sampleRate="false" dataSet="false" security="false"/>
            </SampledValueControl>
            <SampledValueControl name="MSVCB05" datSet="PhsMeas3" confRev="1"
smvID="4005" smpRate="4800" smpMod="SmpPerSec" nofASDU="2" multicast="true">
              <SmvOpts sampleSynchronized="true" refreshTime="false"
sampleRate="false" dataSet="false" security="false"/>
            </SampledValueControl>
          </LN0>
          <LN lnType="PHD" lnClass="LPHD" inst="1"/>
          <LN lnType="CTR-P" lnClass="TCTR" inst="1"/>
          <LN lnType="CTR-P" lnClass="TCTR" inst="2"/>
          <LN lnType="CTR-P" lnClass="TCTR" inst="3"/>
          <LN lnType="CTR-N" lnClass="TCTR" inst="4"/>
          <LN lnType="VTR-P" lnClass="TVTR" inst="1"/>
          <LN lnType="VTR-P" lnClass="TVTR" inst="2"/>
          <LN lnType="VTR-P" lnClass="TVTR" inst="3"/>
          <LN lnType="VTR-N" lnClass="TVTR" inst="4"/>
        </LDevice>
      </Server>
    </AccessPoint>
  </IED>

  <DataTypeTemplates>

    <LNodeType id="LN0" lnClass="LLN0">
      <DO name="NamPlt" type="NamPlt-LN0"/>
      <DO name="Beh" type="Beh"/>
      <DO name="Health" type="Health"/>
      <DO name="Mod" type="Mod"/>
    </LNodeType>
    <LNodeType id="PHD" lnClass="LPHD">
      <DO name="PhyNam" type="PhyNam"/>
      <DO name="PhyHealth" type="Health"/>
      <DO name="Proxy" type="Proxy"/>
      <DO name="NamVariant" type="NamVariant"/>
      <DO name="NamHzRtg" type="NamHzRtg"/>
      <DO name="NamAuxVRtg" type="NamAuxVRtg"/>
      <DO name="NamHoldRtg" type="NamHoldRtg"/>
```

```
      <DO name="NamMaxDlRtg" type="NamMaxDlRtg"/>
    </LNodeType>
    <LNodeType id="CTR-P" lnClass="TCTR">
      <DO name="Beh" type="Beh"/>
      <DO name="AmpSv" type="AmpSAV"/>
      <DO name="NamAccRtg" type="NamAccRtg-PC"/>
      <DO name="NamARtg" type="NamARtg-PC"/>
      <DO name="NamClipRtg" type="NamClipRtg-PC"/>
    </LNodeType>
    <LNodeType id="CTR-N" lnClass="TCTR">
      <DO name="Beh" type="Beh"/>
      <DO name="AmpSv" type="AmpSAV"/>
      <DO name="NamAccRtg" type="NamAccRtg-NC"/>
      <DO name="NamARtg" type="NamARtg-NC"/>
      <DO name="NamClipRtg" type="NamClipRtg-NC"/>
    </LNodeType>
    <LNodeType id="VTR-P" lnClass="TVTR">
      <DO name="Beh" type="Beh"/>
      <DO name="VolSv" type="VolSAV"/>
      <DO name="NamAccRtg" type="NamAccRtg-PV"/>
      <DO name="NamVRtg" type="NamVRtg-PV"/>
      <DO name="NamClipRtg" type="NamClipRtg-PV"/>
    </LNodeType>
    <LNodeType id="VTR-N" lnClass="TVTR">
      <DO name="Beh" type="Beh"/>
      <DO name="VolSv" type="VolSAV"/>
      <DO name="NamAccRtg" type="NamAccRtg-NV"/>
      <DO name="NamVRtg" type="NamVRtg-NV"/>
      <DO name="NamClipRtg" type="NamClipRtg-NV"/>
    </LNodeType>

    <DOType id="NamPlt-LN0" cdc="LPL">
      <DA name="vendor" desc="" bType="VisString255" fc="DC"/>
      <DA name="swRev" bType="VisString255" fc="DC">
        <Val>1v00</Val>
      </DA>
      <DA name="configRev" bType="VisString255" fc="DC">
        <Val>1</Val>
      </DA>
      <DA name="ldNs" bType="VisString255" fc="EX">
        <Val>IEC 61850-7-4:2007B</Val>
      </DA>
    </DOType>
    <DOType id="Beh" cdc="ENS">
      <DA name="stVal" bType="Enum" type="Beh" fc="ST" dchg="true" />
      <DA name="q" bType="Quality" fc="ST" qchg="true"/>
      <DA name="t" bType="Timestamp" fc="ST"/>
    </DOType>
    <DOType id="Health" cdc="ENS">
      <DA name="stVal" bType="Enum" type="Health" fc="ST" dchg="true" />
      <DA name="q" bType="Quality" fc="ST" qchg="true"/>
      <DA name="t" bType="Timestamp" fc="ST"/>
    </DOType>
    <DOType id="Mod" cdc="ENC">
      <DA name="stVal" bType="Enum" type="Mod" fc="ST" dchg="true"/>
      <DA name="q" bType="Quality" fc="ST" qchg="true"/>
      <DA name="t" bType="Timestamp" fc="ST"/>
      <DA name="ctlModel" bType="Enum" type="CtlModels" fc="CF" dchg="true">
        <Val>status-only</Val>
      </DA>
    </DOType>
```

```
    <DOType id="PhyNam" cdc="DPL">
      <DA name="vendor" bType="VisString255" fc="DC">
        <Val>Acme Manufacturing Ltd., 1 North Rodeo Drive, Beverley Hills, CA,
90210</Val>
      </DA>
      <DA name="hwRev" bType="VisString255" fc="DC">
        <Val>1v03</Val>
      </DA>
      <DA name="swRev" bType="VisString255" fc="DC">
        <Val>1v00</Val>
      </DA>
      <DA name="serNum" bType="VisString255" fc="DC">
        <Val>000001, mfg 2011-12-01</Val>
      </DA>
      <DA name="model" bType="VisString255" fc="DC">
        <Val>DigiMeas101</Val>
      </DA>
    </DOType>
    <DOType id="Proxy" cdc="SPS">
      <DA name="stVal" bType="BOOLEAN" fc="ST" dchg="true">
        <Val>false</Val>
      </DA>
      <DA name="q" bType="Quality" fc="ST" qchg="true"/>
      <DA name="t" bType="Timestamp" fc="ST"/>
    </DOType>
    <DOType id="NamVariant" cdc="VSD">
      <DA name="val" bType="VisString255" fc="DC">
        <Val>F4800S1I4U4;F14400S6I4U4;F4800S2I0-24U0-24</Val>
      </DA>
      <DA name="d" bType="VisString255" fc="DC">
        <Val>a semicolon separated list of the variant codes supported, the codes
being as defined in IEC 61869-9:2016 clause 6.903.2</Val>
      </DA>
      <DA name="dataNs" bType="VisString255" fc="EX">
        <Val>IEC 61869-9:2016</Val>
      </DA>
    </DOType>
    <DOType id="NamHzRtg" cdc="VSD">
      <DA name="val" bType="VisString255" fc="DC">
        <Val>dc; 50; 60</Val>
      </DA>
      <DA name="d" bType="VisString255" fc="DC">
        <Val>a semicolon separated list of the nominal frequencies (fR) supported,
in hertz</Val>
      </DA>
      <DA name="dataNs" bType="VisString255" fc="EX">
        <Val>IEC 61869-9:2016</Val>
      </DA>
    </DOType>
    <DOType id="NamAuxVRtg" cdc="VSD">
      <DA name="val" bType="VisString255" fc="DC">
        <Val>80-300 dc;100-250 ac</Val>
      </DA>
      <DA name="d" bType="VisString255" fc="DC">
        <Val>a semicolon separated list or hyphenated range of rated auxiliary
power supply voltages (Uar) in volts, with indication of ac or dc where
applicable</Val>
      </DA>
      <DA name="dataNs" bType="VisString255" fc="EX">
        <Val>IEC 61869-9:2016</Val>
      </DA>
```

```xml
    </DOType>
    <DOType id="NamHoldRtg" cdc="VSD">
      <DA name="val" bType="VisString255" fc="DC">
        <Val>10</Val>
      </DA>
      <DA name="d" bType="VisString255" fc="DC">
        <Val>the rated holdover time in seconds</Val>
      </DA>
      <DA name="dataNs" bType="VisString255" fc="EX">
        <Val>IEC 61869-9:2016</Val>
      </DA>
    </DOType>
    <DOType id="NamMaxDlRtg" cdc="VSD">
      <DA name="val" bType="VisString255" fc="DC">
        <Val>1.5</Val>
      </DA>
      <DA name="d" bType="VisString255" fc="DC">
        <Val>the rated delay time in milliseconds</Val>
      </DA>
      <DA name="dataNs" bType="VisString255" fc="EX">
        <Val>IEC 61869-9:2016</Val>
      </DA>
    </DOType>

    <DOType id="NamAccRtg-PC" cdc="VSD">
      <DA name="val" bType="VisString255" fc="DC">
        <Val>0,5S/5P20</Val>
      </DA>
      <DA name="d" bType="VisString255" fc="DC">
        <Val>the accuracy class rating in the format described in IEC 61869-9
clause 5.6</Val>
      </DA>
      <DA name="dataNs" bType="VisString255" fc="EX">
        <Val>IEC 61869-9:2016</Val>
      </DA>
    </DOType>
    <DOType id="NamARtg-PC" cdc="VSD">
      <DA name="val" bType="VisString255" fc="DC">
        <Val>400;800;1200</Val>
      </DA>
      <DA name="d" bType="VisString255" fc="DC">
        <Val>rated primary currents (IPr) in amperes</Val>
      </DA>
      <DA name="dataNs" bType="VisString255" fc="EX">
        <Val>IEC 61869-9:2016</Val>
      </DA>
    </DOType>
    <DOType id="NamClipRtg-PC" cdc="VSD">
      <DA name="val" bType="VisString255" fc="DC">
        <Val>20</Val>
      </DA>
      <DA name="d" bType="VisString255" fc="DC">
        <Val> the ratio of the clipping limit of the instantaneous current to the
rated primary current multiplied with a square root of two</Val>
      </DA>
      <DA name="dataNs" bType="VisString255" fc="EX">
        <Val>IEC 61869-9:2016</Val>
      </DA>
    </DOType>
```

```
    <DOType id="NamAccRtg-NC" cdc="VSD">
      <DA name="val" bType="VisString255" fc="DC">
        <Val>1/5P</Val>
      </DA>
      <DA name="d" bType="VisString255" fc="DC">
        <Val>the accuracy class rating in the format described in IEC 61869-9 
clause 5.6</Val>
      </DA>
      <DA name="dataNs" bType="VisString255" fc="EX">
        <Val>IEC 61869-9:2016</Val>
      </DA>
    </DOType>
    <DOType id="NamARtg-NC" cdc="VSD">
      <DA name="val" bType="VisString255" fc="DC">
        <Val>400;800;1200</Val>
      </DA>
      <DA name="d" bType="VisString255" fc="DC">
        <Val> rated primary currents (IPr) in amperes</Val>
      </DA>
      <DA name="dataNs" bType="VisString255" fc="EX">
        <Val>IEC 61869-9:2016</Val>
      </DA>
    </DOType>
    <DOType id="NamClipRtg-NC" cdc="VSD">
      <DA name="val" bType="VisString255" fc="DC">
        <Val>20</Val>
      </DA>
      <DA name="d" bType="VisString255" fc="DC">
        <Val> the ratio of the clipping limit of the instantaneous current to the 
rated primary current multiplied with a square root of two</Val>
      </DA>
      <DA name="dataNs" bType="VisString255" fc="EX">
        <Val>IEC 61869-9:2016</Val>
      </DA>
    </DOType>

    <DOType id="NamAccRtg-PV" cdc="VSD">
      <DA name="val" bType="VisString255" fc="DC">
        <Val>0,5/3P</Val>
      </DA>
      <DA name="d" bType="VisString255" fc="DC">
        <Val>the accuracy class rating in the format described in IEC 61869-9 
clause 5.6</Val>
      </DA>
      <DA name="dataNs" bType="VisString255" fc="EX">
        <Val>IEC 61869-9:2016</Val>
      </DA>
    </DOType>
    <DOType id="NamVRtg-PV" cdc="VSD">
      <DA name="val" bType="VisString255" fc="DC">
        <Val>83716</Val>
      </DA>
      <DA name="d" bType="VisString255" fc="DC">
        <Val>the rated primary voltage (UPr) in volts</Val>
      </DA>
      <DA name="dataNs" bType="VisString255" fc="EX">
        <Val>IEC 61869-9:2016</Val>
      </DA>
    </DOType>
    <DOType id="NamClipRtg-PV" cdc="VSD">
      <DA name="val" bType="VisString255" fc="DC">
```

```
        <Val>2</Val>
      </DA>
      <DA name="d" bType="VisString255" fc="DC">
        <Val>the ratio of the clipping limit of the instantaneous voltage to the
rated primary voltage multiplied with a square root of two</Val>
      </DA>
      <DA name="dataNs" bType="VisString255" fc="EX">
        <Val>IEC 61869-9:2016</Val>
      </DA>
    </DOType>

    <DOType id="NamAccRtg-NV" cdc="VSD">
      <DA name="val" bType="VisString255" fc="DC">
        <Val>1</Val>
      </DA>
      <DA name="d" bType="VisString255" fc="DC">
        <Val>the accuracy class rating in the format described in IEC 61869-9
clause 5.6</Val>
      </DA>
      <DA name="dataNs" bType="VisString255" fc="EX">
        <Val>IEC 61869-9:2016</Val>
      </DA>
    </DOType>
    <DOType id="NamVRtg-NV" cdc="VSD">
      <DA name="val" bType="VisString255" fc="DC">
        <Val>115</Val>
      </DA>
      <DA name="d" bType="VisString255" fc="DC">
        <Val>the rated primary voltage (UPr) in volts</Val>
      </DA>
      <DA name="dataNs" bType="VisString255" fc="EX">
        <Val>IEC 61869-9:2016</Val>
      </DA>
    </DOType>
    <DOType id="NamClipRtg-NV" cdc="VSD">
      <DA name="val" bType="VisString255" fc="DC">
        <Val>2</Val>
      </DA>
      <DA name="d" bType="VisString255" fc="DC">
        <Val>the ratio of the clipping limit of the instantaneous voltage to the
rated primary voltage multiplied with a square root of two</Val>
      </DA>
      <DA name="dataNs" bType="VisString255" fc="EX">
        <Val>IEC 61869-9:2016</Val>
      </DA>
    </DOType>

    <DOType id="AmpSAV" cdc="SAV">
      <DA name="instMag" bType="Struct" type="AnalogueValue" fc="MX"/>
      <DA name="q" bType="Quality" fc="MX" qchg="true"/>
      <DA name="units" bType="Struct" type="AmpUnits" fc="CF" dchg="true"/>
      <DA name="sVC" bType="Struct" type="AmpScaledValueConfig" fc="CF"
dchg="true"/>
    </DOType>
    <DOType id="VolSAV" cdc="SAV">
      <DA name="instMag" bType="Struct" type="AnalogueValue" fc="MX"/>
      <DA name="q" bType="Quality" fc="MX" qchg="true"/>
      <DA name="units" bType="Struct" type="VolUnits" fc="CF" dchg="true"/>
      <DA name="sVC" bType="Struct" type="VolScaledValueConfig" fc="CF"
dchg="true"/>
    </DOType>
```

```
<DAType id="AmpScaledValueConfig">
  <BDA name="scaleFactor" bType="FLOAT32">
    <Val>0.001</Val>
  </BDA>
  <BDA name="offset" bType="FLOAT32">
    <Val>0</Val>
  </BDA>
</DAType>
<DAType id="VolScaledValueConfig">
  <BDA name="scaleFactor" bType="FLOAT32">
    <Val>0.01</Val>
  </BDA>
  <BDA name="offset" bType="FLOAT32">
    <Val>0</Val>
  </BDA>
</DAType>
<DAType id="AmpUnits">
  <BDA name="SIUnit" bType="Enum" type="ITSIUnit">
    <Val>A</Val>
  </BDA>
</DAType>
<DAType id="VolUnits">
  <BDA name="SIUnit" bType="Enum" type="ITSIUnit">
    <Val>V</Val>
  </BDA>
</DAType>
<DAType id="AnalogueValue">
  <BDA name="i" bType="INT32"/>
</DAType>

<EnumType id="Mod">
  <EnumVal ord="1">on</EnumVal>
  <EnumVal ord="2">blocked</EnumVal>
  <EnumVal ord="3">test</EnumVal>
  <EnumVal ord="4">test/blocked</EnumVal>
  <EnumVal ord="5">off</EnumVal>
</EnumType>
<EnumType id="Beh">
  <EnumVal ord="1">on</EnumVal>
  <EnumVal ord="2">blocked</EnumVal>
  <EnumVal ord="3">test</EnumVal>
  <EnumVal ord="4">test/blocked</EnumVal>
  <EnumVal ord="5">off</EnumVal>
</EnumType>
<EnumType id="Health">
  <EnumVal ord="1">Ok</EnumVal>
  <EnumVal ord="2">Warning</EnumVal>
  <EnumVal ord="3">Alarm</EnumVal>
</EnumType>
<EnumType id="CtlModels">
  <EnumVal ord="0">status-only</EnumVal>
  <EnumVal ord="1">direct-with-normal-security</EnumVal>
  <EnumVal ord="2">sbo-with-normal-security</EnumVal>
  <EnumVal ord="3">direct-with-enhanced-security</EnumVal>
  <EnumVal ord="4">sbo-with-enhanced-security</EnumVal>
</EnumType>
<EnumType id="ITSIUnit">
  <EnumVal ord="5">A</EnumVal>
  <EnumVal ord="29">V</EnumVal>
</EnumType>
```

```
  </DataTypeTemplates>
</SCL>
```

Annex 9D
(informative)

Test circuits for accuracy measurement

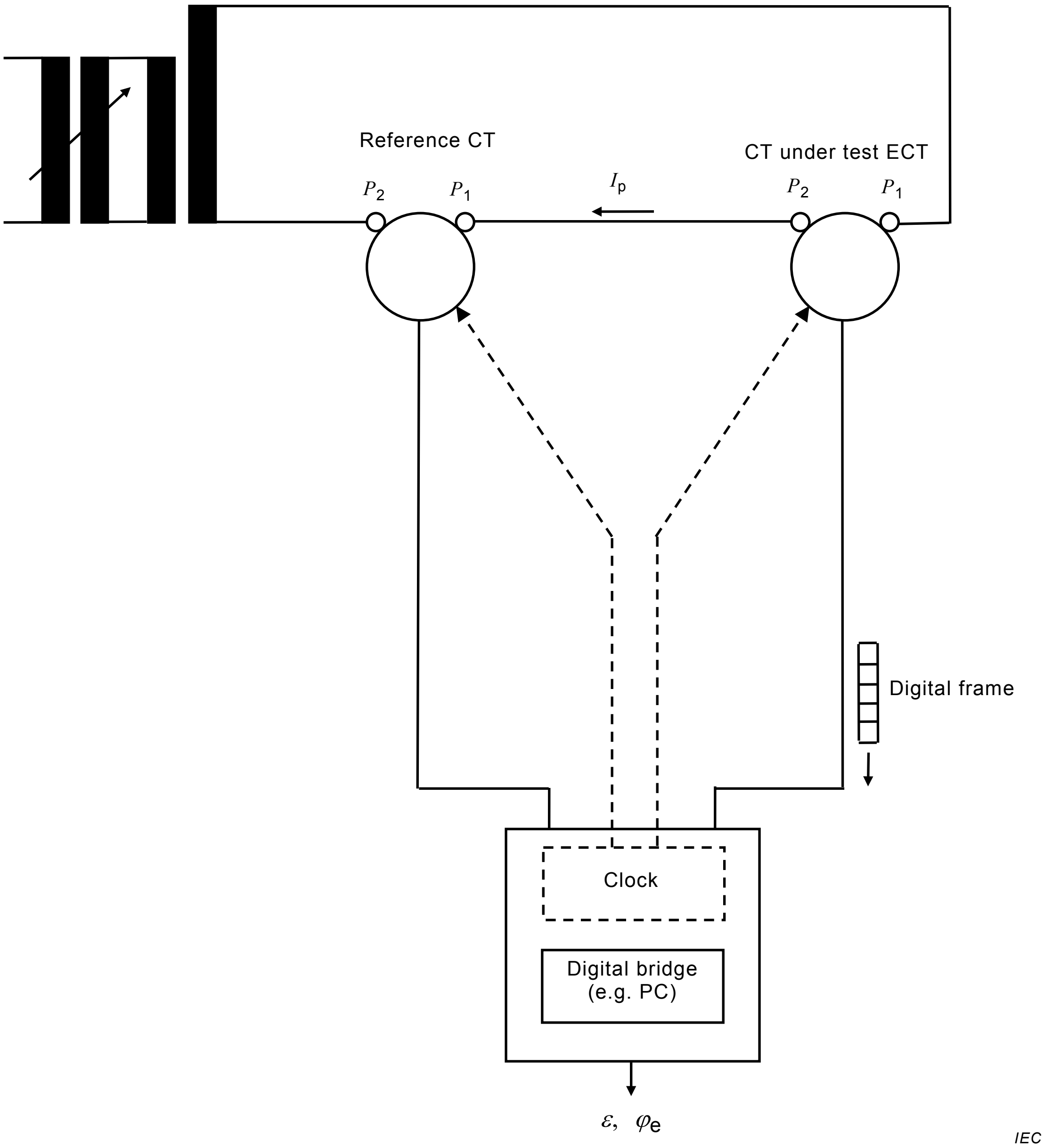


Figure 9D.1 – Example test circuit

For the purposes of accuracy class compliance testing, the ratio error and phase error of an instrument transformer (CT under test in Figure 9D.1) should be calculated using a full cycle Discrete Fourier Transform on the difference between its samples and those of a reference instrument transformer (Reference CT in Figure 9D.1). The composite error shall be calculated as the RMS value of the difference between its samples and those of the reference instrument transformer over a full cycle.

With this method, it is necessary that the composite error of reference transformer R is truly negligible under the conditions of use.

The corresponding formulae are:

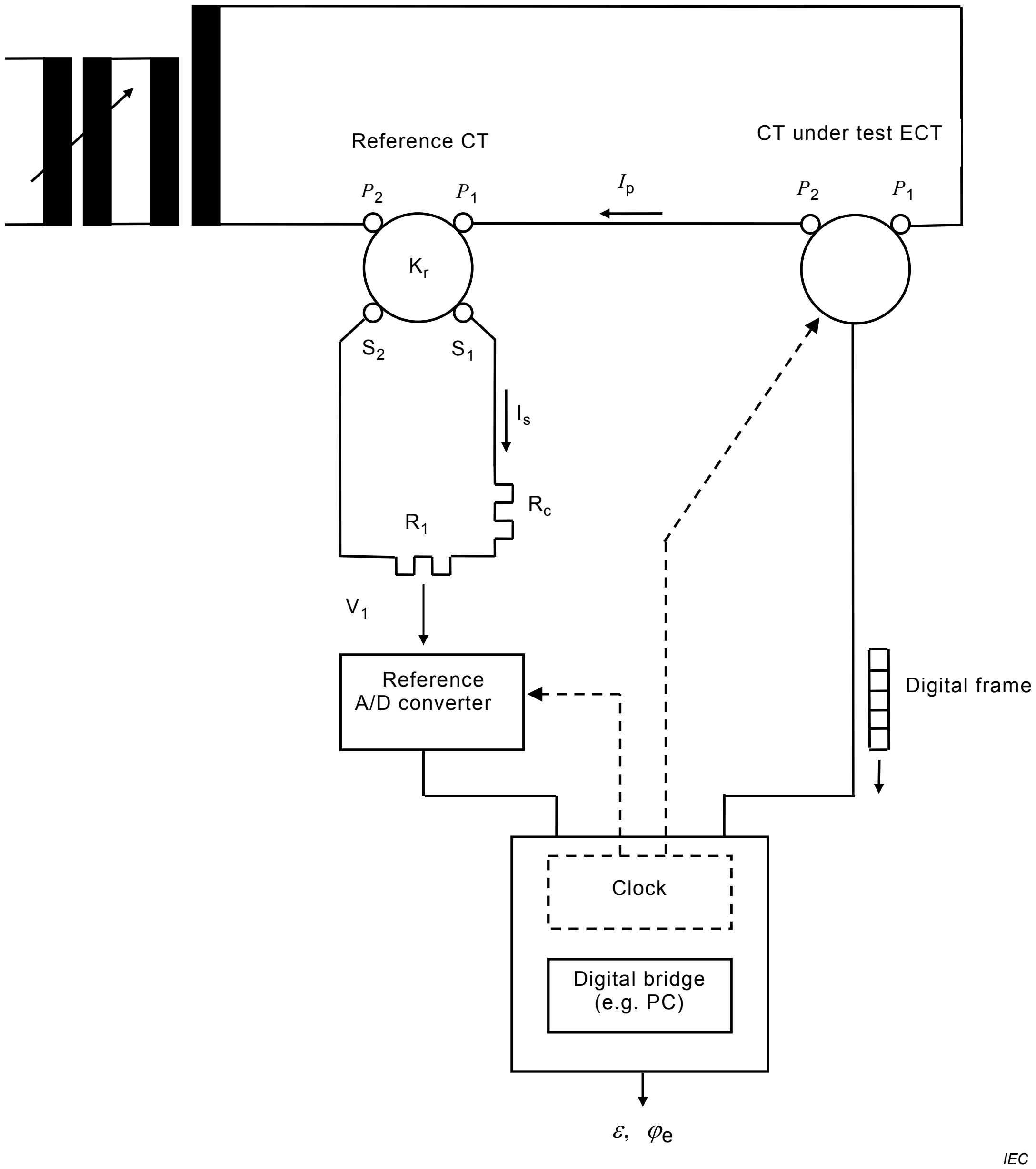
$$\vec{\varepsilon}_{(s)} = \frac{\frac{\sqrt{2}}{N}\sum_{n=0}^{N-1}\left(i_{X(s-n)} - i_{R(s-n)}\right) e^{2\pi\sqrt{-1}\,k\,(s-n)/N}}{\sqrt{\frac{1}{N}\sum_{n=0}^{N-1}\left[\left(i_{R(s-n)}\right)^2\right]}} \cdot 100\ \%$$

$$\varepsilon_{\mathrm{c}(s)} = \sqrt{\frac{\sum_{n=0}^{N-1}\left[\left(i_{X(s-n)} - i_{R(s-n)}\right)^2\right]}{\sum_{n=0}^{N-1}\left[\left(i_{R(s-n)}\right)^2\right]}} \cdot 100\ \%$$

where

- $\vec{\varepsilon}_{(s)}$ is the merging unit's ratio error and phase error, represented as a phasor, at the time instant coded by a SmpCnt with value s;
- $\varepsilon_{\mathrm{c}(s)}$ is the merging unit's composite error at the time instant coded by a SmpCnt with value s;
- $i_{X(s)}$ is the value from the instrument transformer under test of AmpSv.instMag.i or VolSv.instMag.i in the SV ASDU that has a SmpCnt value of s;
- $i_{R(s)}$ is the value from the reference instrument transformer of AmpSv.instMag.i or VolSv.instMag.i in the SV ASDU that has a SmpCnt value of s;
- N is the nominal sample rate in samples per second divided by the fundamental frequency in hertz;
- k is the number of the harmonic being measured ($k > 0$, and is 1 for the fundamental).

Another example test circuit for accuracy measurements in steady state and transient conditions for an Electronic LPCT with digital output is shown in Figure 9D.2.



Key

K_r	Rated transformation ratio of reference CT
V_1	Voltage at the input of the reference A/D converter
R_1	Burden used to adjust the voltage at the input of the reference A/D converter
$R_1 + R_c$	Rated secondary burden of reference CT

R_1 is required to be a high accuracy burden.

Figure 9D.2 – Example test circuit

Annex 9E
(informative)

Electronic nameplate

The electronic nameplate information is contained in extensions to the logical models defined in IEC 61850-7-4. The extensions use the common data class VSD visible string description information that will be added to IEC 61850-7-3. The definition of this CDC (common data class) is provided here for information purposes.

VSD class					
Data attribute name	**Type**	**FC**	**TrgOp**	**Value/Value range**	**M/O/C**
DataName	Inherited from GenDataObject class or from GenSubDataObject class (see IEC 61850-7-2)				
DataAttribute					
		configuration, description and extension			
val	VISIBLE STRING255	DC			M
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX		IEC 61869-9:2016	AC_DLN_M
Services					
As defined in IEC 61850-7-3: 2010, Table 60					

Bibliography

IEC 60044-7:1999, *Instrument transformers – Part 7: Electronic voltage transformers*

IEC 60044-8:2002, *Instrument transformers – Part 8: Electronic current transformers*

IEC 61850 (all parts), *Communication networks and systems for power utility automation*

IEC 61850-5:2013, *Communication networks and systems for power utility automation – Part 5: Communication requirements for functions and device models*

IEC 61850-8-1, *Communication networks and systems for power utility automation – Part 8-1: Specific communication service mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3*

IEC 61850-10, *Communication networks and systems for power utility automation – Part 10: Conformance testing*

IEC TR 61850-90-4:2013, *Communication networks and systems for power utility automation – Part 90-4: Network engineering guidelines*

IEC 61869 (all parts), *Instrument transformers*

IEC 61869-7:—, *Instrument transformers – Part 7: Additional requirements for electronic voltage transformers* [4]

IEC 61869-8:—, *Instrument transformers – Part 8: Additional requirements for electronic current transformers* [4]

IEC 61869-12:—, *Instrument transformers – Part 12: Additional requirements for combined electronic instrument transformers or combined passive transformers* [4]

IEC 61869-13:—, *Instrument transformers – Part 13: Specific requirements for low power passive voltage transformers* [4]

IEC 61869-14:—, *Instrument transformers – Part 14: Specific requirements for low power passive voltage transformers* [4]

IEC 61869-15:—, *Instrument transformers – Part 15: Specific requirements for d.c. voltage transformers* [4]

IEC 62271-3, *High-voltage switchgear and controlgear – Part 3: Digital interfaces based on IEC 61850*

ISO/IEC/IEEE 8802-3:2014, *Standard for Ethernet*

___

4 Under consideration.