TECHNICAL CHARACTERISTICS OF LPITs FOR RGDM/RGDAT

Revision	Data	List of modifications
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Elaborated by		Verified by			Approved by	
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SCOPE

To describe common technical characteristics of Low Power Instrument Transformers to be interfaced with RGDM and RGDAT devices.

REFERENCE DOCUMENTS

IEC 61869-10 (Additional Requirements for low-power passive current transformers)

IEC 61869-11 (Additional requirements for low-power passive voltage transformers)

APPLICATIONS

LPITs to be integrated in:

- Smart Termination (e.g. DJ5400)
- Metal-enclosed indoor switchgears (e.g. DY803, DY800, GSM001, DY900)
- Stand-alone LPITs
- Pole-mounted switchgears (e.g. GSCM002, GSCM003)

COMMON CHARACTERISTICS

- Passive LPITs
- derivative or proportional LPCT
- Combined connector for LPCT and LPVT, compliant with IEC 61869-6, table 603, type RJ45, with the PIN assignments provided by Table 1003 of IEC 61869-10 and the Table 1104 of IEC 61869-11.

  If the signal cable length ≥ 10 m, the RJ45 connector can be compliant to the requirements valid for cables with length < 10 m, as reported in Table 601 of the IEC 61869-6.
- Use of TEDS (for future developments)
- Following common ratings:

Rated frequency	50/60 Hz
highest voltage of equipment	36 kV
Rated power-frequency withstand voltage	70 kV
Rated lightning-impulse withstand voltage	170 kV

Temperature category	–5/50 indoor, plus the heating due to the rated current –30/50 outdoor
Signal cable type	Twisted pair, category ≥ CAT 6
Input circuit on the protection device side	• Balanced pure differential • Unbalanced differential • Single-ended without polarization, i.e. one terminal is connected to the electronic ground and/or to the grounding network of the substation • Single-ended with polarization, i.e. one terminal is connected to a polarization voltage and/or to a resistance that separates the terminal from the ground

LOW-POWER CURRENT TRANSFORMERS

Compliant with IEC 61869-10, with the following characteristics:

rated primary current (Ipr)	500 A
rated secondary voltage (Usr)	225 mV
Secondary voltage noise level at rated primary current	0,1125 mV @500 A primary current (this noise is equivalent to 0,25 A at rated primary current)
Rated short-time thermal current (Ith)	20 kA
Rated burden	According to IEC 61869-10, the rated burden is: 20 kΩ for the resistance, and 500 pF for the parallel capacitance. According to IEC 61869-10, the accuracy of the LPCT, connected with its cable to the protection device, shall be guaranteed also with in the following cases: Resistance: ≥ 20 kΩ Capacitance: ≤ 500 pF

<table>
<tr><td>Maximum common-mode voltage output</td><td>≤ 10 mV (RMS, at highest voltage of equipment, rated frequency, and no primary current).</td></tr>
<tr><td>Frequency Response (for derivative LPCT)</td><td>The derivative LPCT frequency response shall be “high pass (HP) filter like”, with:
linear behavior (+20 dB/dec), until the HP cutoff frequency
HP cutoff frequency ≥ 800 kHz</td></tr>
<tr><td colspan="2">Accuracy based on individual corrected transformation ratio and corrected phase offset, with ranges and resolutions given by IEC 61869-10</td></tr>
<tr><td>Accuracy class</td><td>0,5 S / 5P 10000 A. Summarization in following tables:
<table>
<tr><th rowspan="3">Accuracy class</th><th colspan="5">Ratio error ε, $\varepsilon_{cor\ I}$ ± %</th><th colspan="5">± phase error at primary current shown below</th></tr>
<tr><th colspan="5">at current</th><th colspan="2">Minutes</th><th colspan="3">Centiradians</th></tr>
<tr><th colspan="5">at current</th><th colspan="5">at current</th></tr>
<tr><th>$0{,}01\ I_{pr}$</th><th>$0{,}05\ I_{pr}$</th><th>$0{,}2I_{pr}$</th><th>I_{pr}</th><th>$K_{pcr} \times I_{pr}$</th><th>$0{,}01\ I_{pr}$</th><th>$0{,}05\ I_{pr}$</th><th>$0{,}2I_{pr}$</th><th>I_{pr}</th><th>$K_{pcr} \times I_{pr}$</th><th>$0{,}01\ I_{pr}$</th><th>$0{,}05\ I_{pr}$</th><th>$0{,}2I_{pr}$</th><th>I_{pr}</th><th>$K_{pcr} \times I_{pr}$</th></tr>
<tr><td>0,5 S</td><td>1,5</td><td>0,75</td><td>0,5</td><td>0,5</td><td>0,5</td><td>90</td><td>45</td><td>30</td><td>30</td><td>30</td><td>2,7</td><td>1,35</td><td>0,9</td><td>0,9</td><td>0,9</td></tr>
</table>
<table>
<tr><th rowspan="2">Accuracy class</th><th rowspan="2">± Ratio error at rated primary current
ε, $\varepsilon_{cor\ I}$ in %</th><th colspan="2">± Phase error at rated primary current</th><th rowspan="2">Composite error at rated accuracy limit primary current
ε_c, $\varepsilon_{cor\ I}$ in %</th><th rowspan="2">Maximum peak instantaneous error at rated primary short circuit current I_{psc}
%</th></tr>
<tr><th>Minutes</th><th>Centiradians</th></tr>
<tr><td>5P</td><td>1</td><td>60</td><td>1,8</td><td>5</td><td>-</td></tr>
</table></td></tr>
<tr><td>Deviations respect to the prototype</td><td>
<table>
<tr><th>Current (I/Ipr)</th><th>Deviation of ratio error respect to the prototype (%)</th><th>Deviation of phase displacement respect to the prototype (degree)</th></tr>
<tr><td>0,01</td><td>0,8</td><td>0,8</td></tr>
<tr><td>0,05</td><td>0,2</td><td>0,2</td></tr>
<tr><td>1</td><td>0,01</td><td>0,01</td></tr>
</table></td></tr>
<tr><td>Rated primary time constant for transient performance (Tpr) (not for derivative LPCT)</td><td>150 ms</td></tr>
<tr><td>Expected life</td><td>All of the characteristics shall be guaranteed in compliance to the expected life of the application in which the LPIT is installed.</td></tr>
</table>

CURRENT SENSOR INTERNAL CIRCUIT

Inside the LPCT (linear or derivative), no additive components, passive and/or active, i.e. resistors etc., are allowed, in addition to the sensor device. Other solutions shall be approved by Enel: e.g. additive passive components may be exceptionally allowed by Enel only if the manufacturer justify, with a technical report, the benefits obtained using these components.

The current sensor shall be completely insulated (floating) with respect to any part of the primary circuit (ground and primary wire).

The shield of the LPCT cable shall be connected to the ground only on sensor side. In case of voltage and current integrated sensors, a common shield is present, for both current and voltage sensors wires.

Moreover, all of the current sensors shields shall be connected to the ground inside of the sensor. It is never allowed to use the ground eventually taken from the protection device for grounding sensor and/or cable shields.

LPCT OUTPUT SIGNAL

The current sensor shall be completely insulated (floating) with respect to any part of the primary circuit (ground and primary wire), so the output information is a differential-mode voltage $v_{IL+,IL-}$, as reported in Fig. 1. This voltage shall be proportional to the primary current (in case of proportional LPCT) or to the derivative of the primary current (in case of derivative LPCT).

Referring to Fig. 1, voltages $v_{IL+,G}$ and $v_{IL-,G}$ can be present, e.g. due to a non-perfect and/or non homogeneous sensor shield (capacitive and/or inductive coupling). These voltages, create a common-mode voltage that can creates problems to the protection device.

For the correct operation of the protection system, it is mandatory that:

1. Both open-circuit voltages $v_{IL+,G}$ and $v_{IL-,G}$, shall be ≤ 10 mV (RMS) measured when the primary circuit is supply with the highest voltage of equipment, at rated frequency, but without any current (no load test).
2. Both open-circuit voltages $v_{IL+,G}$ and $v_{IL-,G}$, shall be “high source impedance signal type”. Practically, this means that voltages $v_{IL+,G}$ and $v_{IL-,G}$ shall go to zero when a resistive pull-down load (value: 15 kΩ ≤ $R_{pull-down}$ ≤ 100 kΩ) is connected between one and/or both wire of the current sensor (IL+ and/or IL-) and the ground. The same behavior shall occur when a balanced pull-down load is connected to the LPCT terminals, i.e. a load realized with a couple or two identical resistors (value: 15 kΩ ≤ $R_{pull-down}$ ≤ 100 kΩ) connected between both sensor wires and the ground.
3. Voltages $v_{IL+,G}$ and $v_{IL-,G}$, shall have no effect on differential-mode voltage $v_{IL+,IL-}$. This shall be valid in any regime (any steady state and any transient – e.g. during any kind of fault). This shall be valid for any type of input circuit of the protection device listed in “Input circuit on the protection device side”.
4. In any regime (any steady state and any transient), and for any type of input circuit of the protection device listed in “Input circuit on the protection device side”, the differential voltage $v_{IL+,IL-}$ shall not be influenced by spurious transient that can be generated, for example, from unwanted coupling with other part of the network, and/or from EMC issues.

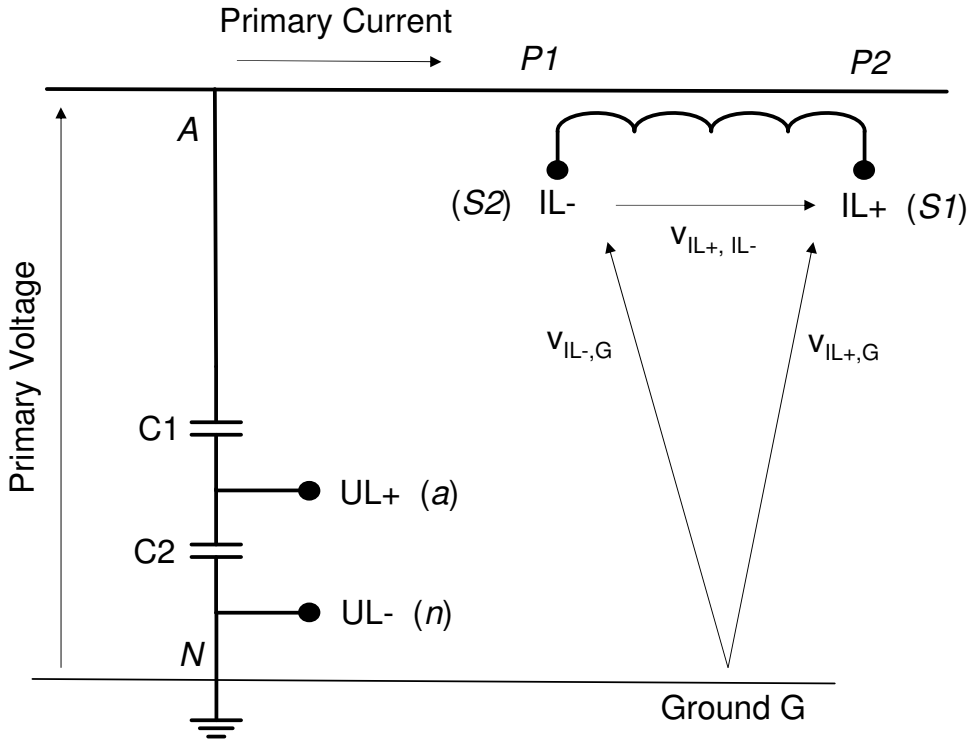

Fig. 1. General schema of an integrated voltage-current LPIT.

TESTING

The LPCT shall be tested according to Table 10 of IEC 61869-10, with the following additions:

1. the accuracy routine tests shall also include the verification of deviation requirements

2. common-mode voltage and effect on the differential voltage test, in open-circuit condition (type test)

Considering the schema of Fig. 1, the sensor shall be supply at the highest voltage of equipment, rated frequency, without any current (i.e., no load) and without any burden and pull-down load. In these conditions, both voltages $v_{IL+,G}$ and $v_{IL-,G}$ shall be ≤ 10 mV (RMS). The verification measurement shall be done with a "thru RMS" voltmeter. The voltmeter input impedance shall have these characteristics: R ≥ 10 MΩ, C ≤ 100 pF. In the same condition, with the same instrument, the voltage $v_{IL+,IL-}$ shall be verified. The result shall be $v_{IL+,IL-} = 0$.

3. Common-mode voltage and effect on the differential voltage test, in pull-down condition (type test)

The previous tests, with the same supply conditions, shall be performed with a single pull-down resistance (value: 15 kΩ ≤ $R_{pull\text{-}down}$ ≤ 100 kΩ) and with a balanced pull-down load (value: 15 kΩ ≤ $R_{pull\text{-}down}$ ≤ 100 kΩ), but without any protection device connected. Measuring voltages with the same voltmeter of the previous test, the result shall be: $v_{IL+,G}$ and $v_{IL-,G}$ equal to zero, and also $v_{IL+,IL-}$ equal to zero.

4. Frequency response tests (type test)

The Manufacturer shall draw a report that contains the frequency response test. The report shall contains: the Bode diagram of the frequency response, a table that summarizes the frequency response parameter (gain, slope, cutoff frequency etc.). In case of resonances, these phenomena shall me underlined and it is necessary an explanation of the origin of the phenomena, that shall be declared and minimized.

LOW-POWER VOLTAGE TRANSFORMERS

Compliant with IEC 61869-11, with the following characteristics:

Range of Rated primary voltages Upr	$6/\sqrt{3} \div 34{,}5/\sqrt{3}$ kV
rated transformation ratio	10 000/1 V/V
Secondary voltage noise level at rated primary voltage	5 mV @10 000 V primary voltage (this noise is equivalent to 50 V on primary side, at rated primary voltage)
Rated voltage factor (Ku)	1,9 for 8 h
Rated burden	According to IEC 61869-11, the rated burden is: 2 MΩ for the resistance, and 50 pF for the parallel capacitance.
Capacity C2 range (see Fig. 1**)**	80 nF ≤ C2 ≤ 170 nF

<table>
<tr><th colspan="2">Accuracy based on individual corrected transformation ratio and corrected phase offset, with ranges and resolutions given by IEC 61869-11</th></tr>
<tr><td>Accuracy class</td><td>1P. Summarization in following tables:
<table>
<tr><th rowspan="4">Accuracy class</th><th colspan="5">Ratio error ε, $\varepsilon_{cor\ U}$
± %</th><th colspan="10">Phase error φ_e, $\varphi_{cor\ \varphi o}$</th></tr>
<tr><th colspan="5">± minutes</th><th colspan="5">± centiradiants</th></tr>
<tr><th colspan="5">at voltage (% of rated)</th><th colspan="5">at voltage (% of rated)</th><th colspan="5">at voltage (% of rated)</th></tr>
<tr><th>2</th><th>20</th><th>80</th><th>100</th><th>F_v x100</th><th>2</th><th>20</th><th>80</th><th>100</th><th>F_v x100</th><th>2</th><th>20</th><th>80</th><th>100</th><th>F_v x100</th></tr>
<tr><td>1P</td><td>4</td><td>2</td><td>1</td><td>1</td><td>1</td><td>160</td><td>80</td><td>40</td><td>40</td><td>40</td><td>4,8</td><td>2,4</td><td>1,2</td><td>1,2</td><td>1,2</td></tr>
</table></td></tr>
<tr><td>Deviations respect to the prototype</td><td>0,1 (both for ratio (0,1%) and for phase displacement (0,1°)), at all verification points of the accuracy class</td></tr>
</table>

VOLTAGE SENSOR INTERNAL CIRCUIT

Inside the LPVT, an high-accuracy capacitive divider is present. No other additive components, passive and/or active, i.e. resistors etc., are allowed. Other solutions shall be approved by Enel: e.g. additive passive components may be exceptionally allowed by Enel only if the manufacturer justify, with a technical report, the benefits obtained using these components.

The shield of the LPVT cable shall be connected to the ground only inside the sensor. In case of voltage and current integrated sensors, a common shield is present, for both current and voltage sensors wires.

Moreover, all of the LPVT shields shall be connected to the ground inside of the sensor. It is never allowed to use the ground eventually taken from the protection device for grounding sensor and/or cable shields. Also the ground point of the capacitive divider shall be connected to the ground only inside the sensor. The ground eventually taken from the protection device cannot be used to ground the capacitive divider.

TESTING

The LPVT shall be tested according to Table 10 of IEC 61869-11, with the following addition: the accuracy routine tests shall also include the verification of deviation requirements.

INTEGRATION TESTS

Enel will perform integration tests in its laboratories to verify correct operation of the whole system, i.e. LPIT connected to the RGDAT/RGDM protection devices. This shall be considered for both LPCT and LPVT.

As example, tests that can be performed are:

1. Accuracy level, with particular reference to the measured zero-sequence current
2. Sensor impedance measurement
3. Transient response (e.g. real fault comtrades, step/dirac/ramp, etc. response)
4. Noise measurement
5. Harmonic response and accuracy level with harmonics
6. Common-mode voltage and effect on the differential voltage test, in any condition, also with a connected RGDAT/RGDM
7. Other tests that Enel considers necessary