SLOVENSKI STANDARD

oSIST prEN IEC 60076-4:2023

01-september-2023

Močnostni transformatorji - 4. del: Vodilo za testiranje impulza strele in preklopnega impulza - Močnostni transformatorji in dušilke

Power transformers - Part 4: Guide to the lightning impulse and switching impulse testing - Power transformers and reactors

Leistungstransformatoren - Teil 4: Leitfaden zur Blitz- und Schaltstoßspannungsprüfung von Leistungstransformatoren und Drosselspulen

Transformateurs de puissance - Partie 4: Guide pour les essais au choc de foudre et au choc de manoeuvre - Transformateurs de puissance et bobines d'inductance

Ta slovenski standard je istoveten z: **prEN IEC 60076-4:2023**

ICS:

29.180	Transformatorji. Dušilke	Transformers. Reactors

oSIST prEN IEC 60076-4:2023 **en**

14/1109/CDV

COMMITTEE DRAFT FOR VOTE (CDV)

PROJECT NUMBER: **IEC 60076-4 ED2**	
DATE OF CIRCULATION: **2023-07-07**	CLOSING DATE FOR VOTING: **2023-09-29**
SUPERSEDES DOCUMENTS: **14/1060/CD, 14/1061C/CC**	

IEC TC 14 : POWER TRANSFORMERS	
SECRETARIAT: United Kingdom	SECRETARY: Ms Stephanie Lavy
OF INTEREST TO THE FOLLOWING COMMITTEES:	PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CDV to the secretary.
FUNCTIONS CONCERNED: ☐ EMC ☐ ENVIRONMENT	☐ QUALITY ASSURANCE ☐ SAFETY
☒ SUBMITTED FOR CENELEC PARALLEL VOTING **Attention IEC-CENELEC parallel voting** The attention of IEC National Committees, members of CENELEC, is drawn to the fact that this Committee Draft for Vote (CDV) is submitted for parallel voting. The CENELEC members are invited to vote through the CENELEC online voting system.	☐ NOT SUBMITTED FOR CENELEC PARALLEL VOTING

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TITLE:

Power transformers - Part 4: Guide to the lightning impulse and switching impulse testing - Power transformers and reactors

PROPOSED STABILITY DATE: 2026

NOTE FROM TC/SC OFFICERS:

POWER TRANSFORMERS

Part 4: Lightning impulse and Switching impulse Tests of Power Transformers and Reactors

FOREWORD

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International Standard IEC 60076-4 has been prepared by IEC technical committee 14: Power transformers.

This International Standard cancels and replaces the first edition published in 2002 and constitutes a technical revision of that document.

This edition includes the following technical changes with respect to the previous edition:

- Lightning impulse tests in presence of a relative overshoot value of 5% and higher (Clause 7.1.2).
- Test voltage function when performing chopped wave (Clause 7.2.1.1).
- Switching impulse tests on 3 phase transformers, test connections (Figure 5 and Figure 6)
- Glaninger circuit, clause A.3 (Annex A).
- New Annex C. Examples of oscillograms with peak voltage overshoot.

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

FDIS	Report on voting

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 3.

Annexes A, B and C are informative only.

IEC 60076 consists of the following parts, under the general title *Power transformers:*

Part 1: General

Part 2: Temperature rise

Part 3: Insulation levels, dielectric tests and external clearances in air

Part 4: Lightning impulse and Switching impulse Tests – Power Transformers and Reactors

Part 5: Ability to withstand short-circuit

Part 8: Application guide

Part 10: Determination of sound levels

Part xx: to be update by TC14 secretary

The committee has decided that the contents of this publication will remain unchanged until 20xx. At this date, the publication will be

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

POWER TRANSFORMERS

Part 4: Lightning impulse and Switching impulse Tests Power Transformers and Reactors

1 Scope

This part of IEC 60076 gives guidance and explanatory comments on the existing procedures for lightning and switching impulse tests of power transformers to supplement the requirements of IEC 60076-3. It is also generally applicable to the testing of reactors (see IEC 60076-6), modifications to power transformer procedures being indicated where required.

Information is given on waveforms, test circuits including test connections, earthing practices, failure detection methods, test procedures, measuring techniques and interpretation of results.

Where applicable, the test techniques are as recommended in IEC 60060-1 and IEC 60060-2.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60060-2, *High-voltage test techniques – Part 2: Measuring systems*

IEC 60076-3, *Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air*

IEC 60076-6, *Reactors*

IEC 61083-1, *Instruments and software used for measurement in high-voltage impulse tests – Part 1: Requirements for instruments*

IEC 61083-2, *Digital recorders for measurements in high-voltage impulse tests – Part 2: Evaluation of software used for the determination of the parameters of impulse waveforms*

IEEE Std C57.98™-2011, *IEEE Guide for Transformer Impulse Tests*

IEEE Std 4™-2013, *IEEE Standard for High-Voltage Testing Techniques*

3 General

This standard is primarily based on the use of conventional impulse generators for both lightning and switching impulse tests of transformers and reactors. The practice of switching impulse generation with discharge of a separate capacitor into an intermediate or low-voltage winding is also applicable. However, the method which employs an additional inductance in series with the capacitor to provide slightly damped oscillations transferred into the high-voltage winding is not applicable.

Alternative means of switching impulse generation or simulation such as d.c. current interruption on an intermediate or low-voltage winding or the application of a part-period of power frequency voltage are not discussed since these methods are not as generally applicable.

Different considerations in the choice of test circuits (terminal connections) for lightning and switching impulse tests apply for transformers and reactors. On transformers, all terminals and windings can be lightning impulse tested to specific and independent levels. In switching impulse test, however, because of the induced voltage transferred, a specified test level may only be obtained on one winding (see IEC 60076-3).

Whilst, on reactors, lightning impulse tests is similar to that on transformers, i.e., all terminals can be tested separately, different considerations apply and different problems arise in switching impulse tests. Hence, in this standard, lightning impulse tests are covered by a common text for both transformers and reactors whilst switching impulse test is dealt with separately for the two types of equipment.

4 Specified waveforms

The voltage waveforms to be used normally during lightning and switching impulse tests of transformers and reactors are given in IEC 60076-3, IEC 60076-6 and the methods for their determination are given in IEC 60060-1.

5 Test circuit

The physical arrangement of test equipment, test object and measuring circuits can be divided into three major circuits:

- the main circuit including the impulse generator, additional waveshaping components and the test object;
- the voltage measuring circuit;
- the chopping circuit where applicable.

This basic arrangement is shown in Figure 1.

The following parameters influence the impulse waveform;

a) the effective capacitance C_t, and inductance of the test object, L_t; C_t is constant for any given design and any given waveform, L_t is also a constant for any given design. The effective L_t, however, may be influenced by the terminal treatment. It varies between the leakage inductance L_s for short-circuited terminals and L_o for open-circuited terminals. More details in this respect are given in 7.1 and 7.3 and in annex A;

b) the generator capacitance C_g;

c) waveshaping components, both internal and external to the generator, R_{si}, R_{se}, R_p, C_L (plus, where applicable, the impedance of a voltage divider Z_1);

d) the stray inductance and capacitance of the generator and the complete test circuit;

e) chopping equipment, where applicable.

f) Non-linear elements in the transformer, which can cause differences between impulses at different voltage levels

The front time T_1 is determined mainly by combination of the effective surge capacitance of the test object, including C_L, and the generator internal and external series resistances.

The time to half-value T_2 is, for lightning impulses, primarily determined by the generator capacitance, the inductance of the test object and the generator discharge resistance or any other parallel resistance. However, there are cases, for example, windings of extremely low inductance, where the series resistance will have a significant effect also on the wavetail. For switching impulses, other parameters apply; these are dealt with in clause 8.

The test equipment used in lightning and switching impulse applications is basically the same. Differences are in details only, such as values of resistors and capacitors (and the terminal connections of the test object).

To meet the different requirements of the waveform for lightning and switching impulses, due consideration has to be given to the selection of the impulse generator parameters, such as capacitance and series and discharge (parallel) resistances. For switching impulses, large values of series resistors and/or load capacitors may be necessary, which will result in significant reduction of the efficiency.

While the output voltage of the impulse generator is determined by the test levels of the windings with respect to their highest voltage for equipment U_m for the test object, the required energy storage capability is essentially dependent on the inherent impedances of the test object.

A brief explanation of the principles of waveform control is given in Annex A.

The arrangement of the test plant, test object and the interconnecting cables, earthing strips, and other equipment is limited by the space in the test room and, particularly, the proximity effect of any structures. During impulse tests, zero potential cannot be assumed throughout the earthing systems due to the high values and rates of change of impulse currents and voltages and the finite impedances involved. Therefore, the selection of a proper reference earth is important.

The current return path between the test object and the impulse generator should be of low impedance. It is good practice to firmly connect this current return path to the general earth system of the test room, preferably close to the test object. This point of connection should be used as reference earth and to attain good earthing of the test object it should be connected to the reference earth by one or several conductors of low impedance (see IEC 60060-2).

The voltage measuring circuit, which is a separate loop of the test object carrying only the measuring current and not any major portion of the impulse current flowing through the windings under test, should also be effectively connected to the same reference earth.

In switching impulse tests, since the rates of change of the impulse voltages and currents are much reduced compared with those in a lightning impulse test and no chopping circuit is involved, the problems of potential gradients around the test circuit and with respect to the reference earth are less critical. Nevertheless, it is suggested that, as a precaution, the same earthing practices should be followed as used for lightning impulse tests.

Electromagnetic compatibility (EMC):

Power transformers are more and more fitted with control and protection devices, which are sensitive in regard of overvoltage, caused by (fast) transients.

Potential differences, caused by special groundings at lightning and switching impulse tests the different grounding of the control-and protection device (in regard of safety) can damage electronic parts.

Examples of affected device:

- Mainly large transformers are fitted with (computerized) condition monitoring systems.
- Cooling equipment (fans, pumps) is driven in dependence of transformer load and transformer noise. Such an operation is controlled by electronic device etc.

During impulse tests it is recommended to disconnect all electric and electronic equipment installed on the transformer.

6 Verification of the impulse voltage measuring system before a test

It is not the intention of this standard to give any recommendation on measuring systems or their calibration but, of course, the apparatus which is used should be approved in accordance with IEC 60060. Before a test, an overall check of the test circuit and the measuring system may be performed at a voltage lower than the reduced voltage level. In this check, voltage may be determined by means of a sphere gap or by comparative measurement with another approved device. When using a sphere gap, it should be recognized that this is only a check and does not replace the periodically performed calibration of the approved measuring system. After any check has been made, it is essential that neither the measuring nor the test circuit is altered except for the removal of any devices for checking.

Information on types of voltage dividers, their applications, accuracy, calibration and checking is given in IEC 60060-2.

7 Lightning impulse tests

7.1 Waveforms

7.1.1 General

The values of waveform specified may not always be obtainable. In the impulse tests of large power transformers and reactors, of low winding inductance and/or high surge capacitance, wider tolerances may have to be accepted.

7.1.2 Front time T1

The surge capacitance of the transformer under test being constant, the series resistance may have to be reduced in an attempt to obtain the correct front time T_1 or rate of rise, but the reduction should not be to the extent that oscillations on the crest of the voltage wave become excessive. If it is considered desirable to have a short front time (preferably within the specified limits) then oscillations and/or overshoots may have to be accepted. In such an event, a compromise between the extent of allowable oscillations and the obtainable front time is necessary. In general, the test circuit should be arranged in such way, that the overshoot/oscillation is minimal.

If the relative overshoot (ß’) exceeds 5% here are the tests options (ref. IEC 60076-3 Edition 3.0 2013-07; clause 13.2.1) :

- For windings receiving chopped wave(s) lightning impulse tests, T1 can be increased up to 2.5 µs to reduce the overshoot (ß).
- During the tests, if the relative overshoot (ß’) exceed 5% at full voltage level, the test voltage function should be applied in accordance with IEC 60060-1 to determine the test voltage value.
- *Irrespective of the overshoot value*, it is permissible to apply the requirements of IEC 60060-1 Annex B to evaluate the parameters of the lightning impulse.

In case of a ß’ higher than 5 %, it is allowed to proceed with the test when the test voltage function is enabled.

NOTE 1: When the manufacturer does not have the software with the test voltage function according to IEC 60060-1, the second option of IEC 60076-3 with a larger front time, less overshoot and additional chopped wave test should be chosen.

Examples of oscillograms having overshoot are shown in Annex C.

NOTE 2: In case of high beta value and an overshoot with frequency above 500 kHz, the test voltage function significantly reduces the test voltage value U_t compared to the peak value of the recorded curve U_e. This may lead to higher electrical stress and possible breakdown of the insulation system.

In general, manual evaluation of the test voltage is unreliable for lightning impulse tests of transformers. If the manufacturer does not have the software with the test voltage function according to IEC 60060-1, the buyer should be informed of this at the offer stage.

7.1.3 Non-linear elements

In some cases, the active parts of power transformers are protected with non-linear elements (surge arresters). These components can cause different waveforms, depending on the voltage level of the impulse. The required test sequences are defined in IEC 60076-3. Generally, it must be clarified: The parameters of the waveform of an impulse have to be adjusted at the reference voltage level. Further adjustments on 100 % voltage level are not allowed, if there are changes in the shape of the curve, this has to be accepted.

NOTE: As specified in 60076-3, 3 references impulses are recommended prior the 100% full waves impulses. These impulses are:

1. Impulse reference between 50% and 60% of the full test wave.
2. Impulse reference between 60% and 75% of the full test wave.
3. Impulse reference between 75% and 90% of the full test wave.

7.1.4 Time to half-value T2

For large power transformers and particularly the intermediate and low-voltage windings thereof, the virtual time to half-value T_2 may not be achievable within the value set by the tolerance. The inductance of such windings may be so low that the resulting waveform is oscillatory. This problem may be solved to some extent by the use of large capacitance within the generator, by parallel stage operation, by adjustment of the series resistor or by specific test connections of the terminals of windings not under test or, in addition, of the non-tested terminals of windings under test.

If lightning impulse tests are carried out on phase-terminals of a delta-winding, the not-tested terminals of that winding can be resistance earthed.

If the neutral of a star-connected winding is tested, the phase-terminals can be resistance earthed.

If the phase terminals of a star-connected winding are tested, the neutral-terminal has to be solidly grounded or grounded through a low-ohmic shunt.

When resistance earthing of any non-tested line terminal is employed, it is necessary to ensure that the voltage to earth appearing on any non-tested terminal does not exceed

– 75 % of the rated lightning withstand voltage of that terminal for star-connected windings;
– 50 % of the rated lightning withstand voltage of that terminal for delta-connected windings (because of the undershoot voltages to earth on the delta terminals – see also 7.4).

When the waveform is oscillatory due to extremely low inductance and/or small impulse generator capacitance, the amplitude of the undershoot should not exceed 50 % of the test voltage. With this limitation, guidance for selecting impulse generator capacitance and adjusting waveforms is given in annex A.

7.2 Impulses chopped on the tail

7.2.1 Time to chopping

Different times to chopping T_c (as defined in IEC 60060-2), will result in different stresses (voltage and duration) in different parts of the winding(s) depending on the winding construction and arrangement employed. Hence, it is not possible to state a time to chopping which is the most onerous either in general or for any particular transformer or reactor. The time to chopping should be between 3 µs and 6 µs. A time, between 2 µs and 6 µs can be accepted, provided that the peak value of the lightning impulse wave is achieved before the chop, as required by IEC 60076-3, clause 13.3.1.

Oscillograms or digital recordings of chopped waves, are only comparable up to the times to chopping.

7.2.1.1 Test voltage function when performing chopped wave

In general, for liquid immersed transformers the chopped wave is 110% of the full wave, while in dry type transformers the chopped wave is 100%.The k-factor (test voltage function) evaluation of a chopped wave of 110% of the full wave (as recommended in 60060-1, Annex B), should give a peak value U_t of 110% of the full wave.
When the calculated test value U_t is inconsistent, the following steps are recommended:

a) Front chopped lightning impulse:
Not applicable to chopped waves on transformers.

b) Tail chopped lightning impulse with chopping time occurring *after* the peak value:
Voltage reduction ratio Method (Ref. IEEE Std 4™-2013)

- Apply a reduced full wave (RFW).
- The test voltage function should provide the test voltage value U_t and the peak value U_e of the original recorded curve. If U_e is not available, it could be graphically determined on the recorded oscillogram.
- Find the Voltage Reduction Ratio. $Rv = U_t / U_e$
- Apply a full voltage chopped wave, having a recorded voltage U'_e
- The calculated U'_t is defined as:
  - $U'_t = Rv * U'_e$

c) The value of front time T1 of the reduced full wave (RFW) is used to determine the T1 value of the chopped wave.

7.2.1.2 Test voltage function and presentation of test results

When the test voltage function is enabled, the following test results should be displayed:

- U_t is the test voltage
- ß' is the relative overshoot magnitude

The following optional value should be available for display:

- U_e the peak value of the original recorded curve

7.2.2 Rate of collapse and amplitude of reversed polarity of the chopped impulse

The characteristic events during chopping are largely dependent on the geometrical arrangement of the chopping circuit involved and on the impedance of the chopping circuit and of the test object, all of which determine both the rate of collapse and the amplitude of the undershoot.

In IEC 60076-3, the undershoot has been limited to 30 % of the amplitude of the chopped impulse. This, in fact, represents a guideline for the arrangement of the chopping circuit and may entail the introduction of additional impedance Z_c in this circuit to meet the limit (see Figure 1).

The chopping loop, however, should be as small as possible to obtain the highest rate of collapse, but the undershoot should be limited to less than, or equal to 30 %. On multiple layer windings, the layer impedance may damp the collapse normally to the extent that it does not oscillate around zero (see Figure B.20).

The recommendation in IEC 60076-3 to use a triggered-type chopping gap is made because of its advantage in obtaining consistency of the time to chopping, thereby facilitating the comparison of oscillograph or digital recordings not only before but also after chopping. *The latter part will only be comparable for reasonably identical times to chopping.*

7.3 Terminal connections and applicable methods of failure detection

7.3.1 Terminal connections

It is essential that the terminal connections of the test object and the earthing practices employed relate to the method of failure detection adopted.

Connections for impulse tests are detailed in IEC 60076-3 for transformers and in IEC 60076-6 for reactors. Normally the non-tested terminals of the phase winding under test are earthed and the non-tested phase windings are shorted and earthed. However, in order to improve the wavetail T_2, resistance earthing of the non-tested windings may be advantageous (see clause 5 and 7.1) and, in addition, the non-tested line terminals of the winding under test may also be resistance earthed.

In addition to the methods of waveform adjustment in 7.1, the following factors have to be considered:

a) if a terminal has been specified to be directly earthed or connected to a low-impedance cable in service, then that terminal should be directly earthed during the test or earthed through a resistor with an ohmic value not in excess of the surge impedance of the cable;

b) earthing through a low-resistance shunt for the purpose of impulse current measurements may be considered the equivalent of direct earthing.

When non-linear elements or surge diverters – built into the transformer or external – are installed for the limitation of transferred overvoltage transients, the impulse test procedure should be as defined in IEC-60076-3. External non-linear element should be disconnected for tests.

7.3.2 Applicable methods of failure detection

Failure detection is normally accomplished by examination of the oscillograms of digital records of the applied test voltage and the impulse current.

Different transients can be recorded and used separately or in combination, as shown in Figure 2. These are listed a) to e) below. It is essential, in acceptance testing, to record at least one of these transients in addition to the applied test voltage:

a) the neutral current (for star and zigzag connected windings of which the neutral is earthed during the test);

b) the winding current (for all other windings and star and zigzag connected windings of which the neutral may not be earthed during the test);

c) the current transferred to an adjacent shorted and non-tested winding, sometimes referred to as capacitively transferred current;

d) the tank current;

e) the voltage transferred to a non-tested winding.

The sum of items a), c) and d) or of items b), c) and d), is sometimes referred to as line current.

When testing reactors, both of the shunt and series types, items c) and e) are inapplicable; item d) may be applied but only as an additional means of transient recording since it is likely to be less sensitive than when used in transformer testing.

7.4 Test procedures

The relevant test sequences for full-wave tests or for full and chopped-wave tests are given in IEC 60076-3.

The preferred method of test is that of direct application although in special cases where the intermediate or low-voltage winding cannot, in service, be subjected to lightning overvoltage from the system connected to it, the "transferred surge" method may alternatively be employed. The impulse test of the low-voltage winding is then carried out simultaneously with the test of the associated high-voltage winding. In these conditions, the waveform of the transferred voltage does not conform with that specified in IEC 60076-3. It is more important to try to obtain the required voltage level by means of termination resistors of sufficiently high value. However, this may not always be possible even with the highest values of resistors. In this test, high inter-phase voltages may occur on delta-connected windings and the danger of overstressing inter-phase insulation, internal or external, may limit the voltage that can be applied to the low-voltage winding. The appropriate limits may be established by transient analysis with a low-voltage recurrent surge generator.

By their nature, non-linear protection devices connected across the windings or its parts may cause differences between the reduced full-wave and the full-wave impulse oscillograms. Proof that these differences are indeed caused by operation of these devices should be demonstrated by making three reduced full-wave impulse test at different voltage levels to show the trend in their operation. To show the reversibility of any non-linear effects, the same reduced full-wave impulses should follow up the full-wave test voltage in a reversed way.

One example in conformity with 60076-3:
50%, 65%, 80%, 100%, 100%, 100%, 80%, 65%, 50%.

Test methods for transformer neutrals are given in IEC 60076-3. The direct method, involving an impulse voltage applied to the neutral with all line terminals earthed, permits a longer duration of wavefront, up to 13 μs. In this case, the inductive loading of the generator is significantly increased and it may be difficult to achieve times to half-value set by the tolerances. Impedance earthing of the non-tested terminals of the winding under test may then be applied.

7.5 Recording of tests

7.5.1 General

Digital recording systems should be used for the recording of lightning impulse voltage and current waveforms.

NOTE: Digital recorders provide a much higher resolution than analogue measuring equipment. This might lead to more (small) differences that need to be explained. Nevertheless, it is recommended not to use analogue measuring equipment anymore, since this is no longer state of the art.

7.5.2 Digital recording systems

The requirements for digital recorders are given in IEC 61083-1.

It should be emphasized that for the purpose of presenting results for acceptance by comparison of traces, the waveforms obtained by digital measurements should be produced from the raw data and not subjected to any mathematical processing, filtering, smoothing, etc…,except the rescaling of the oscillograms for comparison purpose.

It is equally important to use the raw data for non-standard waveform evaluation.

Figures B.18, B.19 and B.20 show significant differences in amplitude and front time T_1 and time to half value T_2 evaluations.

IEC 60076-3 requires simultaneously the measurement of

a) the applied voltage;
b) at least one of the transients listed in 7.3.2;

Hence, at least two independent recording channels are necessary.
While the applied voltage is uniquely defined, the choice of the other characteristic to be recorded is dependent on the selection of the method of failure detection.

7.5.3 This clause is intentionally left blank

7.5.4 Digital recording

7.5.4.1 Recording of waveforms

The principle of digital recording is the measurement of voltage or current waveforms by taking samples during the test at regular time intervals. These samples should be presented directly as raw data for evaluating waveform parameters (see 7.5.3.1) and also for the assessment of test results based on the comparison of recordings taken at reduced and full impulse voltage levels (see 7.5.3.2). Additionally, the recorded data may also be processed by wave analysing algorithms, for example, for fault analysis in recordings (see clause 10).

During impulse tests, high electromagnetic fields are produced in the vicinity of the test set-up. Protection of the sensitive electronic devices in the digital recording system, the entire processing equipment and its power supply against these fields is required.

7.5.4.2 Recording of the impulse voltage waveform

a) Determination of the impulse voltage waveform

The preferred period for the presentation of data for the records taken for waveform determination during preliminary adjustment of test-circuit parameters is ≤10 μs for the wavefront record (longer presentation times may be necessary when testing transformer neutrals). The wavetail record should permit the evaluation of the time to half-value and, on occasions, the amplitude of reversed polarity.

IEC 61083-1 specifies a 9-bit, 60 MHz digitizer as the minimum resolution of the digitizer for the recording of impulse voltage and current waveforms. When zooming in on 10 μs time-periods or less for the evaluation of the wavefront or for the evaluation of chopped impulses, the use of a 10-bit digitizer and 100 MHz sampling frequency should be considered.

Historically, waveform evaluation is based on oscilloscopic records, engineering rules and eye evaluation of waveform parameters. With the application of digital recorders in high-voltage testing of power transformers, a warning with respect to amplitude and time parameters should be given with respect to the evaluation of non-standard waveforms. In particular, when testing high-power-rated low-voltage windings with resulting unipolar overshoots with frequencies less than 0,5 MHz, IEC 61083-2 is not applicable for the amplitude evaluation of such non-standard waveforms. Errors in excess of 10 % have been observed due to the built-in curve smoothing algorithms in the digitizers (see Figures B.18, B.19 and B.20).

In such cases, careful evaluation of the raw data plots using engineering judgement is required. A parallel measurement of the test voltage by a peak voltmeter according to IEC 61083-1 is highly recommended.

b) Applied impulse test voltage wave recording

In order to determine the amplitude of the test wave and to permit detection of any fault which may be present

– for full waves, the period for the presentation of sampled data should not be less than 100 μs;

– for chopped waves, a period for presentation of 10 μs to 25 μs is usually found sufficient.

Sampling frequencies of 10 MHz to 20 MHz per channel of the digitizer normally suffice because the maximum frequencies of part winding resonance normally do not exceed 1 MHz to 2 MHz. If high frequencies are observed in the voltage or current traces these are due to parasitic resonance in the measuring circuit or noise in the earthing system. It is therefore recommended that higher sampling frequencies (as mentioned before) be used to discriminate noise in the measuring circuit from the actual behaviour of the test object.

For wave analysis, it is important to take samples over the complete waveform until the wave is completely damped, using the maximum available memory of the digitizer. It is important to programme the digitizer in such a way that a sufficient number of samples is present to determine the virtual starting-point of the wave.