

# B3. Harmonic filter reactors / compensation filters - routine tests

## Standard Approach

The main reactor standard may be IEC/EN 60076-6 - Reactors. IEC 60076-6 covers filter/tuning reactors, capacitor damping reactors and capacitor discharge reactors in addition to series reactors. If the product is evaluated together with a capacitor bank as a compensation system, IEC 60831-1 is the auxiliary main reference for LV self-healing shunt power capacitors, while IEC 61921 is the auxiliary main reference for low-voltage power factor correction banks. For harmonic measurement / field analysis, IEC 61000-4-7 should be used for the harmonic and interharmonic measurement method.

## 1. Routine Tests

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### Winding resistance

<b>Main standard</b>	IEC/EN 60076-6
<b>Construction / method standard</b>	DC resistance measurement; manufacturer routine test procedure
<b>Description</b>	Each phase is measured separately. The resistance difference between phases is evaluated in terms of connection error, contact resistance, incorrect conductor cross-section or winding difference.

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### Inductance measurement

<b>Main standard</b>	IEC/EN 60076-6
<b>Construction / method standard</b>	Measurement at nominal frequency with an LCR meter, AC test setup or power analyzer
<b>Description</b>	This is the main functional test of the product. In a harmonic filter reactor, the inductance value must be measured accurately because it determines the resonance frequency that will occur together with the capacitor.

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### Inductance phase balance

<b>Main standard</b>	IEC/EN 60076-6
<b>Construction / method standard</b>	L measurement for each phase under the same frequency/current condition
<b>Description</b>	The L1-L2-L3 inductance values must be balanced within the design tolerance. Phase imbalance may cause phase current imbalance in the compensation step and stress on the capacitor.

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### Resonance frequency verification

<b>Main standard</b>	IEC/EN 60076-6; IEC 61921 for capacitor bank
<b>Construction / method standard</b>	Calculation based on measured L and capacitor C value; system test if required
<b>Description</b>	The target frequency, such as 134 Hz, 189 Hz, 210 Hz or 215 Hz, is verified according to the product type. This value shows the frequency region from which the filter reactor, together with the capacitor, will stay detuned.

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### 134 Hz / 189 Hz / 210 Hz / 215 Hz product type check

<b>Main standard</b>	IEC/EN 60076-6; customer specification
<b>Construction / method standard</b>	Cross-check of label, design sheet, measured L and capacitor value
<b>Description</b>	Whichever filter class the product has been manufactured for must be clearly written in the test report. Selecting an incorrect resonance frequency may cause the capacitors to be overloaded under harmonic current.

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**Filter factor p% verification**

<b>Main standard</b>	IEC/EN 60076-6; IEC 61921; customer specification
<b>Construction / method standard</b>	Calculation of p% from the measured inductance, capacitor capacitance and system frequency
<b>Description</b>	Values such as p%14, p%7, p%5.67 and p%5.41 are verified by calculation. It is very useful to provide "target p% / calculated p% / conformity" as a report line.

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**p%14 / p%7 / p%5.67 / p%5.41 product distinction**

<b>Main standard</b>	IEC/EN 60076-6; IEC 61921
<b>Construction / method standard</b>	Comparison of technical datasheet, label, measurement result and project calculation
<b>Description</b>	The p% value determines the detuned characteristic of the capacitor bank. Therefore, not only the L value but also the p% value together with the capacitor must be reported.

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**Nominal current check**

<b>Main standard</b>	IEC/EN 60076-6
<b>Construction / method standard</b>	Check of design current, capacitor step current and harmonic current capacity
<b>Description</b>	The current that the reactor can safely carry continuously is checked. In the OMSAN technical glossary, nominal current is defined as the current that the reactor can safely carry continuously, and it is stated that ambient temperature and ventilation conditions must be considered.

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**Harmonic current capacity check**

<b>Main standard</b>	IEC/EN 60076-6; IEC 61000-4-7 for harmonic measurement
<b>Construction / method standard</b>	Design calculation, RMS current and harmonic spectrum check
<b>Description</b>	The filter reactor carries not only the fundamental-frequency current, but also harmonic components. If a field harmonic analysis report is available, THDU/THDI and dominant harmonics must be checked in the design file.

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**Loss measurement - copper loss**

<b>Main standard</b>	IEC/EN 60076-6
<b>Construction / method standard</b>	I <sup>2</sup> R calculation based on DC resistance and nominal current
<b>Description</b>	Copper loss is one of the main losses determining temperature rise. In the OMSAN technical glossary, copper loss is defined as the I <sup>2</sup> R loss caused by the current flowing through the windings.

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**Loss measurement - total loss**

<b>Main standard</b>	IEC/EN 60076-6
<b>Construction / method standard</b>	AC load test or design calculation; including core loss in cored reactors
<b>Description</b>	In iron-core filter reactors, core loss and stray losses are also evaluated in addition to copper loss. Total loss should be taken as the basis for the thermal design.

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**Insulation resistance**

<b>Main standard</b>	IEC/EN 60076-6; IEC/EN 61558-1 / IEC/EN 61558-2-20 auxiliary for small LV reactors
<b>Construction / method standard</b>	Insulation resistance measurement; IEC 61557-2 as an auxiliary reference for practical measurement
<b>Description</b>	Winding-to-body and, depending on the design, phase-to-phase insulation are measured. In products operating inside capacitor banks, insulation quality is important due to contamination, humidity and temperature effects.

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**Dielectric withstand / hipot**

<b>Main standard</b>	IEC/EN 60076-6; IEC/EN 61558-1 auxiliary
<b>Construction / method standard</b>	AC withstand test
<b>Description</b>	Winding-to-body and, if required, phase-to-phase main insulation are verified. The test level should be selected according to system voltage, insulation class and customer specification.

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**Phase balance**

<b>Main standard</b>	IEC/EN 60076-6
<b>Construction / method standard</b>	Phase-based comparison of R, L and, if required, current
<b>Description</b>	In a three-phase filter reactor, resistance and inductance phase balance should be evaluated together. Phase difference may cause unequal current and heating in capacitor steps.

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**Core air-gap process control**

<b>Main standard</b>	IEC/EN 60076-6
<b>Construction / method standard</b>	Production drawing, air-gap measurement, mechanical control
<b>Description</b>	In iron-core reactors, the air gap directly affects inductance, saturation and acoustic behavior. The OMSAN technical glossary states that saturation limits in iron-core reactors must be managed carefully.

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**Magnetic linearity process control**

<b>Main standard</b>	IEC/EN 60076-6
<b>Construction / method standard</b>	L measurement at nominal current or at several current points
<b>Description</b>	In a harmonic filter reactor, the inductance should not drop excessively with current. If saturation occurs, the filter factor and resonance behavior deteriorate.

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**Terminal connection check**

<b>Main standard</b>	IEC/EN 60076-6; IEC 61921 for capacitor bank
<b>Construction / method standard</b>	Terminal, busbar, terminal marking, torque and continuity check
<b>Description</b>	Since the reactor is connected in series with the capacitor, input/output terminal names, phase sequence and capacitor connection ends must be clear.

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**Capacitor connection label check**

<b>Main standard</b>	IEC 60831-1; IEC 61921; IEC/EN 60076-6
<b>Construction / method standard</b>	Label, connection diagram and terminal check
<b>Description</b>	Capacitor power, capacitor voltage, phase connection, reactor p% value and resonance frequency must be consistent with one another on the label/diagram.

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**Loose connection check**

<b>Main standard</b>	IEC/EN 60076-6; IEC 61921
<b>Construction / method standard</b>	Visual inspection, torque check, and low-resistance connection check if required
<b>Description</b>	Loose terminal and busbar connections may cause local heating, capacitor failure and fire risk. This must definitely be checked during routine final inspection.

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**Mechanical tightness / vibration visual check**

<b>Main standard</b>	IEC/EN 60076-6; IEC 60076-10 / IEC 60068-2-6 auxiliary if a quantitative test is required
<b>Construction / method standard</b>	Visual-listening inspection, core/winding tightness check
<b>Description</b>	Harmonic currents and magnetic forces may create vibration/noise. In the OMSAN technical glossary, mechanical vibration is stated to be important in terms of noise, connection life and field comfort.

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**Label check**

<b>Main standard</b>	IEC/EN 60076-6; IEC 61921; IEC 60831-1
<b>Construction / method standard</b>	Cross-check of label, technical datasheet, project and test report
<b>Description</b>	Current, voltage, frequency, inductance, p%, resonance frequency, capacitor power/voltage, insulation class, number of phases and connection information are checked.

## 2. Optional / Special Tests

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**Resonance performance test**

<b>Main standard</b>	IEC/EN 60076-6; IEC 61921; IEC 61000-4-7 for harmonic measurement
<b>Construction / method standard</b>	Current/voltage frequency response together with the capacitor or verification at the target frequency
<b>When is it recommended?</b>	Recommended for large compensation banks, plants with high THDU/THDI or critical industrial applications.

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**Heating test under harmonic current**

<b>Main standard</b>	IEC/EN 60076-6; IEC 61000-4-7 / IEC 61000-4-30 for measurement
<b>Construction / method standard</b>	Temperature measurement with THD current or equivalent RMS/harmonic loading
<b>When is it recommended?</b>	Used to show that the reactor remains thermally safe not only under 50 Hz current, but also under real harmonic currents. The OMSAN technical glossary also states that harmonic effects may cause additional heating.

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**Temperature rise test**

<b>Main standard</b>	IEC/EN 60076-6; IEC/EN 61558-2-20 auxiliary for small LV reactors
<b>Construction / method standard</b>	Steady-state temperature rise measurement at nominal RMS current
<b>When is it recommended?</b>	Recommended for continuous compensation, enclosed panels, high ambient temperature or facilities where high harmonic current is expected.

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**Noise test**

<b>Main standard</b>	IEC/EN 60076-10
<b>Construction / method standard</b>	Measurement by sound pressure or sound intensity method
<b>When is it recommended?</b>	Recommended for indoor areas, hospitals, shopping malls, offices or acoustically sensitive technical rooms. IEC 60076-10 covers sound measurement methods for transformers and reactors.

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**Magnetic linearity test**

<b>Main standard</b>	IEC/EN 60076-6
<b>Construction / method standard</b>	Obtaining the L-I curve at different current points
<b>When is it recommended?</b>	Applied when the saturation limit and inductance stability are critical in iron-core filter reactors.

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**Saturation curve test**

<b>Main standard</b>	IEC/EN 60076-6
<b>Construction / method standard</b>	Inductance measurement at points such as 50% / 100% / 120% / 150% I <sub>n</sub>
<b>When is it recommended?</b>	Recommended if the reactor must not enter saturation due to harmonic currents or transient overcurrents.

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**System test together with capacitor**

<b>Main standard</b>	IEC 61921; IEC 60831-1 for capacitor; IEC/EN 60076-6 for reactor
<b>Construction / method standard</b>	Current, voltage, resonance and temperature check of reactor + capacitor step together
<b>When is it recommended?</b>	Very useful if the reactor and capacitor come from different suppliers or if the project is critical. IEC 61921 provides the system approach for LV power factor correction banks.

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**Design verification report according to field harmonic analysis report**

<b>Main standard</b>	IEC 61000-4-7; IEC 61000-4-30; IEC 61921
<b>Construction / method standard</b>	THDU, THDI, individual harmonics, short-circuit power, capacitor power and p% calculation
<b>When is it recommended?</b>	This is the most important document if a harmonic analysis report is among the selection criteria. The report should explain the selected p%, resonance frequency, capacitor voltage and harmonic current withstand together.

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**Thermal camera test**

<b>Main standard</b>	IEC/EN 60076-6 thermal performance approach
<b>Construction / method standard</b>	IR thermography at nominal load or under harmonic load
<b>When is it recommended?</b>	Recommended for terminals, busbars, capacitor connections, winding outlets, core/air gap and hot spots inside the panel.

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**IP test - in cabinet-type compensation panel**

<b>Main standard</b>	IEC/EN 60529
<b>Construction / method standard</b>	IEC 60529
<b>When is it recommended?</b>	Applied in cabinet-type compensation/filter panels with an IP declaration.

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**Vibration test**

<b>Main standard</b>	IEC 60068-2-6; customer specification in special applications
<b>Construction / method standard</b>	Sinusoidal vibration test
<b>When is it recommended?</b>	Recommended for marine, railway, machine-mounted or vibration-prone facilities.

**Power quality performance test**

<b>Main standard</b>	IEC 61000-4-7; IEC 61000-4-30
<b>Construction / method standard</b>	THDU, THDI and individual harmonic measurement while the reactor/capacitor is in operation
<b>When is it recommended?</b>	Applied after field commissioning to demonstrate the filtering effect.

### 3. Recommended Lines to Add to the Test Report

Report line	Recommended content
Product type	Harmonic filter reactor / compensation filter reactor
Nominal values	Voltage, current, frequency, number of phases
Inductance	L value for each phase, measurement frequency, tolerance
Filter factor	p%14 / p%7 / p%5.67 / p%5.41
Resonance frequency	134 Hz / 189 Hz / 210 Hz / 215 Hz or project-specific value
Capacitor information	kVAR, capacitor voltage, connection type
Phase balance	R and L phase deviations
Loss	Copper loss, total loss in cored type
Nominal/harmonic current	In, RMS current, harmonic current assumption if any
Insulation / dielectric	Winding-to-body, phase-to-phase test results
Linearity / saturation	L-I check at nominal current or multiple points
Mechanical check	Air gap, core tightness, connection torque, vibration
Label check	Current, voltage, L, p%, resonance frequency, capacitor connection label
Field analysis reference	Harmonic analysis report no/date, THDU/THDI and dominant harmonics, if any