# A9. 3 Phase Input / 1 Phase Output Transformers - Open Delta / Scott-T

Test standards and report attachments for 3-phase input / 1-phase output special-connection transformers

Standard approach: For these products, the main product standard is usually IEC/EN 60076-1, because IEC 60076-1 provides the general standard for three-phase and single-phase power transformers. For dry-type power-transformer applications, and where the scope is applicable, IEC/EN 60076-11 may be used as a supporting reference. This standard covers dry-type power transformers; however, since its scope requires at least one winding to operate above 1.1 kV, it should be used carefully for products that are entirely LV/LV. For special products evaluated as LV safety/isolation transformers, IEC/EN 61558-1 may be used; and where the product has the characteristics of an isolation transformer, IEC/EN 61558-2-4 may also be used. IEC 61558-1 covers the safety aspects of dry-type transformers, reactors and power supply units, while IEC 61558-2-4 covers general-purpose isolation transformers.

## 1. Routine Tests

This section summarizes the routine test headings for Open Delta / Scott-T special-connection transformers, such as connection verification, phase relationship, voltage under load, unbalance, insulation, dielectric and nameplate checks.

**1**

### Winding resistance

| | |
|---|---|
| **Main standard** | IEC/EN 60076-1; IEC/EN 61558-1 for LV safety-type products |
| **Construction / method standard** | IEC 60076-1 winding resistance measurement approach |
| **Explanation for Open Delta / Scott-T** | Each winding is measured separately. In Scott-T, the windings of the main transformer and the teaser transformer must be evaluated separately. In Open Delta, the resistance balance and connection continuity of the two used limbs are checked. |

**2**

### Voltage ratio

| | |
|---|---|
| **Main standard** | IEC/EN 60076-1; IEC/EN 61558-1 |
| **Construction / method standard** | IEC 60076-1 ratio test |
| **Explanation for Open Delta / Scott-T** | The transformation ratio between the 3-phase input and the 1-phase output is verified. If taps are present, each tap must be measured separately. |

## 3 Special connection group verification

| | |
|---|---|
| **Main standard** | IEC/EN 60076-1 |
| **Construction / method standard** | Connection diagram, continuity test, phasor check |
| **Explanation for Open Delta / Scott-T** | This is the most critical test for this product group. The conformity of the Open Delta or Scott-T connection with the production drawing must be verified through terminal names, bridges, input/output terminals and phasor relationship. The OMSAN technical glossary states that the vector group defines the connection type and phase displacement, and that it is critical for parallel operation and harmonic behavior. |

## 4 Phase relationship / phase angle check

| | |
|---|---|
| **Main standard** | IEC/EN 60076-1 |
| **Construction / method standard** | Verification by phasor measurement, oscilloscope/power analyzer or phase-angle meter |
| **Explanation for Open Delta / Scott-T** | In Scott-T, phase angle verification is especially important because of the logic of balanced two-phase/single-phase conversion from a 3-phase supply. In Open Delta, it must be checked that the output voltage is obtained from the correct phasor combination of the input phases. |

## 5 No-load output voltage

| | |
|---|---|
| **Main standard** | IEC/EN 60076-1; IEC/EN 61558-1 |
| **Construction / method standard** | Measurement of no-load output voltage at nominal input voltage |
| **Explanation for Open Delta / Scott-T** | The nominal 3-phase input is applied and the 1-phase output voltage is measured. The output voltage is compared with the special connection diagram and the nameplate value. |

## 6 Output voltage under load

| | |
|---|---|
| **Main standard** | IEC/EN 60076-1; IEC/EN 61558-1 |
| **Construction / method standard** | Voltage measurement at nominal load or with the customer load profile |
| **Explanation for Open Delta / Scott-T** | In the OMSAN test approach, operation under load is specifically indicated for Open Delta. In this test, it is verified that the output voltage remains within the acceptable range at nominal load. |

## 7 Phase unbalance check

| | |
|---|---|
| **Main standard** | IEC/EN 60076-1 |
| **Construction / method standard** | Comparison of input phase currents, output voltage and, if possible, phase current under load |
| **Explanation for Open Delta / Scott-T** | Because a 1-phase load is supplied from a 3-phase system, unbalance may occur on the input side. The load sharing of the two phase limbs in Open Delta, and the current balance of the main/teaser windings in Scott-T, must be checked. |

## 8 Impedance and load loss

| | |
|---|---|
| **Main standard** | IEC/EN 60076-1; IEC/EN 60076-11 for dry-type power applications |
| **Construction / method standard** | IEC 60076-1 short-circuit impedance and load-loss measurement |
| **Explanation for Open Delta / Scott-T** | Z% / Uk% and load loss are measured. The OMSAN technical glossary states that impedance voltage limits the short-circuit current and is decisive for voltage regulation. |

## 9 No-load current and no-load loss

| | |
|---|---|
| **Main standard** | IEC/EN 60076-1; IEC/EN 61558-1 |
| **Construction / method standard** | IEC 60076-1 no-load operation test |
| **Explanation for Open Delta / Scott-T** | No-load current and P0 are measured at nominal input voltage. Since an incorrect phase/bridge connection in a special connection can increase the no-load current, this test also indirectly indicates connection errors. |

## 10 Insulation resistance

| | |
|---|---|
| **Main standard** | IEC/EN 60076-3; IEC/EN 60076-11; IEC/EN 61558-1 for LV products |
| **Construction / method standard** | IEC 60076-3 dielectric test preparation; IEC 61557-2 as a supporting reference for practical measurement |
| **Explanation for Open Delta / Scott-T** | Primary-secondary, primary-frame and secondary-frame are measured. If a screen or intermediate connection is present, screen-frame and screen-winding measurements may also be performed. IEC 60076-3 defines insulation requirements and related insulation tests for power transformers. |

## 11 Dielectric withstand / applied voltage test

| | |
|---|---|
| **Main standard** | IEC/EN 60076-3; IEC/EN 60076-11; IEC/EN 61558-1 |
| **Construction / method standard** | IEC 60076-3 separate-source AC withstand test or IEC 61558-1 dielectric withstand test |
| **Explanation for Open Delta / Scott-T** | The main insulation is verified. The test level must be selected according to the product voltage class, insulation structure and customer specification. |

## 12 Induced voltage / inter-turn insulation test

| | |
|---|---|
| **Main standard** | IEC/EN 60076-3; IEC/EN 61558-1 |
| **Construction / method standard** | IEC 60076-3 induced AC voltage test approach |
| **Explanation for Open Delta / Scott-T** | Inter-turn insulation is verified. In special-connection transformers, this test is important because an incorrect connection or winding fault can affect the output phasor and no-load current. |

## 13 Earth continuity / PE continuity

| | |
|---|---|
| **Main standard** | IEC/EN 60076-11; IEC/EN 61558-1; IEC 60204-1 as a supporting reference for panel/cabinet products |
| **Construction / method standard** | Low-resistance continuity measurement |
| **Explanation for Open Delta / Scott-T** | Continuity is checked between the metal enclosure, cover, mounting foot, lifting lug, screen and PE terminal. |

## 14 Nameplate check

| | |
|---|---|
| **Main standard** | IEC/EN 60076-1; IEC/EN 61558-1 |
| **Construction / method standard** | Cross-check of nameplate, technical datasheet and test report |
| **Explanation for Open Delta / Scott-T** | Power, input/output voltage, frequency, number of phases, connection type, cooling, insulation class, IP rating and serial number are checked. |

## 15 Special connection diagram check

| | |
|---|---|
| **Main standard** | IEC/EN 60076-1; customer specification |
| **Construction / method standard** | Verification of connection diagram, terminal number, bridges and terminals |
| **Explanation for Open Delta / Scott-T** | The Open Delta or Scott-T connection diagram must be clearly included on the nameplate or in the document supplied with the product. Since incorrect field connection creates a high risk in these products, the diagram check should be added to the routine report. |

## 16 Output polarity / terminal verification

| | |
|---|---|
| **Main standard** | IEC/EN 60076-1 |
| **Construction / method standard** | Polarity test, terminal-block continuity check |
| **Explanation for Open Delta / Scott-T** | The single-phase output terminals must be provided with the correct polarity and correct terminal names. In a Scott-T connection, terminal errors in the main/teaser winding impair the phase conversion performance. |

## 17 Mechanical and cooling check

| | |
|---|---|
| **Main standard** | IEC/EN 60076-11; IEC/EN 61558-1 |
| **Construction / method standard** | Visual-mechanical check, air-duct and connection tightness check |
| **Explanation for Open Delta / Scott-T** | Visual/mechanical inspection and final quality control are included in the routine flow within OMSAN's general quality process. In special connections, it is especially important that the connecting busbars are not loose. |

# 2. Optional / Special Tests

These tests may be recommended for projects with a special load profile, continuous single-phase load, unbalance risk, harmonic load, critical industrial application or customer specification.

## 1 Unbalanced load test

| | |
|---|---|
| **Main standard** | IEC/EN 60076-1; customer specification |
| **Construction / method standard** | While the single-phase output is loaded, input phase currents, output voltage and temperature behavior are monitored |
| **When is it recommended?** | Because a single-phase load is supplied from a 3-phase network, input-side unbalance may be critical. It is recommended for Open Delta and Scott-T applications if the site load profile is known. |

## 2 Temperature rise test

| | |
|---|---|
| **Main standard** | IEC/EN 60076-11 for dry-type power transformers; IEC/EN 61558-1 for LV safety-type products |
| **Construction / method standard** | Temperature rise test method in the relevant product standard |
| **When is it recommended?** | It is recommended when there is continuous single-phase load, enclosed cabinet operation, high ambient temperature or a customer specification. The OMSAN technical glossary states that the hot spot is the critical region that determines insulation life. |

## 3 Harmonic load test

| | |
|---|---|
| **Main standard** | IEC/EN 60076-1 as supporting reference; IEC 61000-4-7 / IEC 61000-4-30 for harmonic measurement |
| **Construction / method standard** | Load with THD or harmonic current/voltage measurement by power analyzer |
| **When is it recommended?** | It is recommended when UPS, rectifier, inverter, drive or electronic loads will be supplied. The OMSAN technical glossary states that harmonics may increase winding losses, cause additional heating and affect transformer sizing. |

## 4 Functional test with customer load profile

| | |
|---|---|
| **Main standard** | IEC/EN 60076-1; customer specification |
| **Construction / method standard** | Checking output voltage, input phase current, heating, sound and regulation with actual or equivalent load |
| **When is it recommended?** | In special-connection transformers, even if the theoretical ratio is correct, voltage drop and phase unbalance under real load may differ. For this reason, testing with the actual load profile is very valuable in critical projects. |

## 5 Phase conversion performance report

| | |
|---|---|
| **Main standard** | IEC/EN 60076-1; customer specification |
| **Construction / method standard** | Phasor diagram, input/output measurement table, phase angle, voltage regulation and load-sharing calculations |
| **When is it recommended?** | For Open Delta / Scott-T products, this is the strongest additional document in terms of sales and technical confidence. It is especially useful to provide it to the customer before project approval. |

## 6 Sound level test

| | |
|---|---|
| **Main standard** | IEC/EN 60076-10 |
| **Construction / method standard** | IEC 60076-10 sound pressure / sound intensity measurement method |
| **When is it recommended?** | It is recommended for indoor, office, hospital, laboratory or acoustically sensitive areas. IEC 60076-10 defines methods for determining sound levels for transformers, reactors and cooling equipment. |

## 7 Short-circuit withstand verification

| | |
|---|---|
| **Main standard** | IEC/EN 60076-5 |
| **Construction / method standard** | Calculation, design verification or type test if requested by the customer |
| **When is it recommended?** | It is recommended for high power ratings, systems with high short-circuit power or critical industrial applications. |

## 8 Hot-spot check by thermal camera

| | |
|---|---|
| **Main standard** | IEC/EN 60076-11 or IEC/EN 61558-1 thermal safety approach |
| **Construction / method standard** | IR thermography under load; manufacturer procedure |
| **When is it recommended?** | Local heating is checked at the two-limb connection in Open Delta, the main/teaser connections in Scott-T, terminals, busbars and winding surfaces. |

## 9 Suitability for parallel / common busbar operation

| | |
|---|---|
| **Main standard** | IEC/EN 60076-1 |
| **Construction / method standard** | Comparison of ratio, impedance, phase angle and connection compatibility |
| **When is it recommended?** | It is applied when more than one special-connection transformer will operate in the same system. The OMSAN technical glossary states that voltage ratio, impedance and vector group compatibility are mandatory for parallel operation. |

# 3. Recommended Lines to Add to the Test Report

For Open Delta / Scott-T special-connection products, adding the following lines to the standard routine test report enables clearer tracking of the connection type, phasor verification, load profile and functional verification.

| | |
|---|---|
| 1 | **Connection type**<br>Open Delta / Scott-T |
| 2 | **Phasor verification**<br>Input phases, output terminals, measured phase angle |
| 3 | **Connection diagram check**<br>Terminal numbers, bridges, polarity and special connection note |
| 4 | **No-load output voltage**<br>1-phase output voltage at nominal 3-phase input |
| 5 | **Output voltage under load**<br>Output voltage at nominal load or with the customer load profile |
| 6 | **Input phase currents**<br>L1-L2-L3 currents and unbalance under load |
| 7 | **Impedance / load loss**<br>Z% / Uk%, Pk and reference temperature correction |
| 8 | **No-load current / loss**<br>I0 and P0 |
| 9 | **Insulation / dielectric**<br>Primary-secondary, primary-frame and secondary-frame results |
| 10 | **Function note**<br>The statement “3-phase input / 1-phase output special connection verified” |

## 11 Customer load profile

Actual load or equivalent load test result, if available