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# Relay Protection Testing

## Standards, Test Items and Test-Set Requirements

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*Every value is cited to a standard number, edition and clause. Unverified items are listed in Appendix B.*

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## Executive summary

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Relay protection is the last line of defence in a power system. It does nothing in normal operation; in a fault it decides, within tens of milliseconds, what to trip and how fast. Testing exists to find three failure modes before the power system does: **failure to operate**, **spurious operation** and **slow operation**.

This whitepaper answers four questions:

- 1. What does each standard require?** China separates method (GB/T 7261-2016), field practice (DL/T 995-2016) and installation acceptance (GB/T 50976-2014). IEC separates generic requirements (IEC 60255-1:2022) from function-specific standards. North America adds a system-level test framework (IEEE C37.233-2023) and acceptance/maintenance checklists by device number (NETA ATS/MTS 7.9).
- 2. Which items are common?** Eight device-level groups — appearance, insulation, accuracy, timing, communication, climate, mechanical, EMC — appear in every mature system. Three function-level groups — operate value, operate time, characteristic/transient performance — are substantively universal.
- 3. Which items are unique?** China is distinctive for whole-scheme trip tests, load tests before energisation, secondary-loop limits and fixed maintenance intervals. IEC is distinctive for declared values and variations, and for test-point maps in the function standards. North America is distinctive for scheme-based testing, device-number checklists, setting-sheet comparison and end-to-end trigger-delay compensation.
- 4. What does a test set need?** Test sets follow a three-document chain — DL/T 624 (product technical conditions), DL/T 1153 (calibration specification) and JJG 1112 (verification regulation). Field instruments must be at least class 0.5 (DL/T 995 5.2.1.1), while calibration grades are 0.1 and 0.2 (DL/T 1153-2025, JJG 1112-2015).

**The one-sentence conclusion:** the test items are broadly similar; the **criteria system** is where the standards diverge. The same "pickup test" is compared with a setting sheet in China, with a manufacturer's declared value and variation in IEC, and with the manufacturer's recommended tolerance in NETA. Transplanting criteria between systems is the most common technical error in relay testing.

# 1. Why relay protection needs a dedicated test discipline

## 1.1 Three failure modes

| Failure mode       | Symptom                                      | Typical consequence                             | Test response                                          |
|--------------------|----------------------------------------------|-------------------------------------------------|--------------------------------------------------------|
| Failure to operate | No trip during a fault                       | Fault escalation, equipment damage, instability | Pickup, trip circuit, whole-scheme trip test           |
| Spurious operation | Trip with no fault, or for an external fault | Unnecessary outage, cascading trips             | Settings, direction, bias characteristic, EMC immunity |
| Slow operation     | Trip, but later than intended                | Extended fault current, loss of coordination    | Timing, curve verification, transient performance      |

Protection devices rarely "break". They drift, age, are set incorrectly, carry the wrong firmware or are wired wrongly. That is why testing has two non-negotiable properties: it must be **traceable** (setting sheet, report) and **reproducible** (same stimulus, same result).

## 1.2 Four questions every test programme must answer

1. **Is the operate value correct** — against the setting sheet, the declared value or the manufacturer's tolerance?
2. **Is the timing correct** — operate time, reset time, inverse-time curve?
3. **Is the logic correct** — direction, bias, blocking, reclosing, backup transfer?
4. **Is the system coordinated** — whole-scheme trip, channel, end-to-end, load-current phasor check?

The first three can be answered at the relay terminals. The fourth requires the loop and the system — which is why DL/T 995, IEEE C37.233 and NETA devote so much space to whole-scheme, end-to-end and load tests.

## 1.3 Five test stages

| Stage                  | Object             | Performed by                          | Main basis                                              |
|------------------------|--------------------|---------------------------------------|---------------------------------------------------------|
| Type test              | New product design | Manufacturer / third-party laboratory | GB/T 7261, IEC 60255-1 and function standards, C37.90.x |
| Routine (factory) test | Every unit         | Manufacturer                          | Product standard, GB/T 14598.2                          |
| Commissioning          | After installation | Commissioning contractor              | GB/T 50976, DL/T 995 acceptance tests, NETA ATS         |
| Periodic maintenance   | In service         | Utility maintenance team              | DL/T 995 periodic tests, NETA MTS                       |
| Post-fault             | After a trip       | Protection team                       | DL/T 995 supplementary tests                            |

The item set is **not the same** at each stage. Type tests pursue coverage and severity; field tests pursue executability and a clear verdict. Mixing the two is the main reason field testing becomes slow and inconclusive.

## 1.4 Scope of this whitepaper

AC protection for lines, transformers, busbars, generators, reactors and capacitors; relay and device testing; secondary-loop and system testing; and the requirements placed on the test set itself. It does not cover primary equipment testing, setting calculation or project-specific commissioning procedures.

## 2. The four-layer standards landscape

### 2.1 Four layers, four jobs

| Layer                 | Question it answers                                 | China                                              | International / North America               |
|-----------------------|-----------------------------------------------------|----------------------------------------------------|---------------------------------------------|
| Configuration         | Which protection, to what performance               | GB/T 14285-2023                                    | IEEE C37.233-2023 (application sections)    |
| Method                | How to test                                         | GB/T 7261-2016                                     | IEC 60255-1:2022                            |
| Field                 | What to test on site, how often, against what limit | DL/T 995-2016, GB/T 50976-2014                     | NETA ATS-2025 / MTS-2023                    |
| Product & conformance | Is the device itself compliant and interoperable    | GB/T 14598 series, GB/T 7261 communication clauses | IEC 60255 function standards, IEEE C37.90.x |

The layers reference each other rather than replace each other. A method standard supplies the procedure; a field standard supplies the verdict; a product standard supplies the characteristic limit. Any test plan should be able to state, for every item, which layer it came from.

### 2.2 Why criteria cannot be transplanted

- Different reference conditions.** IEC 60255-1 declares accuracy under specified reference conditions; site conditions deviate, and the declared variation must be applied. DL/T 995 writes limits directly for operating conditions.
- Different tolerance models.** IEC uses a manufacturer's declared value from a preferred series (6.5.2.1). NETA uses "manufacturer's recommended tolerance". Chinese field practice uses the setting sheet. These are not interchangeable.
- Different severity sources.** GB/T 7261 takes immunity levels from the product standard; C37.90.x states its own levels; IEC 60255-26 assigns levels by port and application zone.

*Edition note.* GB/T 7261-2026 was published on 2 July 2026 and takes effect on 1 February 2027. The replacement of DL/T 995 (plan 能源 20240963) is in development and unpublished. This whitepaper cites the editions in force as of 27 October 2026.

### 2.3 A traceability example

Take a 220 kV line differential protection at commissioning:

| Test item                 | Field basis               | Method basis        | Product basis                   |
|---------------------------|---------------------------|---------------------|---------------------------------|
| Secondary loop insulation | DL/T 995 5.3.2.4 (>10 MΩ) | GB/T 7261 clause 13 | Device technical conditions     |
| Dielectric strength       | DL/T 995 5.3.2.4          | GB/T 7261 clause 13 | Type-test report                |
| Setting verification      | DL/T 995 5.3.4            | GB/T 7261 6.5 / 6.6 | Manufacturer's declared value   |
| Pilot channel             | DL/T 995 6.3              | —                   | Channel equipment specification |
| Whole-scheme trip         | DL/T 995 5.3.7            | —                   | —                               |

A plan that says only "in accordance with GB/T 7261" or only "in accordance with DL/T 995" is technically incomplete: 7261 does not provide field limits, and 995 does not provide type-test methods. Review the traceability table before reviewing the prose.

## 3. A taxonomy of test items

### 3.1 Three dimensions

- **By object:** device level (the unit), function level (elements and logic), loop and system level (secondary circuits, channel, whole scheme, end-to-end).
- **By stage:** type, routine, commissioning, periodic, post-fault.
- **By stress:** electrical (magnitude, phase, frequency, harmonics, DC component), non-electrical (temperature, humidity, vibration, shock, EM field), information (messages, time stamps, protocol).

### 3.2 Device level — six groups

| Group                  | Items                                                                                                                              | Purpose                                      |
|------------------------|------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| Electrical performance | Power consumption, supply variation, overload, contact performance and life                                                        | Availability at rated and extreme conditions |
| Measurement            | Characteristic accuracy, timing, measurement and control                                                                           | Correct measurement and timing               |
| Insulation and safety  | Insulation resistance, dielectric strength, impulse voltage, safety tests                                                          | Personnel and equipment safety               |
| Climate                | Cold/heat operating and storage, temperature change, damp heat, low pressure                                                       | Environmental robustness                     |
| Mechanical             | Vibration, shock and bump, seismic                                                                                                 | Transport and installation survival          |
| EMC                    | ESD, radiated immunity, EFT, surge, conducted immunity, power-frequency magnetic field, damped oscillation, voltage dips, emission | No maloperation, no failure to operate       |

### 3.3 Function level — four groups

| Group          | Items                                                                                             | Notes                                                    |
|----------------|---------------------------------------------------------------------------------------------------|----------------------------------------------------------|
| Operate values | Pickup, reset, reset ratio, setting range                                                         | Compared with setting sheet, declared value or tolerance |
| Timing         | Operate time, reset time, repeatability, inverse-time curve                                       | Steady-state and step application                        |
| Characteristic | Directional boundary, impedance characteristic, bias slope, harmonic restraint, load encroachment | 2-D or multi-dimensional scan                            |
| Transient      | DC offset, transient overreach, CVT transient, CT saturation, evolving fault                      | Requires waveform-level output                           |

### 3.4 Loop and system level — four groups

| Group          | Items                                                                                      | Notes                                |
|----------------|--------------------------------------------------------------------------------------------|--------------------------------------|
| Loop integrity | Secondary insulation, PT voltage drop, binary input level, output contacts, trip-coil drop | China gives the most specific limits |
| Channel        | Fibre/PLC pilot channel, attenuation, alarm                                                | Specific to line protection          |

| Group        | Items                                                                   | Notes                                         |
|--------------|-------------------------------------------------------------------------|-----------------------------------------------|
| Whole scheme | Trip test with the actual breaker, anti-pumping, reclosing, trip matrix | Verifies protection → breaker                 |
| System       | Load-current phasor check, end-to-end, scheme performance               | Verifies CT/PT → relay → channel → remote end |

### 3.5 Three ways a requirement is written

| Form                          | Meaning                                                                 | Typical source                                      |
|-------------------------------|-------------------------------------------------------------------------|-----------------------------------------------------|
| <b>Fixed limit</b>            | The standard states the number or verdict                               | DL/T 995 (insulation >10 MΩ, PT drop ≤3%), C37.90.x |
| <b>Declared value</b>         | The manufacturer declares; the test proves the declaration              | IEC 60255-1 6.5.2.1, GB/T 14598.2                   |
| <b>Manufacturer tolerance</b> | The standard requires "within the manufacturer's recommended tolerance" | NETA ATS/MTS 7.9, C37.233                           |

This is the most important table in the whitepaper. Before citing any criterion, identify which of the three forms it takes.

### 3.6 Three constraints on item selection

- 1. Stage constraint.** Type tests may be destructive or extreme (1 s thermal withstand, mechanical life); field tests must be non-destructive and reversible. Copying type-test items into commissioning is unnecessary and unsafe.
- 2. Object constraint.** Items must match the actual scheme. A line protection without a pilot channel needs no channel test; a busbar panel without a breaker can only be tested to its output contacts.
- 3. Criterion constraint.** An item without a limit is an **observation item**, not a pass/fail item. Self-check messages and event logs usually fall here; label them as such in the report.

The practical consequence: every item should answer *why it is done, how far it goes, and what makes it pass*. If it cannot, delete it or downgrade it to an observation.

## 4. What each standard actually requires

### 4.1 China — GB/T 7261-2016, the method library

GB/T 7261 is a **method** standard: it defines how to test and how to express error, not a universal tolerance.

Clause structure:

| Clause | Content                      | Key points                                                                                                                              |
|--------|------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| 4      | Test conditions              | Reference conditions, instrument selection, pre-treatment, cold/hot state, application order                                            |
| 5      | Construction and appearance  | Enclosure, terminals, wiring, marking, controls                                                                                         |
| 6      | Basic performance            | Contacts, coils, transducers, on/off relays, characteristic accuracy, timing, binary I/O, measurement and control, time synchronisation |
| 8      | Power consumption            | Device and circuit consumption                                                                                                          |
| 9      | Temperature rise             | Rated and overload conditions                                                                                                           |
| 10     | Climate                      | Cold/heat, temperature change, damp heat, low pressure                                                                                  |
| 11     | Supply variation             | Auxiliary voltage, AC supply frequency                                                                                                  |
| 12     | Mechanical                   | Vibration, shock, seismic                                                                                                               |
| 13     | Insulation                   | Resistance, dielectric strength, impulse voltage                                                                                        |
| 14     | EMC                          | ESD, radiated, EFT, surge, conducted, magnetic field, dips                                                                              |
| 15     | Overload                     | Continuous, short-time thermal, dynamic withstand                                                                                       |
| 16     | Contact performance and life | Switching capacity, electrical and mechanical life                                                                                      |
| 17     | Safety                       | Safety requirements                                                                                                                     |
| 18     | Communication and protocol   | Protocol conformance, reliability, network stress                                                                                       |
| 19     | Device functions             | Functional logic                                                                                                                        |

**How tolerances are expressed.** 6.5.1 allows accuracy as an absolute value, a percentage of setting, or a percentage plus a fixed absolute value, using maximum or mean error. 6.5.2.2.1 and 6.6.3.3 require five repeat measurements. 6.6.1.1 allows timing accuracy to be expressed as "percentage of setting plus a minimum fixed error (e.g. 5% or 20 ms, whichever is greater)" — a **notation**, not a criterion.

**Self-contained limits (a minority).** 6.6.4 a) coil voltage variation  $\leq 5\%$ ; 15.2.1.1 short-time thermal 1 s for current circuits and 10 s for voltage circuits; 15.3.1.1 dynamic peak  $\geq 2.5\times$  short-time thermal; 15.4.1 continuous overload  $2\times$  rated current /  $1.4\times$  rated voltage; 16.2.3 c) dielectric strength after life test at  $0.75\times$  the specified value.

**The 2026 edition** adds time-keeping performance (6.10), optical power (8.2), cyber-security tests (clause 17) and device function tests (clause 19); communication expands to 19 sub-tests; insulation moves into safety (clause 16).

### 4.2 China — DL/T 995-2016, the 19 field items

DL/T 995 is the **first reference for Chinese field commissioning**: category, interval, item and criterion in one document.

| #  | Item                                             | Key points                                                            | Criterion / clause                                                                                                   |
|----|--------------------------------------------------|-----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| 1  | Preparation                                      | Work permit, all trip outputs isolated, valid instrument certificates | 5.2.2.6; instruments $\geq$ class 0.5 (5.2.1.1)                                                                      |
| 2  | CT/VT tests                                      | Ratio, polarity, excitation/VA characteristic                         | —                                                                                                                    |
| 3  | CT/VT secondary loop                             | Wiring, single-point grounding, open/short protection                 | PT drop $\leq 3\%$ of rated voltage (5.3.2.3 f)                                                                      |
| 4  | Secondary insulation                             | To earth and between circuits                                         | $>10 \text{ M}\Omega$ acceptance, $>1 \text{ M}\Omega$ periodic (5.3.2.4 b/c); $\geq 1 \text{ M}\Omega$ per core (d) |
| 5  | External inspection                              | Enclosure, terminals, marking, modules                                | —                                                                                                                    |
| 6  | Device insulation                                | Resistance, dielectric strength                                       | —                                                                                                                    |
| 7  | Power-on check                                   | Self-test, version, alarms                                            | —                                                                                                                    |
| 8  | Auxiliary supply                                 | DC ramped from zero to 80% rated                                      | Must start at 80% rated (5.3.3.5)                                                                                    |
| 9  | A/D conversion                                   | Zero drift, amplitude and phase accuracy                              | Device specification, DL/T 478 (5.3.3.6)                                                                             |
| 10 | Binary inputs                                    | Per-channel energisation and change verification                      | High-voltage inputs $0.55\text{--}0.7\times$ rated, $\geq 5 \text{ W}$ (5.3.3.7 d)                                   |
| 11 | Output contacts and signals                      | Per-channel operation                                                 | —                                                                                                                    |
| 12 | Event records                                    | Trip report, SOE                                                      | $\geq 8$ records, COMTRADE export (5.3.3.9)                                                                          |
| 13 | Stability-control information and start criteria | Special protection systems                                            | 5.3.3.10/.11                                                                                                         |
| 14 | Setting verification                             | Item-by-item against the setting sheet                                | 5.3.4                                                                                                                |
| 15 | Pilot channel                                    | Fibre/PLC, attenuation, alarm                                         | Fibre interface power (6.3.1.3.1)                                                                                    |
| 16 | Trip/close auxiliary                             | Trip and close circuits, anti-pumping                                 | —                                                                                                                    |
| 17 | <b>Whole-scheme trip test</b>                    | With the actual breaker, anti-pumping, reclosing, phase agreement     | Close-coil drop $\geq 90\%$ rated (5.3.7.5 e)                                                                        |
| 18 | SCADA / fault-record system                      | Data upload, point-to-point check                                     | 5.4                                                                                                                  |
| 19 | Energisation                                     | Setting sheet, trip links, load test                                  | <b>No formal energisation without a load test (5.5.2.7)</b>                                                          |

**Intervals:** full test every 6 years for microprocessor relays, 4 years for non-microprocessor, 6 years for channels; partial test every 2–4 years (microprocessor) or 1 year (non-microprocessor); first full test within 1 year of new commissioning (5.1.2.3).

The difference in intervals reflects failure mechanisms: mechanical wear and contact oxidation in electromechanical relays, capacitor and memory ageing in microprocessor relays. The 2–4 year band for partial tests is deliberately elastic: the actual year should follow the environment, trip frequency and defect history, not always the lower bound. High-risk parts — trip circuits, power modules, trip auxiliaries — should be covered in partial tests even when the full-test interval has not expired.

### 4.3 China — GB/T 50976-2014, installation acceptance

| Clause | Acceptance content                  |
|--------|-------------------------------------|
| 3      | Drawings, test reports, spare parts |

| Clause | Acceptance content                                                                                                               |
|--------|----------------------------------------------------------------------------------------------------------------------------------|
| 4      | Installation and workmanship: environment, panels, secondary cables and fibre, cores/terminals, marking, shielding and grounding |
| 5      | Secondary circuits: DC supply, AC current, AC voltage, breaker/disconnector circuits, pilot channel, other critical circuits     |
| 6      | Devices and fault-information substation                                                                                         |
| 7      | Whole-scheme trip test                                                                                                           |
| 8      | Pre-energisation checks and load test                                                                                            |

GB/T 50976 governs "installed correctly and accepted in the right sequence" and interfaces with DL/T 995 5.3.7/5.5. Its clauses contain specific values (grounding, insulation, loop resistance); the full text was not obtained for this whitepaper, so those values are marked unverified in Appendix B.

#### 4.4 IEC — 60255-1:2022 and the function standards

**Generic requirements.** IEC 60255-1:2022 Edition 2 covers appearance and functional pre-check, power consumption, insulation, climate, mechanical, EMC (by reference to 60255-26), overload and contact performance. Safety and EMC have moved out to 60255-27:2023 and 60255-26:2023 Edition 4. Accuracy centres on **6.5.2.1**: the manufacturer declares error limits at reference conditions, with percentages from the preferred series 0.2 / 0.5 / 1.0 / 1.5 / 2.5 / 5.0 / 7.5 / 10 / 20%. Clause 6.5.3 requires the **variation** caused by temperature, auxiliary quantities, harmonics and frequency to be declared item by item.

##### Function standards:

| Standard                       | Main items                                                                                                                                     | Criterion logic                                                                                      |
|--------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|
| 60255-151 (over/under-current) | Pickup, reset ratio, start/operate time, reset time, transient overreach, overshoot, inverse-time response, time constants                     | Time accuracy by class index (Class 5 = 12.5/7.5/5%); test points in Tables 3–7                      |
| 60255-121 (distance)           | Steady-state characteristic, transient overreach, CVT transient, load encroachment, dynamic performance, phase selection/direction/start/delay | Declared value + characteristic maps (Figures 2/13/14) + test-point tables; Annex I ramp method      |
| 60255-127 (over/under-voltage) | Operate value, reset ratio, operate time, reset time, transient/overshoot                                                                      | Table 5 test points; declared value                                                                  |
| 60255-181 (frequency)          | Frequency operate value, delay, $df/dt$ , ramp test, reset hysteresis                                                                          | Table 18 test points / Table 19 accuracy; ramps must be smooth and continuous in phase and magnitude |
| 60255-187-1 (differential)     | Bias characteristic, harmonic restraint, load-harmonic performance, CT saturation, unrestrained differential                                   | Test lines a–h; Figures 9/10, Tables 5–7/10/11; Annex C normative CT requirements                    |

**How reference conditions and variations are used.** IEC accuracy is not a universal statement; it holds at the declared reference conditions. On site, the permitted error follows the declared variation. Two engineering consequences:

- A purchase specification should require a **complete variation table**, not a single accuracy figure. Accuracy without variation cannot be used to judge a field deviation.

- When comparing products, confirm whether the figures are **guaranteed** or **typical**. Typical values are often one-half to one-third of guaranteed values.

The test-point maps in the function standards follow the same logic: the standard does not mandate a fixed number of points; it defines how to select points that cover the characteristic boundary. A plan that tests only the rated point completes the form but not the verification.

#### 4.5 IEEE C37.233-2023 — scheme-based system testing

| Clause  | Content                                                                                                                                                                                                                             |
|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 4       | Test types: 4.1 manufacturer certification, 4.2 conformance, 4.3 performance, 4.4 laboratory application, 4.5 commissioning, 4.6 maintenance, 4.7 maintenance practice, 4.8 test modules and case generation, 4.9 results retention |
| 5       | Scheme types: 5.2 line, 5.3 transformer, 5.4 shunt capacitor, 5.5 busbar, 5.6 breaker failure, 5.7 shunt reactor, 5.8 generator, 5.9 trip-circuit logic                                                                             |
| 6       | Communication testing: power-line carrier, wireless                                                                                                                                                                                 |
| 7       | Proof of concept, field commissioning, system performance within the maintenance interval, state-estimator verification, automated/manual periodic testing of the full scheme                                                       |
| 8       | Non-conventional V/I sensing: primary injection, special analogue/digital inputs, sensor outputs, condition-based maintenance verification                                                                                          |
| Annexes | B line current differential procedure; C high-impedance faults; D transformer thermal algorithms; E end-to-end trigger-delay measurement and compensation                                                                           |

The methodology is bottom-up—component, function group, interconnected system—across performance, application and commissioning tests. There is **no single numeric tolerance and no fixed interval**.

#### 4.6 IEEE C37.90.x — EMC and surge withstand

| Standard      | Test                         | Level (public values of earlier editions; check the current edition)                                          | Verdict                                                           |
|---------------|------------------------------|---------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|
| C37.90.1-2024 | Damped oscillatory SWC + EFT | SWC 2.5 kV / 1 MHz (75 ns rise, 400 Hz repetition, both polarities, $\geq 2$ s); EFT 4 kV / 5/50 ns / 2.5 kHz | No maloperation or damage; assess in both trip and no-trip states |
| C37.90.2-2024 | Radiated RF immunity         | 35 V/m, 80 MHz–1 GHz (earlier edition)                                                                        | Correct operation, no spurious trip                               |
| C37.90.3-2023 | ESD                          | Refers to IEC 61000-4-2:2008; contact 2/4/6/8 kV, air 2/4/8/15 kV (levels actually adopted unverified)        | No maloperation during and after discharge                        |

The base standard C37.90-2005 became inactive in 2022 with no current replacement. Do not accept "complies with C37.90" as a complete statement.

#### 4.7 NETA ATS-2025 / MTS-2023 clause 7.9

**Structure:** 7.9.1 electromechanical and solid-state relays; 7.9.2 microprocessor relays. ATS covers acceptance of new equipment; MTS covers maintenance of equipment in service.

| Device number | Test and inspection content (selection)     |
|---------------|---------------------------------------------|
| 50/51         | Pickup, reset, two-point inverse-time delay |

| Device number        | Test and inspection content (selection)                                                                                              |
|----------------------|--------------------------------------------------------------------------------------------------------------------------------------|
| 27/59                | Reset, pickup, 1.2× step delay                                                                                                       |
| 67                   | Minimum pickup at maximum torque angle, operating zone, characteristic curve, two-point overcurrent delay                            |
| 87                   | Operate-element pickup, restraint elements, slope, harmonic restraint, unrestrained, bias-side characteristics                       |
| 79                   | Reclosing delays, lockout after unsuccessful reclose, reset time, close pulse, instantaneous-overcurrent blocking                    |
| 81/85/25             | Frequency setting/delay/undervoltage blocking; pilot-wire operating level; close zone, differential voltage, live/dead-line settings |
| 21/40/46/47          | Maximum reach and torque angle, offset, impedance circle; loss-of-field impedance; negative-sequence pickup and slope                |
| 24/32/49/55/60/63/64 | Frequency operation, reverse power, thermal curve, trip angle, differential voltage, pressure rate, ground impedance                 |

**7.9.2 microprocessor checklist:** nameplate and firmware/software version; LEDs, display and targets; passwords and permissions; terminal tightness and panel grounding; settings downloaded from the calculation sheet and compared item by item; battery and time source; insulation resistance; full analogue injection against metering; element-by-element function; binary inputs/outputs/internal logic/pilot loop-back/end-to-end/direct trip; clearing of min/max and fault counters; communication statistics; SOE; trip/close coil monitoring; setting-change alarm to SCADA; post-energisation magnitude and phase check of every input.

**Criterion:** NETA 7.9 requires "within the manufacturer's recommended tolerance". It contains **no universal pickup or timing percentage**. The widely repeated " $\pm 5\%$ " is a misattribution; Table 100.10 is a motor vibration limit table.

**ATS vs MTS.** ATS asks "can we accept new equipment", so nameplate/version, setting-sheet comparison and post-energisation phasors are prominent. MTS asks "can in-service equipment continue to operate", so function re-check, loop integrity, contacts and mechanical condition dominate. The device-number structure is shared, but the item selection is not. NETA does not fix a universal interval; the owner's maintenance strategy does. Whether the 2023 edition retains the older 1/12/12-year bands is unverified (Appendix B).

## 5. Common and unique test items

### 5.1 Comparison matrix

● explicit item and requirement · ○ principle or reference — not addressed.

| Item                                       | GB/T 7261 | DL/T 995 | GB/T 50976 | IEC 60255-1/family | C37.233 | C37.90.x | NETA 7.9 |
|--------------------------------------------|-----------|----------|------------|--------------------|---------|----------|----------|
| Appearance and construction                | ●         | ●        | ●          | ●                  | ○       | —        | ●        |
| Power consumption                          | ●         | —        | —          | ●                  | —       | —        | —        |
| Supply variation                           | ●         | ●        | —          | ●                  | ○       | —        | —        |
| Overload                                   | ●         | —        | —          | ●                  | —       | —        | —        |
| Contact performance/life                   | ●         | —        | —          | ●                  | —       | —        | ○        |
| Insulation/dielectric/impulse              | ●         | ●        | —          | ●                  | ○       | ●        | ●        |
| Temperature rise                           | ●         | —        | —          | ○                  | —       | —        | —        |
| Operate value/characteristic               | ●         | ●        | —          | ●                  | ○       | —        | ●        |
| Operate/reset time                         | ●         | ●        | —          | ●                  | ○       | —        | ●        |
| Inverse-time curve                         | ○         | ●        | —          | ●                  | ○       | —        | ●        |
| Transient (DC/CVT/CT)                      | ●         | ●        | —          | ●                  | ○       | —        | ○        |
| Harmonic influence/restraint               | ○         | ●        | —          | ●                  | ○       | —        | ●        |
| Measurement/binary I/O                     | ●         | ●        | —          | ○                  | —       | —        | ●        |
| Time sync/time keeping                     | ●         | ●        | —          | ○                  | ○       | —        | —        |
| Communication/protocol                     | ●         | ●        | —          | ○                  | ○       | —        | ●        |
| Cyber security                             | ● (2026)  | —        | —          | —                  | —       | —        | —        |
| Climate                                    | ●         | —        | —          | ●                  | ○       | —        | —        |
| Mechanical/seismic                         | ●         | —        | —          | ●                  | —       | —        | —        |
| EMC                                        | ●         | —        | —          | ●                  | ○       | ●        | —        |
| Secondary loop insulation/drop/input level | —         | ●        | ●          | —                  | —       | —        | —        |
| Pilot channel                              | —         | ●        | ●          | —                  | ○       | —        | —        |
| Whole-scheme trip                          | —         | ●        | ●          | —                  | ●       | —        | ○        |
| Load test/phasor check                     | —         | ●        | ●          | —                  | ○       | —        | ●        |
| End-to-end/system                          | —         | ○        | —          | —                  | ●       | —        | ○        |

### 5.2 The common core

Eight device-level groups appear with explicit items in at least four systems: appearance, insulation, accuracy, timing, communication, climate, mechanical and EMC. Three function-level groups are substantively shared: operate value, operate time, and curve/transient performance.

A plan without these eleven groups is incomplete. A plan with only these eleven is not sufficient for commissioning.

Communication and time synchronisation entered the common set with modern substation architectures: relays exchange trip commands and sampled values as messages, and clock loss displaces samples and distorts time stamps. A decade ago these were communication-acceptance items; today they are relay test items. **The test boundary moves with the architecture** — that is how to predict the next common item.

### 5.3 China-specific or strongly emphasised

| Item                                                          | Why it stands out                                                                          |
|---------------------------------------------------------------|--------------------------------------------------------------------------------------------|
| Whole-scheme trip test with the actual breaker                | Verifies protection → trip auxiliary → breaker, including anti-pumping and phase agreement |
| Load test with phasor check                                   | Mandatory before formal energisation (DL/T 995 5.5.2.7)                                    |
| Secondary-loop drop, insulation, input level, close-coil drop | Field limits are numeric and directly executable                                           |
| Fixed maintenance intervals                                   | 6/4 years full, 2–4/1 years partial                                                        |
| Pilot channel testing                                         | Overlaps with North American end-to-end, but more equipment-level                          |
| Time keeping, optical power, cyber security (GB/T 7261-2026)  | New chapters driven by digitalisation and security                                         |

### 5.4 IEC-specific

- **Declared value plus variation** (60255-1 6.5.2.1/6.5.3) replaces a universal limit with a declaration and an influence-quantity table.
- **Test-point maps** in the function standards: impedance-plane maps (121), class-index tables (151), ramp rules (181) — a methodology for choosing points, not just a list.
- **Normative CT requirements** for differential protection (187-1 Annex C).

### 5.5 North America-specific

- **Scheme-based system testing** (C37.233 clause 5) organises requirements by line, transformer, busbar, breaker failure and generator, not by device model.
- **End-to-end trigger-delay compensation** (Annex E).
- **Acceptance/maintenance checklists by ANSI device number** (NETA 7.9), usable directly as a work order.
- **Setting-sheet comparison** as a mandatory step (NETA 7.9.2).
- **Post-energisation magnitude and phase check** of every input.

### 5.6 Three traps when reusing criteria

1. Treating an IEC declared value as a fixed limit (e.g. writing one manufacturer's  $\pm 2.5\%$  as "the 60255 requirement").
2. Writing "NETA  $\pm 5\%$ " when NETA says "manufacturer's tolerance".
3. Treating a GB/T 7261 method clause as a criterion (7261 defines notation and calculation, not limits).

### 5.7 Recommended item sets by stage

| Stage | Core items | Can be trimmed | Should not be done |
|-------|------------|----------------|--------------------|
|-------|------------|----------------|--------------------|

| Stage            | Core items                                                                                                                          | Can be trimmed                                | Should not be done                               |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|--------------------------------------------------|
| Commissioning    | Secondary insulation and drop, setting-by-setting verification, binary I/O, device functions, channel, whole-scheme trip, load test | Some climate/EMC items (covered by type test) | Destructive or extreme thermal tests             |
| Full periodic    | Insulation, settings, A/D, binary I/O, functions, whole scheme, channel                                                             | Load test when no load is available           | Type-test items                                  |
| Partial periodic | Settings, binary I/O, channel alarms, reports and self-check                                                                        | Whole scheme (rotate by interval)             | Dielectric strength unless moisture is suspected |
| Post-fault       | Trip report and record, settings and version, trip circuit, insulation if contaminated                                              | Whole scheme if wiring untouched              | Full retest                                      |

Use one record format across all four stages so that "commissioning baseline — periodic trend — post-fault comparison" is possible. The common failure is not too little testing but **incomparable data**: wiring, test set, environment and criterion source change every time, so history becomes an archive rather than a baseline.

## 6. Requirements on relay test sets

### 6.1 What a test set really is

A relay test set is four instruments in one: a programmable voltage/current source, a precision measurement unit and a timing controller. It must satisfy three constraints at once: the output must look like a fault (magnitude, phase, frequency, harmonics, DC offset, transient waveform); the measurement must be an order of magnitude better than the device under test; the timing must align with external events (GPS/IRIG-B/PTP, binary trigger).

### 6.2 The standards chain: product — calibration — verification

| Standard         | Nature                           | What it covers                                                                                      | Status                                                                                                                               |
|------------------|----------------------------------|-----------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|
| <b>DL/T 624</b>  | Product technical conditions     | Classification, technical requirements, test methods, acceptance, packaging, warranty               | <b>2023 edition</b> (issued 2023-05-26, effective 2023-11-26, replaces 2010); some platforms still list 2010 — recheck before tender |
| <b>DL/T 1153</b> | Calibration specification        | Metrological characteristics, conditions, items, methods, result expression, recalibration interval | <b>2025 edition</b> (issued 2025-12-18, effective 2026-06-18, replaces 2012); covers relay test sets                                 |
| <b>JJG 1112</b>  | National verification regulation | First verification, subsequent verification, in-service check                                       | <b>2015 edition</b> (effective 2015-07-10)                                                                                           |

The relationship: **624 is the manufacturer's product standard, 1153 is the user's calibration method, JJG 1112 is the legal verification procedure.** A purchase should obtain all three: type-test report (624), calibration certificate (1153), verification certificate (JJG 1112).

### 6.3 Performance requirements

| Parameter               | Typical requirement                                                                                                                                   | Source                        |
|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| AC current output       | ≥30 A per phase; portable sets ≥10 A per phase; $I_N = 1\text{ A}$ or 5 A                                                                             | DL/T 624-2023                 |
| Current amplitude error | $0.1I_N - I_{\max}$ : basic <b>±0.2%</b> , operating <b>±0.5%</b> ; $\leq 0.1I_N$ : $\pm 1\text{ mA}$ / $\pm 2.5\text{ mA}$                           | DL/T 624-2010 Table 3         |
| Amplitude-frequency     | 10–65 Hz: $\pm 0.001\text{ Hz}$ , $\leq 0.5\%$ ; 65–450 Hz: $\pm 0.01\text{ Hz}$ , $\leq 0.5\%$ ; 450–1000 Hz: $\pm 0.02\text{ Hz}$ , $\leq 1.0\%$    | DL/T 624-2023 extract         |
| DC component in output  | <b>≤0.5%</b> of current peak                                                                                                                          | DL/T 624-2023 extract         |
| THD                     | 1 A/5 A into $0.5\ \Omega$ $\leq 0.1\%$ ; reference $\leq 0.2\%$ , operating $\leq 0.5\%$                                                             | DL/T 624-2010 Table 6         |
| Time measurement        | 1 ms–9999.999 s; <1 s error $\leq \pm 1\text{ ms}$ ; resolution 0.1 ms                                                                                | DL/T 624 4.3.5.1; JJG 1112    |
| 4-hour stability        | Amplitude accuracy $\leq 0.1\%$ , amplitude change $\pm 0.1\%$ , frequency $\pm 0.002\text{ Hz}$ , phase $\pm 0.2^\circ$ , DC drift $\pm 2\text{ mA}$ | DL/T 624                      |
| DC output               | 0–300 V; zero drift $\leq \pm 5\text{ mV}$ ; $\leq 5\text{ V}$ error $\leq \pm 25\text{ mV}$                                                          | DL/T 624 extract              |
| Accuracy class          | <b>Class 0.1</b> : AC $\pm 0.1\%$ , DC $\pm 0.2\%$ ; <b>Class 0.2</b> : AC $\pm 0.2\%$ , DC $\pm 0.5\%$                                               | JJG 1112-2015; DL/T 1153-2025 |

| Parameter                  | Typical requirement                                                                                      | Source           |
|----------------------------|----------------------------------------------------------------------------------------------------------|------------------|
| Field instrument threshold | Setting tests: instrument class $\geq 0.5$ ; phase $\geq 1.0$ ; temperature error $\leq 1^\circ\text{C}$ | DL/T 995 5.2.1.1 |

#### Matching instrument to measurand (GB/T 7261-2016 4.3):

| Permitted error of the measurand | Instrument accuracy | Digital instrument |
|----------------------------------|---------------------|--------------------|
| <0.5%                            | Class 0.1           | 6½ digits          |
| 0.5%–1.5%                        | Class 0.2           | 5½ digits          |
| 1.5%–5%                          | Class 0.5           | 4½ digits          |
| $\geq 5\%$                       | Class 1.0           | 4½ digits          |

*Class 0.1/0.2 is a **calibration** grade. Class 0.5 is the **minimum field instrument** threshold in DL/T 995. They are different concepts; a "class 0.5 test set" cannot be advertised as "class 0.1 calibration".*

**Why THD and DC offset are called out separately.** Protection algorithms are sensitive to waveform quality. Harmonics shift the result of RMS and fundamental-based algorithms and therefore the operate value; DC offset in the output is read as fault transient and can start the relay incorrectly. If the test set itself has excessive THD or DC offset, the measured "relay error" is instrument error plus relay error, with no way to separate them. The same logic explains why type testing demands an instrument an order of magnitude better than the device, while field work accepts class 0.5: **the error budget must leave headroom.**

Amplitude-frequency flatness determines the ability to reproduce high-frequency components (5th harmonic, fault transients). A 1 ms timing error looks small, but against a 3 ms trip-command allowance it is one third of the budget.

## 6.4 Functional requirements

| Capability             | Requirement                                                                   | Test item supported                               |
|------------------------|-------------------------------------------------------------------------------|---------------------------------------------------|
| Steady-state output    | Multi-phase V/I, independent magnitude/phase/frequency, long-term stability   | Pickup, reset ratio, power/direction              |
| Harmonic superposition | 2nd–20th harmonic, independent magnitude/phase, DC superposition, THD display | Harmonic restraint, harmonic influence            |
| Transient output       | DC offset and decay time constant adjustable; waveform playback               | Transient overreach, CT saturation, CVT transient |
| State sequence         | Multiple states, evolving fault, controlled timing                            | Reclosing, backup transfer, state sequence        |
| COMTRADE playback      | IEEE C37.111, GPS/IRIG-B triggered                                            | Real-fault replay, end-to-end                     |
| Binary I/O             | Multiple inputs/outputs, event timing, debounce                               | Logic, whole scheme, trip/close timing            |
| Time sync              | GPS/IRIG-B/PTP; multi-unit synchronisation                                    | End-to-end, multi-terminal                        |
| Reporting              | Automatic report, traceable raw data                                          | Acceptance and archive                            |

## 6.5 Calibration versus verification

**Calibration (DL/T 1153) and verification (JJG 1112) are not the same.** Calibration produces results and uncertainty, usually without a pass/fail verdict; verification produces a legally recognised pass/fail against a

regulation. Both matter: the type-test report proves the design, the calibration certificate proves the current state, the verification certificate proves metrological compliance.

Check three things on a certificate:

1. **Does the class cover the use?** A class 0.2 set is enough for a class 0.5 field threshold; it may not be enough for reference measurement in type testing.
2. **Does the range cover the test point?** Certificates are valid only for calibrated ranges; low-current small-signal points are often missed.
3. **Validity and repair history.** An expired instrument must not be used for acceptance. After repair, drop or module replacement, recalibrate; do not reuse the old certificate.

Record the instrument and certificate numbers in the test report. Without them, you cannot prove that a compliant instrument was used — a technical issue and a liability issue.

## 6.6 Selection checklist

1. Does the output cover the device: high current for electromechanical relays; 30 A per phase is usually enough for numerical relays; six current channels for multi-ended differential.
2. Does accuracy match the criterion: class  $\geq 0.5$  in the field; class 0.1/0.2 for type testing per GB/T 7261 4.3.
3. Transient capability: DC offset, decay constant, COMTRADE playback.
4. Harmonic capability: 2nd–20th, independent magnitude and phase, DC superposition.
5. Timing and synchronisation: multi-unit sync, GPS/IRIG-B/PTP, binary trigger accuracy.
6. Metrological status: valid verification/calibration certificate, matching class and range.
7. Traceability: report contains raw data, test conditions and instrument ID.

## 7. Test methods and field practice

### 7.1 Steady-state testing

Slow application and sudden application are the two basic methods (GB/T 7261 6.5.2.2). Slow application finds the operate boundary; sudden application measures operate time. Essentials: zero the output before each test, repeat five times (6.5.2.2.1/6.6.3.3), record environment and wiring.

### 7.2 Transient testing

- **DC offset:** reproduce the decaying DC component of a fault current to check overcurrent and distance transient overreach.
- **CVT transient:** evaluate distance overreach against the characteristic map in 60255-121.
- **CT saturation:** verify that differential protection remains stable for an external fault with CT saturation, following 60255-187-1 Annex C/D and C37.233 Annex C.
- **Evolving fault:** use a state sequence to move from single-phase-to-ground to phase-to-phase and verify phase selection and acceleration.

CT saturation is difficult to test because the test set can only inject the secondary equivalent; it cannot reproduce primary DC offset and remanence. There are two practical routes: a CT model/saturation module, or COMTRADE replay of a recorded fault. The verdict is not simply "does not trip": check whether the differential current crosses the bias region and whether restraint grows along the slope. Testing only "no trip for an external fault" verifies half the characteristic.

### 7.3 State sequences and whole-scheme testing

A state sequence is controlled multi-state switching: pre-fault → fault → trip → reclose → permanent fault. The whole-scheme test (DL/T 995 5.3.7) adds the actual breaker and verifies anti-pumping, reclosing, phase agreement and close-coil drop ( $\geq 90\%$  rated).

### 7.4 End-to-end testing

Inject at two or more ends simultaneously and compare operating times and channel delay. Both triggers must be synchronised (GPS/IRIG-B/PTP), and the post-trigger delay must be compensated per C37.233 Annex E. A change in channel delay affects pilot protection dependability.

### 7.5 Uncertainty and the verdict

Three steps: (1) establish measurement uncertainty (test-set accuracy, wiring, environment); (2) identify the criterion source (fixed limit, declared value, manufacturer tolerance); (3) apply the decision rule (is uncertainty included?). IEC 60255-1 6.5.2.1 and GB/T 7261 require the test equipment uncertainty to be considered, so test-set error cannot be ignored in the result.

### 7.6 Safety and wiring

The high-risk part of relay testing is not the test set; it is the live equipment and trip circuits.

1. Isolate all trip links before testing; confirm breaker position and mechanical safety; confirm again before the whole-scheme test.

2. Never open a current circuit under load: short first, then disconnect. Never short a voltage circuit: isolate first, then connect.
3. Ground the CT secondary at one point; ground the test set; take supply from a dedicated maintenance source.
4. Use a work permit and a second person; mark adjacent live panels.
5. On completion: disconnect, verify, restore links, verify again, then check trip-circuit continuity.

A significant share of incidents come from **failure to restore**, not from the test itself. Put restoration on the work card and tick each step.

## 7.7 Reporting

A reproducible report contains nine items: nameplate and model; firmware/software version; setting-sheet number and version; test conditions (temperature, humidity, supply); instrument and certificate numbers; wiring diagram; raw data or waveforms; criterion source (standard clause); verdict, tester and date.

The value is not the word "pass" but **traceability**: six months later, the setting, instrument state and method must still be recoverable. Keep a report folder per device, with device ID and date in the filename, so that baseline comparison is possible.

## 8. Trends

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### 8.1 From device testing to system testing

C37.233-2023 organises tests by scheme; DL/T 995 emphasises whole-scheme and load tests. Both point the same way: **a compliant device does not make a compliant protection system**. Future test plans should be organised by fault scenario, not by device model.

### 8.2 Cyber security and time keeping become mandatory

GB/T 7261-2026 adds cyber-security tests, time-keeping performance and optical power. The test boundary is expanding from electrical behaviour to the device's information behaviour. A plan that covers only analogue quantities will have a gap once the new edition takes effect.

### 8.3 Test assets

Reports, raw waveforms, setting sheets and calibration certificates should form a traceable asset package. Historical reports for one device give a baseline; reports for one model across a fleet give batch insight. That is more valuable than "test and archive".

### 8.4 Five requirements on the next generation of test sets

1. **Higher fidelity:** controllable transient waveforms, DC offset and harmonic superposition.
2. **Stronger timing:** multi-unit sync, external trigger, sub-millisecond time stamps.
3. **Better metrology:** class 0.1 calibration, traceable certificates.
4. **More open interfaces:** COMTRADE, SCL and report data for automation and asset management.

## 9. Recommended VA-TEK instruments

### 9.1 How to read this chapter

This chapter recommends instruments from VA-TEK, the electrical testing brand of Shenzhen Feso Automation Technology Co., Ltd. (FESO). All figures are **datasheet values** from the current VA-TEK product documentation; they are not third-party measurements. Confirm the current datasheet, options and calibration certificate with VA-TEK before ordering.

The recommendation follows the test taxonomy in this whitepaper: a relay test set for function-level and device-level injection, plus a CT/PT analyser for the instrument-transformer checks that precede protection testing.

### 9.2 VAE-430 — three-phase protection relay test set

The VAE-430 is a portable three-phase set for commissioning, maintenance and scheme validation of electromechanical, static and numerical relays. Its high per-phase power is aimed at high-burden electromechanical relays, while  $\leq 0.2\%$  AC accuracy supports numerical relays and measuring-CT injection.

| Parameter          | VAE-430                                                                  |
|--------------------|--------------------------------------------------------------------------|
| Current output     | 3 × 0–40 A AC                                                            |
| Paralleled current | 1 × 0–120 A (900 VA)                                                     |
| Current power      | 3 × 420 VA at 40 A                                                       |
| Voltage output     | 4 × 0–120 V AC · 1 × 0–240 V                                             |
| DC output          | 3 × $\pm 10$ A · 3 × $\pm 160$ V                                         |
| Accuracy           | AC $\leq 0.2\%$ · DC $\leq 0.5\%$                                        |
| Binary I/O         | 8 inputs / 4 outputs                                                     |
| Operation          | Stand-alone with built-in controller and LCD; serial port for PC control |
| Weight             | 18 kg                                                                    |

**Typical fit:** distribution feeders and industrial systems; overcurrent, distance, frequency and three-phase differential schemes; high-burden electromechanical relays; measuring-CT injection. The four voltage channels and 120 A parallel current make it a practical single-box set for most substation secondary work.

### 9.3 VAE-660 — six-phase protection relay test set

The VAE-660 provides six current and six voltage channels with an embedded controller. It is intended for schemes where two sets of currents must be energised and synchronised — transformer, generator, busbar and line differential — or where three-phase current and three-phase voltage are needed simultaneously.

| Parameter          | VAE-660                                          |
|--------------------|--------------------------------------------------|
| Current output     | 6 × 0–30 A AC (1 mA resolution)                  |
| Paralleled current | 3 × 0–60 A (450 VA each) · 1 × 0–180 A (1000 VA) |
| Current power      | 6 × 300 VA at 30 A                               |
| Voltage output     | 6 × 0–120 V AC · 3 × 0–240 V                     |

| Parameter       | VAE-660                                                           |
|-----------------|-------------------------------------------------------------------|
| DC output       | $6 \times \pm 10 \text{ A} \cdot 6 \times \pm 160 \text{ V}$      |
| Phase control   | $\pm 360^\circ$                                                   |
| Frequency range | 0–1000 Hz                                                         |
| Accuracy        | AC $\leq 0.2\%$ · DC $\leq 0.5\%$                                 |
| Operation       | Stand-alone embedded controller; USB and serial for PC automation |
| Weight          | 21 kg                                                             |

**Typical fit:** transformer, generator and busbar differential; line differential requiring two-end injection; distance and auto-reclosing schemes; test benches and training laboratories. Six independent current channels remove the "two-pass" approach to differential testing and reduce wiring changes on site.

## 9.4 VACTP200P — CT/PT analyser

Protection testing starts before the relay: ratio, polarity, excitation and burden determine whether the relay sees the primary fault correctly. The VACTP200P is an all-in-one instrument-transformer analyser for protection CTs, measuring CTs, TP-class CTs and inductive PTs.

| Parameter            | VACTP200P                                                      |
|----------------------|----------------------------------------------------------------|
| CT ratio             | 1–30,000 · $\pm 0.05\%$                                        |
| PT ratio             | 1–10,000 · $\pm 0.05\%$                                        |
| Knee-point voltage   | up to 40 kV (low-frequency excitation)                         |
| Output               | 0–180 V / 0–12 A                                               |
| Phase accuracy       | $\pm 2 \text{ min}$                                            |
| Secondary resistance | 0–300 $\Omega$ · 0.1% $\pm 1 \text{ m}\Omega$                  |
| Burden               | 0–300 VA · 0.1% $\pm 0.1 \text{ VA}$                           |
| Standards            | IEC 61869-2/-3 (incl. IEC 60044-1/-2/-6) · IEEE/ANSI C57.13    |
| Operation            | 5.7" LCD, rotary control, local or PC remote, on-board printer |
| Weight               | 9 kg                                                           |

**Typical fit:** pre-commissioning CT/PT verification; knee-point and error-curve derivation for high-knee-point protection CTs; ratio and polarity checks before secondary injection; burden measurement against the relay's rated burden. Testing the CT first prevents a relay "failure" that is actually a wiring or CT problem.

## 9.5 Selection guide

| Need                                                       | Recommended instrument | Reason                                                                         |
|------------------------------------------------------------|------------------------|--------------------------------------------------------------------------------|
| Feeder, motor, capacitor, three-phase overcurrent/distance | VAE-430                | Three currents + four voltages; 120 A parallel; high per-phase VA              |
| Transformer, generator, busbar or line differential        | VAE-660                | Six independent currents + six voltages; $\pm 360^\circ$ phase; 180 A parallel |
| CT/PT ratio, polarity, excitation, burden                  | VACTP200P              | 40 kV knee point without an external HV source; 0.05% ratio                    |

| Need                                          | Recommended instrument  | Reason                                           |
|-----------------------------------------------|-------------------------|--------------------------------------------------|
| Both instrument-transformer and relay testing | VACTP200P + VAE-430/660 | Complete secondary test workflow from CT to trip |

## 9.6 Scope and honest limits

Other limits to confirm against the current datasheet: COMTRADE playback, state-sequence depth, harmonic order, multi-unit synchronisation and the exact binary I/O configuration. These capabilities vary by model, firmware and option; they should be verified for the specific project rather than assumed from this whitepaper.

## 9.7 Before you order

1. Send the relay models and schemes to be covered — overcurrent, distance, transformer differential, busbar, generator.
2. State the required accuracy and the criterion source (setting sheet, IEC declared value, NETA tolerance).
3. Ask for the datasheet, calibration certificate and lead time for the exact configuration.
4. Plan the verification/calibration interval with your metrology team before the first site use.

## Appendix A — Standards cited

| Standard                                    | Edition                                  | Use                                         |
|---------------------------------------------|------------------------------------------|---------------------------------------------|
| GB/T 7261                                   | 2016 (2026 edition effective 2027-02-01) | Basic test methods                          |
| DL/T 995                                    | 2016 (replacement in development)        | Field test regulation                       |
| GB/T 14285                                  | 2023                                     | Technical code (configuration)              |
| GB/T 50976                                  | 2014                                     | Installation and acceptance                 |
| GB/T 14598.2                                | 2025                                     | Generic requirements (IDT IEC 60255-1:2022) |
| IEC 60255-1                                 | 2022 Ed.2                                | Generic requirements                        |
| IEC 60255-151 / -121 / -127 / -181 / -187-1 | 2009 / 2014 / 2010 / 2019 / 2021         | Function-specific requirements              |
| IEC 60255-26 / -27                          | 2023                                     | EMC / safety                                |
| IEEE C37.233                                | 2023                                     | Protection system testing guide             |
| IEEE C37.90.1 / .2 / .3                     | 2024 / 2024 / 2023                       | EMC and surge withstand                     |
| NETA ATS / MTS                              | 2025 / 2023                              | Acceptance / maintenance testing            |
| DL/T 624                                    | 2023                                     | Relay test set technical conditions         |
| DL/T 1153                                   | 2025                                     | Test set calibration specification          |
| JJG 1112                                    | 2015                                     | Test set verification regulation            |

## Appendix B — Unverified items and clause conflicts

1. **IEC 60255-1:2022 clause structure conflict.** One source (a GOST translation of the same text) places tests in Clause 7 (7.1 reference conditions, 7.2 overview, 7.3 load measurement); another (a laboratory interpretation) places test items in Clause 6 (6.10 power, 6.12 insulation/climate, 6.13 mechanical, 6.15 EMC) and 7.3 under family testing. Only 6.5.2.1 is retained here with full-text support; other items are cited by name.
2. **60255-1 table numbering.** Table 10 (reference conditions) and Tables 11/12 are both cited in secondary sources; check the original.
3. **60255-121.** The 302-page text was not obtained; clause numbers, test-point maps and CVT/load-encroachment criteria are unverified.
4. **60255-151.** Harmonic-influence and setting-range clauses and limits were not obtained; the 40/50/55 ms fallback values come from product manuals.
5. **60255-181.** The  $df/dt$  clause number and reset-hysteresis clause are unverified;  $\pm 10$  mHz/0.01% are typical declared values.
6. **60255-187-1.** The unrestrained-differential clause is unverified.
7. **60255-26:2023.** Level values in the normative tables are unverified; EMC levels quoted in this whitepaper come from manufacturer manuals.
8. **C37.233-2023.** The full official TOC and clause numbering were not obtained (the framework comes from a sales-site extract); reclosing/SPS sections and the time-synchronisation chapter are unverified.
9. **C37.90.1/.2-2024.** Current-edition levels and clause numbers are unverified; the 2.5 kV/4 kV and 35 V/m values are from earlier editions.
10. **C37.90.3-2023.** The levels actually adopted and clause numbers are unverified.
11. **NETA.** ATS-2025 full text was not obtained (7.9 content is based on ATS-1999 extracts and engineering texts citing ATS); whether MTS-2023 retains the 1/12/12-year maintenance bands is unverified.
12. **DL/T 624-2023.** Clause numbers were not obtained; phase accuracy, synchronisation and insulation/EMC criteria are unverified; platform edition labels conflict.
13. **DL/T 1153-2025.** The recalibration interval and the class 0.1/0.2 tolerance tables are unverified.
14. **JIG 1112-2015.** THD limits, minimum insulation resistance and response-time limits are unverified; the  $\pm(0.1\% + 0.01 \text{ ms})$  timing figure comes from an interpretation source.
15. **DL/T 995-2016 5.2.1.1.** Content is supported by several secondary sources but was not checked word for word against the original.
16. **GB/T 50976-2014.** Clause values and numbers are unverified (catalogue-level information only).
17. **GB/T 14285-2023.** Clause numbers for most configuration items are unverified.

## Appendix C — Glossary

| Term                 | Meaning                                                                          |
|----------------------|----------------------------------------------------------------------------------|
| Pickup / reset value | Input at which the relay starts to operate / starts to reset                     |
| Reset ratio          | Reset value divided by pickup value                                              |
| Class index          | Graded representation of inverse-time timing accuracy                            |
| Transient overreach  | Operation beyond the setting boundary during a fault transient                   |
| Whole-scheme test    | Trip test from protection device through to the breaker                          |
| Load test            | Phasor, differential-current and direction check using actual load               |
| End-to-end test      | Simultaneous injection at two or more ends to verify the pilot scheme            |
| PIXIT                | Protocol Implementation eXtra Information for Testing                            |
| SWC                  | Surge withstand capability (damped oscillatory)                                  |
| EFT                  | Electrical fast transient/burst                                                  |
| Variation            | Error change caused by an influence quantity departing from reference conditions |

## About FESO and VA-TEK

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**Shenzhen Feso Automation Technology Co., Ltd. (FESO)** is an electrical test equipment company headquartered in Shenzhen, China. Under the **VA-TEK** brand it supplies relay protection test sets, CT/PT analysers and high-voltage test instruments to utilities, commissioning contractors, laboratories and training institutions. Instruments are produced with specialised manufacturing partners and integrated, verified and finally inspected by FESO in Shenzhen. **VA-TEK** is the electrical testing brand, served through an engineer-led sales and support network.

Product families include relay protection test sets (VAE-430, VAE-660), the VACTP200P CT/PT analyser, VLF hipot testers, transformer diagnostic instruments and related secondary test equipment.

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