

Trust In **Grid**

TECHNICAL WHITE PAPER · FIELD ENGINEERING KIT

OLTC Direction **Safety** **Pack**

Preventing Reversed Tap-Changer Handle Failures in Weak-
Grid Projects

Contract Clauses · FAT/SAT Checklists · Field Correction

Procedures

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A — Executive Summary

On-load tap-changers (OLTCs) account for **over 40% of all transformer failures** according to CIGRÉ and IEEE data. One of the most underreported root causes is a semantic mismatch between the **mechanical handle direction** and the **system voltage regulation logic**.

Three Key Findings

① IEC Does Not Mandate Direction

Neither IEC 60214 nor IEC 60076 defines "clockwise = raise output voltage." This must be explicitly specified in procurement documents.

② Standard FAT Never Tests Direction

Conventional FAT verifies turns ratio, winding resistance, polarity, and vector group—but never whether clockwise handle rotation actually raises the secondary voltage under load.

③ The Failure Cascade Is Predictable

Voltage sag → operator turns handle the "wrong" way → secondary voltage collapses further → panic re-operation → arcing → contact welding → Buchholz trip → total outage.

What This Pack Contains

Section	Content	Use Case
B	Contract Clauses (6 items)	Copy into RFQ / Technical Annex
C	FAT Procedure (MTD-01/02/03)	Add to factory test protocol
D	SAT Verification Form	Site acceptance testing
E	10-Minute On-Site Check Card	Laminate & attach to transformer
F	Post-Failure Recovery Flow	DGA thresholds & repair steps
G	Multi-Language Label Templates	Send to nameplate supplier
H	Site-Wide Audit Table	Multi-unit emergency audit

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B — Contract Clauses (Copy-Paste Ready)

Insert the following clauses into your RFQ technical annex, purchase contract, or specification document. These clauses are designed to survive legal review and translate into enforceable supplier obligations.

Clause 1 — Tap Direction Definition

"Clockwise rotation of the manual operating handle shall correspond to raising the secondary voltage under constant primary voltage conditions (i.e., decreasing HV turns). This direction shall be clearly marked on the nameplate, gearbox cover, and AVC HMI interface.

This definition shall apply regardless of internal OLTC design, cam orientation, or manufacturer's standard practice. Any deviation must be explicitly approved in writing by the Purchaser prior to FAT."

Clause 2 — Dual Labeling Requirement

"The Supplier shall provide direction markings in three locations:

- (a) Main nameplate: 'CW = RAISE LV' with directional arrow
- (b) Gearbox cover: engraved or etched arrow + text
- (c) AVC / HMI interface: on-screen indicator matching handle direction

All labels shall be provided in English plus the following local language(s): _____. Labels shall be permanently affixed using engraving, etching, or industrial-grade adhesive rated for the operating environment (UV, salt mist, temperature)."

Clause 3 — FAT Add-Item: Manual Direction Verification

"The FAT procedure shall include test item MTD-01: Manual Tap Direction Verification.

- (a) Apply 100% Un to HV side
- (b) Record secondary voltage at neutral tap
- (c) Rotate handle clockwise one step
- (d) Measure new secondary voltage

PASS CRITERIA: Secondary voltage must increase by the designed tap step (1.25%–2.5%).

FAIL CRITERIA: Secondary voltage decreases, or any ambiguity in direction.

Test shall be video-recorded. Video file shall be included in the FAT documentation package delivered to the Purchaser."

Clause 4 — AVC ↔ Manual Consistency

"The AVC 'Raise' command shall produce the same physical rotation as clockwise manual handle operation. The AVC 'Lower' command shall match counterclockwise manual rotation.

This consistency shall be verified during SAT. A written declaration from the AVC supplier confirming parameter settings shall be provided.

In the event of AVC failure or communication loss, the manual handle direction shall remain correct and clearly labeled."

Clause 5 — OLTC Replacement Documentation

"When supplying a replacement OLTC (whether same brand or different manufacturer), the Supplier shall deliver:

- (a) Drive Angle Drawing (showing 0° reference and rotation direction)
- (b) Keyway Orientation Diagram (preventing 180° misalignment)
- (c) Cam Phase Chart (cam dwell angles vs. tap position)
- (d) Installation Angle Declaration (signed by manufacturer)
- (e) Pre-shipment Direction Verification Video

Failure to provide any of the above shall be grounds for rejection of the replacement unit."

Clause 6 — Video Evidence Requirement

"The Supplier shall provide a video record of the following FAT tests:

- (a) MTD-01: Manual Direction Verification (full procedure)
- (b) MTD-02: AVC ↔ Manual Consistency
- (c) MTD-03: Multi-Step Direction Stability

Each video shall include:

- Visibility of the handle/display
- Multimeter or instrument reading of secondary voltage
- Verbal narration stating the test step and result
- Timestamp

Videos shall be delivered in MP4 format, minimum 1080p resolution."



Tip: These six clauses create a contractual "force field" around the direction problem. The supplier cannot claim "this is our standard" or "nobody asked for that." Every clause is specific, measurable, and enforceable.

C — FAT Procedure: Manual Tap Direction Tests

These three test items (MTD-01, MTD-02, MTD-03) should be inserted into the standard FAT protocol. They are designed to be executed with minimal additional equipment—just a voltmeter and a video camera.

MTD-01: Manual Direction Verification

Step	Action	Expected Result
1	De-energize transformer	Safe to work
2	Move tap to neutral (N)	Mechanical indicator at N
3	Apply 100% Un to HV side	HV voltage within $\pm 1\%$
4	Record secondary voltage (U_{2_0})	Document baseline
5	Rotate handle clockwise 1 step	Smooth operation, no binding
6	Record new secondary voltage (U_{2_1})	$U_{2_1} > U_{2_0}$ by tap step
7	Return to neutral	U_2 returns to U_{2_0}
8	Rotate handle counterclockwise 1 step	Smooth operation
9	Record secondary voltage ($U_{2_{-1}}$)	$U_{2_{-1}} < U_{2_0}$ by tap step

MTD-02: AVC ↔ Manual Consistency

Step	Action	Pass Criteria
1	Send AVC "Raise Tap" command	Motor rotates clockwise (same as CW handle)
2	Send AVC "Lower Tap" command	Motor rotates counterclockwise
3	Switch to manual mode	Handle direction still CW = Raise
4	Video record full sequence	Clear audio narration + visible meter

MTD-03: Multi-Step Direction Stability

Step	Action	Pass Criteria
1	From neutral, step +3 taps clockwise	Each step: monotonic voltage increase

2	Return to neutral	Voltage returns to baseline
3	Step -3 taps counterclockwise	Each step: monotonic voltage decrease
4	Check for sticking or jumping	Smooth operation throughout

FAILURE HANDLING: If any MTD test fails, the transformer shall NOT be shipped until the root cause is identified and corrected. The Purchaser must be notified within 24 hours of any failure. A corrective action report shall be submitted before re-testing.

D — SAT Verification Form (Fillable)

Print this page and complete during Site Acceptance Test. Keep one copy on file and one attached to the transformer O&M manual.

Project Information

Project Name: _____

Transformer ID: _____ Serial No.: _____

Site Location: _____

Test Date: _____ Tested By: _____

Ambient Temp: _____ Weather: _____

Test 1: Manual Direction Verification

Item	Measurement	Pass / Fail
U2 at neutral (baseline)	_____ V	☐ Pass ☐ Fail
U2 after CW 1 step	_____ V	☐ Pass ☐ Fail
Voltage change	_____ V (expected: +1.25% to +2.5%)	☐ Pass ☐ Fail
U2 after CCW 1 step	_____ V	☐ Pass ☐ Fail
Smooth operation (no sticking)	N/A	☐ Pass ☐ Fail

Test 2: AVC ↔ Manual Consistency

Item	Observation	Pass / Fail
AVC "Raise" → motor direction	☐ CW ☐ CCW	☐ Pass ☐ Fail
AVC "Lower" → motor direction	☐ CW ☐ CCW	☐ Pass ☐ Fail
Manual CW = AVC Raise?	☐ Yes ☐ No	☐ Pass ☐ Fail

Test 3: Label Verification

Location	Label Present?	Direction Correct?	Language OK?
Main nameplate	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
Gearbox cover	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
AVC / HMI	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No

Sign-Off

Site Engineer: _____Purchaser Rep: _____

Signature: _____Signature: _____

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E — 10-Minute On-Site Check Card

Instructions: Print this page. Laminate it. Attach to the transformer cabinet door or gearbox cover. Use before first energization and after any OLTC maintenance.

 OLTC DIRECTION VERIFICATION CARD

Before You Begin

- ☐ Transformer de-energized and locked out (LOTO)
- ☐ HV side disconnected and tagged
- ☐ Multimeter / voltmeter available and calibrated
- ☐ Two qualified personnel present

Step-by-Step Procedure

Step	Action	Expected Result	✓ / ✗
1	Move tap to neutral (N)	Indicator at N	
2	Apply 100% Un to HV	HV = rated voltage ±1%	
3	Record U2 at neutral	Write value: _____V	
4	Turn handle CLOCKWISE 1 step	Smooth, no binding	
5	Measure U2	U2 INCREASED?	
6	Return to neutral	U2 back to baseline	
7	Turn handle CCW 1 step	Smooth, no binding	
8	Measure U2	U2 DECREASED?	

Decision

 **PASS**

CW = Voltage ↑

CCW = Voltage ↓

Tag: "DIRECTION VERIFIED – CW = RAISE LV"

 **FAIL**

CW = Voltage ↓

CCW = Voltage ↑

Tag: "REVERSED – DO NOT OPERATE LIVE"

Emergency Contacts

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F — Post-Failure Recovery & DGA Thresholds

If the OLTC has already been operated with reversed direction under load, follow this structured recovery procedure. Do NOT attempt re-energization until all steps are complete.

DGA Threshold Table

Gas	Normal	Warning	Critical	Action
Acetylene (C ₂ H ₂)	< 1 ppm	1–10 ppm	> 10 ppm	>10: Do NOT re-energize
Hydrogen (H ₂)	< 100 ppm	100–500 ppm	> 500 ppm	>500: Investigate
Methane (CH ₄)	< 40 ppm	40–120 ppm	> 120 ppm	Thermal fault indicator
Ethylene (C ₂ H ₄)	< 20 ppm	20–80 ppm	> 80 ppm	High temp fault
Ethane (C ₂ H ₆)	< 15 ppm	15–60 ppm	> 60 ppm	Monitor trend
CO	< 300 ppm	300–800 ppm	> 800 ppm	Insulation degradation

Recovery Procedure

Phase 1 — Immediate Response

- ☐ Full shutdown, LOTO applied
- ☐ Take DGA oil sample from OLTC compartment BEFORE any work
- ☐ Check Buchholz relay gas collection volume
- ☐ Photograph all gauge readings and indicator positions

Phase 2 — Physical Inspection

- ☐ Remove diverter switch / vacuum interrupter assembly
- ☐ Inspect contacts: welding, pitting, carbon deposits
- ☐ Measure transition resistors (replace if > ±10% deviation)
- ☐ Check operating counter reading
- ☐ Verify torque values against manufacturer specs

Phase 3 — Oil Treatment

- ☐ Offline oil filtration ($\leq 1 \mu\text{m}$ filter)
- ☐ Vacuum dehydration (≤ 10 ppm moisture)
- ☐ Re-sample DGA after treatment
- ☐ If C_2H_2 still $> 5\text{ppm}$ → replace with new IEC 60296 oil
- ☐ NEVER mix OLTC compartment oil with main tank oil

Phase 4 — Reassembly & Verification

- ☐ Install new diverter switch if required
- ☐ Recalibrate drive mechanism torque
- ☐ Reset operation counter to zero
- ☐ Full SAT: turns ratio, transition waveform, direction verification
- ☐ AVC ↔ manual consistency test
- ☐ 24-hour no-load observation before full load

G — Multi-Language Label Templates

Send this page to your nameplate supplier or engraving vendor. All labels should be permanently affixed using engraving, etching, or industrial adhesive.

Language	"Raise LV" (Clockwise)	"Lower LV" (Counter-CW)	Direction Arrow
English	RAISE LV	LOWER LV	↑ / ↓
Spanish	SUBIR BT	BAJAR BT	↑ / ↓
French	MONTER BT	DESCENDRE BT	↑ / ↓
Portuguese	AUMENTAR BT	DIMINUIR BT	↑ / ↓
Swahili	PANDISHA LV	SHUSHA LV	↑ / ↓
Arabic	رفع الجهد المنخفض	خفض الجهد المنخفض	↑ / ↓
Chinese	升压	降压	↑ / ↓
Russian	ПОВЫСИТЬ НН	ПОНИЗИТЬ НН	↑ / ↓

Label Specifications

- **Material:** Stainless steel engraving / anodized aluminum / industrial polymer
- **Minimum size:** 40mm × 20mm for gearbox; 80mm × 40mm for nameplate
- **Font:** Arial Bold or equivalent, minimum 12pt
- **Color:** White text on dark background (gearbox); matching nameplate scheme
- **Adhesive:** Rated for -40°C to +120°C, UV-resistant, salt-mist resistant (C5-M)
- **Attachment:** Rivets or screws preferred over adhesive for high-vibration environments

H — Site-Wide Audit Table

For sites with multiple transformers. Complete within 24 hours of detecting a direction issue on any unit.

Transformer ID	Nameplate Direction	Gearbox Marking	AVC Logic	Actual Measurement	Status	Corrective Action
TR-01						
TR-02						
TR-03						

TR-04						
TR-05						
TR-06						
TR-07						
TR-08						

Audit Actions

☐ Suspend all manual OLTC operations site-wide

☐ Energize AVC or install temporary voltage stabilizer

☐ Complete audit table for all transformers

☐ Issue formal Site Directive with correction plan

☐ Train all operators in local language

☐ Update O&M manuals and site procedures

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Contact Trust In Grid

Need help with OLTC direction verification, transformer specification,
or a custom FAT procedure for your project?

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