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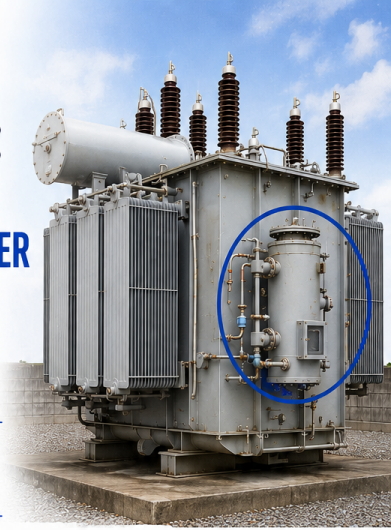
OLTC RELIABILITY:
WHY MOISTURE AND CARBON PARTICLES MATTER



The On-Load Tap Changer (OLTC) is one of the most failure-prone components in a transformer. Most major transformer outages can be traced back to problems that start inside the OLTC compartment.

ONE MAJOR TRANSFORMER OUTAGE CAN OFTEN BE TRACED BACK TO A FAILURE MECHANISM THAT STARTED YEARS EARLIER INSIDE THE OLTC COMPARTMENT.

INDUSTRY FINDINGS

Studies from CIGRÉ, utilities, and transformer manufacturers consistently identify the OLTC as a major contributor to transformer failures.

TRANSFORMER COMPONENT	TYPICAL FAILURE CONTRIBUTION
OLTC	**25 – 40%**
Main Insulation	**20 – 35%**
Bushings	**10 – 20%**
Cooling System	**5 – 15%**
Other Components	**Balance**

OLTCs are widely recognized as one of the most failure-prone components, accounting for approximately 25 – 40% of transformer failures in many industry surveys.

WHY OLTCs FAIL

- Electrical arcing during switching operations
- Carbon particles generation and accumulation
- Moisture contamination from various sources
- Oxidation products and acidity increase
- Contact wear and material degradation
- Reduced dielectric strength and insulation stress

TRANSFORMER (OLTC COMPARTMENT) → SWITCHING ARCING → MOISTURE + CARBON PARTICLES → INSULATION STRESS → INCREASED FAILURE RISK

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OLTC RELIABILITY:
MOISTURE AND CARBON PARTICLES – THE HIDDEN ENEMIES

Inside the OLTC compartment, moisture and carbon particles are continuously generated and accumulated due to switching operations, arcing and aging of oil and components. These contaminants work together to accelerate insulation degradation and increase the probability of OLTC failures.

Every tap operation can generate arcing, creating moisture and carbon particles that deteriorate oil and insulation.

MOISTURE EFFECTS IN OLTC

Moisture, even in small quantities, has a significant impact on OLTC performance and insulation life.

Reduced dielectric strength
Moisture lowers the oil's ability to withstand electrical stress, increasing the risk of flashover.

Increased flashover risk
Moisture facilitates the formation of conductive paths between contacts and across insulation.

Accelerated insulation aging
Moisture speeds up cellulose degradation, reducing the life of paper insulation.

Increased contact corrosion
Moisture promotes corrosion of contacts, joints and metallic components.

Higher probability of switching failures
Moisture and its by-products reduce the reliability of switching operations.

CARBON PARTICLES EFFECTS IN OLTC

Carbon particles are generated primarily due to arcing, contact wear and oil degradation.

Flashover initiation
Carbon particles can bridge the gap between contacts, causing tracking and flashovers.

Insulation contamination
Deposited carbon particles reduce surface insulation and increase leakage current.

Reduced dielectric withstand
Fine carbon particles create weak points in oil and insulation barriers.

Filter clogging and oil flow restriction
High particle load can block filters and affect oil circulation in OLTC.

Formation of sludge and deposits
Combining with oil oxidation products, particles form sludge that damages components.

CONSEQUENCES OF MOISTURE AND CARBON PARTICLE CONTAMINATION

CONTAMINATION	IMPACT	RESULT
MOISTURE	Reduces dielectric strength and insulation capability	→ Flashover, partial discharge, failures
CARBON PARTICLES	Contaminates insulation and oil	→ Tracking, arcing, burn-through
ACIDS & OXIDATION PRODUCTS	Increases oil acidity and sludge formation	→ Corrosion, contact wear, insulation aging
COMBINED EFFECT	Accelerates degradation of oil and insulation	→ Reduced OLTC life, higher failure risk

TECHNICAL INSIGHT

Unlike the main transformer tank, the OLTC compartment is subjected to:

- Repetitive switching arcing
- Higher local temperatures
- Oxidation reactions
- Moisture ingress
- Carbon particles generation

Therefore, contamination generation is continuous, and its effects are amplified.

MOISTURE AND CARBON PARTICLES ARE NOT INDEPENDENT PROBLEMS.
TOGETHER THEY ACCELERATE INSULATION DEGRADATION AND INCREASE OLTC FAILURE PROBABILITY.

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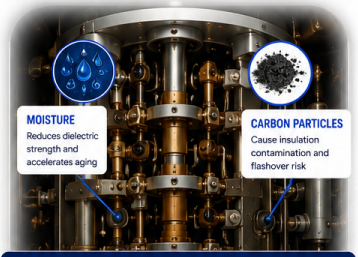
OLTC RELIABILITY: THE COST OF WAITING FOR FAILURE

Ignoring moisture and carbon particles in the OLTC compartment is not just a maintenance issue—it is a financial and reliability risk.



A small amount of moisture and carbon particles today can lead to a major failure tomorrow.

DIRECT COSTS OF OLTC FAILURES

EVENT	TYPICAL COST (USD)
Emergency Repair / Troubleshooting	$20,000 – $150,000
OLTC Overhaul	$50,000 – $500,000
Replacement OLTC	$100,000 – $1,000,000
Transformer Replacement	Millions
Unplanned Outage Duration	Hours to Weeks

INDIRECT COSTS (OFTEN HIGHER THAN DIRECT COSTS)

- Production losses
- Outage penalties
- Contractual penalties
- Loss of revenue
- Reputation and customer impact
- Emergency mobilization
- Increased insurance cost
- Grid reliability impact

AVOIDING JUST ONE MAJOR OLTC FAILURE CAN SAVE HUNDREDS OF THOUSANDS OF DOLLARS.

Proactive moisture and carbon particles management is one of the highest ROI investments for transformer assets.

WHAT OLTC FAILURE CAN CAUSE

Failures do not happen suddenly.
They are the result of slow degradation driven by moisture, carbon particles and oil aging.

REAL-WORLD EXAMPLE

A utility transformer (230 kV, 150 MVA) experienced an OLTC flashover due to moisture and carbon particle contamination.

OLTC Overhaul Cost	$220,000
Unplanned Outage Cost	$180,000
Production Loss	$350,000
Total Impact	**$750,000+**

Estimated cost of continuous moisture and carbon particles removal system over 5 years **<$60,000**

THE IMPACT ON ASSET LIFE

POOR CONTAMINATION CONTROL	EFFECTIVE CONTAMINATION CONTROL
Moisture ingress continues	Moisture kept at low levels
Carbon particles accumulate	Carbon particles continuously removed
Flashover & contact wear increases	Lower flashover risk & cleaner contacts
Frequent failures & high maintenance cost	Fewer failures & lower maintenance cost
Shorter OLTC life and reduced reliability	Extended OLTC life and higher reliability

KEY TAKEAWAY

The true cost of OLTC failures is not just the repair cost—it is the impact on reliability, operations, and business.

CONTINUOUS MOISTURE AND CARBON PARTICLES MANAGEMENT IS THE SMARTEST INVESTMENT TO PROTECT YOUR ASSETS AND YOUR BOTTOM LINE.

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OLTC RELIABILITY:

FROM PERIODIC MAINTENANCE TO CONTINUOUS ASSET MANAGEMENT

Contamination in the OLTC compartment is continuously generated due to switching operations, arcing, oil oxidation and moisture ingress. Therefore, a continuously generated problem requires a continuously operating solution.

Monitoring tells you a problem exists. **Continuous treatment helps prevent the problem from growing.**

WHY PERIODIC FILTRATION IS NOT ENOUGH

PERIODIC FILTRATION (Traditional Approach)

- Contamination builds up
- Periodic oil filtration
- Temporary improvement
- Contamination returns
- Cycle repeats – risk remains high

Gap between filtration intervals allows contamination and risk to grow again.

CONTINUOUS TREATMENT (Modern Approach)

- Contamination generated continuously
- Continuous online treatment
- Contamination removed continuously
- Stable oil quality and lower risk
- Extended OLTC life & higher reliability

Continuous protection leads to long-term reliability and significant cost savings.

KEY BENEFITS OF CONTINUOUS OLTC TREATMENT

LOWER MOISTURE LEVELS
Maintains low moisture content for stronger insulation life

REDUCED CARBON PARTICLES
Removes carbon particles and sludge precursors

IMPROVED SWITCHING RELIABILITY
Cleaner oil & contacts lead to smooth tap operations

EXTENDED OIL LIFE
Reduces oxidation products, acidity and oil degradation

LOWER MAINTENANCE COSTS
Fewer interventions, overhauls and emergency repairs

HIGHER ASSET AVAILABILITY
Minimizes unplanned outages and downtime

BETTER RETURN ON INVESTMENT
Avoiding one major OLTC failure can justify the system for years

DRYTRANS TRTC – ONLINE CONTINUOUS MOISTURE & CARBON PARTICLES REMOVAL SYSTEM

TRTC SYSTEM – INTERNAL VIEW

TRTC SYSTEM – FRONT VIEW

Designed for continuous online removal of moisture and carbon particles from OLTC oil while the transformer remains energized.

- 24/7 CONTINUOUS OPERATION
- ONLINE & NON-INVASIVE INSTALLATION
- EFFICIENT MOISTURE REMOVAL
- EFFECTIVE CARBON PARTICLE REMOVAL

SYSTEM REMOVES

MOISTURE

- Dissolved moisture
- Free water traces
- Moisture migrating through insulation system
- Moisture from breather and oil oxidation

CARBON PARTICLES

- Carbon particles from arcing and switching
- Contact wear particles
- Oxidation by-products
- Sludge precursors
- Insulation debris

TYPICAL APPLICATIONS

- Power Transformers (All Ratings)
- Generator Step-Up Transformers
- Industrial Transformers
- Wind, Solar & Renewables
- Utilities & Power Plants
- Critical Infrastructure

TRUSTED BY INDUSTRY LEADERS WORLDWIDE

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Continuous oil conditioning is a key driver for transformer reliability, operational safety and life extension.

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OLTC RELIABILITY – KEY MANAGEMENT TAKEAWAYS

EXECUTIVE SUMMARY

Moisture and carbon particles are among the most significant contributors to OLTC deterioration and reliability loss.

- Early intervention
- Continuous contamination control
- Risk-based maintenance planning
- Condition-based asset management
- Long-term lifecycle cost optimization

RECOMMENDED DEPLOYMENT PRIORITY

01 Oldest transformers (> 20 years)

02 High operation-count OLTCs

03 Generator step-up transformers

04 Industrial process transformers

05 Critical utility transformers

06 Strategic infrastructure assets

ASSET MANAGEMENT PHILOSOPHY

TRADITIONAL PHILOSOPHY

Repair after failure → Investigate root cause → Replace damaged components → Repeat cycle

MODERN PHILOSOPHY

Monitor continuously → Manage continuously → Protect continuously → Extend asset life & reduce cost

TYPICAL CRITICAL INFRASTRUCTURE

Hospitals | Data Centres | Airports

Industrial Plants | Power Stations | Water Treatment Facilities

THE OBJECTIVE IS NOT CLEANER OIL

The objective is:

- Improved OLTC reliability
- Reduced maintenance costs
- Reduced outage risk
- Improved transformer availability
- Extended oil life
- Longer transformer service life

REFERENCES

- CIGRÉ Working Group Reports on Transformer Reliability
- CIGRÉ Technical Brochures on OLTC Condition Assessment
- IEEE C57 Transformer Reliability Studies
- IEC 60214 OLTC Standards
- Transformer Reliability and Failure Statistics Publications
- Hitachi Energy (ABB) OLTC Technical Publications
- MR Reinhausen OLTC Technical Papers
- Weidmann Transformer Insulation Publications
- Qualitrol Transformer Monitoring Publications

CLOSING STATEMENT

The goal of an OLTC moisture and carbon particle management system is not simply cleaner oil.

The goal is improved reliability, lower lifecycle cost, and longer transformer service life.

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