OMICRON

Diagnostic testing and monitoring on high-voltage switchgear

Assessing the condition of HV switchgear for reliable operation

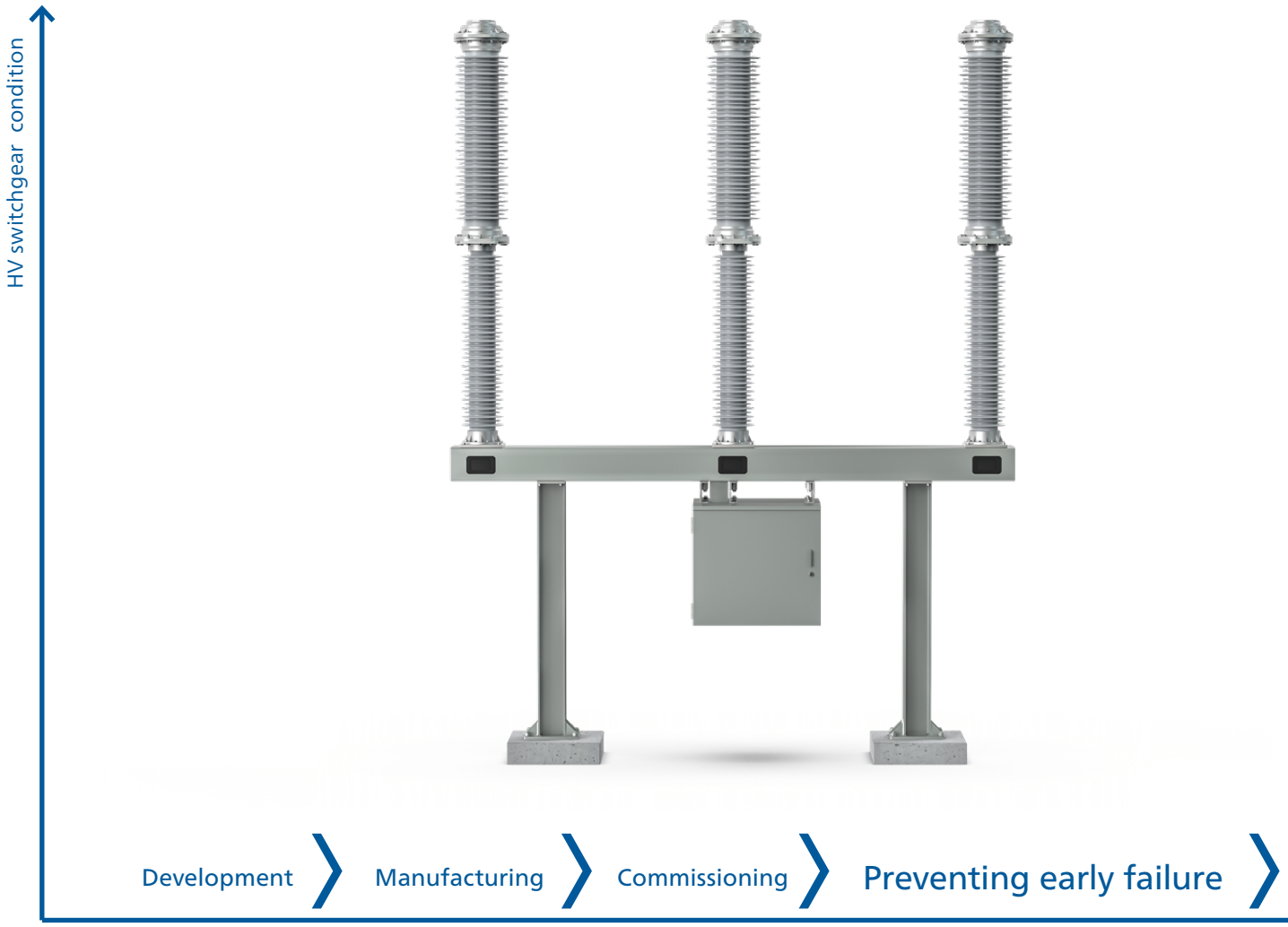
Reducing the risk of failure in HV switchgear

The testing of high-voltage (HV) switchgear is vital for ensuring the reliability, safety, and longevity of electrical equipment and power systems. By identifying potential issues early, testing helps prevent costly downtime, accidents, and regulatory non-compliance.

Failures are often attributed to a combination of factors, including environmental conditions, aging, poor maintenance, and operational issues.

These failures can range from minor disruptions to catastrophic system outages, highlighting the importance of proactive maintenance and preventative measures.

Regular switchgear testing offers numerous benefits, including enhanced safety, improved reliability, compliance with industry standards, and cost savings, by identifying and addressing potential issues early on, testing helps prevent accidents, equipment damage, and costly downtime, ultimately leading to a safer and more efficient power system.



HV switchgear testing

- **Initial testing:** Switchgear should undergo comprehensive testing before being commissioned and put into operation;
- **Periodic testing:** Regular testing should be performed at intervals determined by equipment criticality, age, and operational environment, typically every 2-5 years;
- **After repairs or modifications:** Testing is essential after any repairs or modifications to ensure the switchgear's continued reliability;
- **Following anomalies:** If any unusual behavior or measurement values are observed, testing should be performed to diagnose the issue.

The benefits of testing

- **Safety:**
  Testing helps identify and mitigate potential hazards, reducing the risk of potential of electrical accidents, arc flashes and fires;
- **Reliability:**
  Regular testing ensures the switchgear operates correctly, preventing breakdowns and maintaining an uninterrupted power supply
- **Compliance:**
  Many industry standards and regulations mandate switchgear testing for safety and performance compliance;
- **Cost savings:**
  Early detection and addressing of issues through testing can save significant costs compared to dealing with unexpected failures;
- **Equipment protection:**
  Testing verifies the proper functioning of circuit breakers, relays, and other components, protecting equipment from damage;
- **Optimal performance:**
  Testing ensures the switchgear operates within specific parameters, maximizing efficiency and reducing energy costs.

Negative influences on HV switchgear reliability and life expectancy

- **Environmental factors:**
  Moisture, dust and contaminants, temperature fluctuations, vibration, ice and snow;
- **Aging and deterioration:**
  Aging components, insulation breakdown, corrosion, wear of components;
- **Poor maintenance:**
  Inadequate inspection and testing, lack of cleaning, improper lubrication;
- Operational issues:
  Overloading, voltage fluctuations, faults and arcs, operator errors;
- **Other factors:**
  Manufacturing defects, external damage (animals, accidents), inadequate design.

Normal life
Ensuring reliable operation

End of life
Extending lifetime

HV switchgear life expectancy

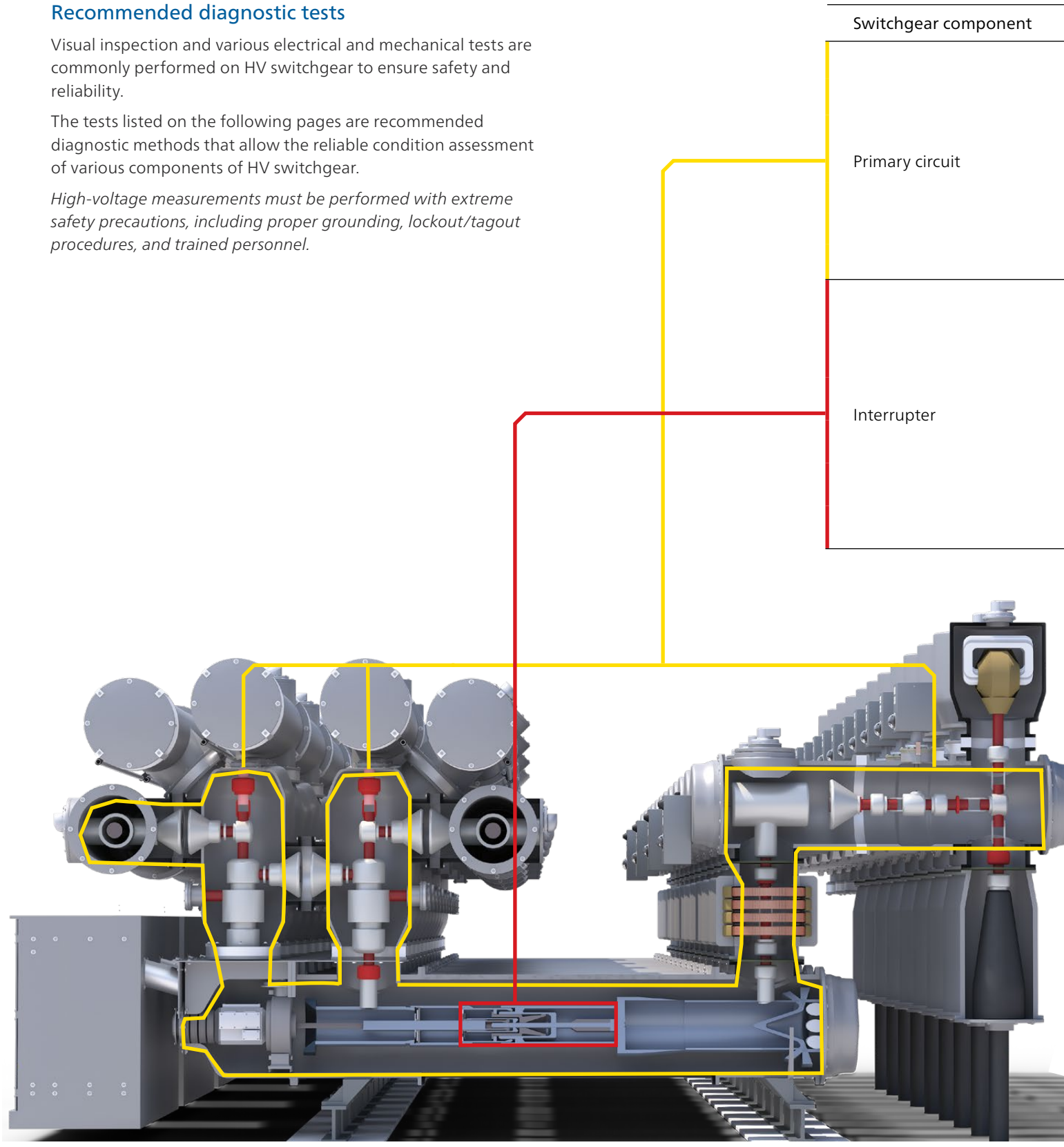
HV switchgear parts and recommended diagnostic tests

Recommended diagnostic tests

Visual inspection and various electrical and mechanical tests are commonly performed on HV switchgear to ensure safety and reliability.

The tests listed on the following pages are recommended diagnostic methods that allow the reliable condition assessment of various components of HV switchgear.

High-voltage measurements must be performed with extreme safety precautions, including proper grounding, lockout/tagout procedures, and trained personnel.



Subcomponent	Failure Mode	Condition indicator	Recommended tests				
Conductor joint	Loose, overtight connection	Resistance	■				
Insulation medium	Particles, protrusions, or voids	Partial discharge					■
Shielding Electrode	Poor electrical contact	Partial discharge					■
Cable joint	Degrading dielectric condition	Partial discharge					■
Bushing	Degrading dielectric condition	Partial discharge					■
		Tan Delta				■	
Closing resistor	Not operating	Resistance over time			■		
Main contact	Missaglinment, high resistance	Resistance static	■				
Arcing contact	Erosion, increased commutation time	Resistance over time			■		
	Missaglinment, deformed	Bounces		■			
Grading capacitors	Loosing capacitance	Tan Delta				■	
		Capacitance				■	
Insulation medium	Gas degradation	Partial discharge					■
			1	2	3	4	5

Recommended tests

1 Static contact resistance measurement
Apply high current source across the closed contact and measure the resulting voltage drop using four-wire to ensure high accuracy. (Pages 10-11)

2 Timing tests
Various methods for determining operating time, pole discrepancy and pre-insertion resistor timing on switchgear contacts. (Pages 12-15)

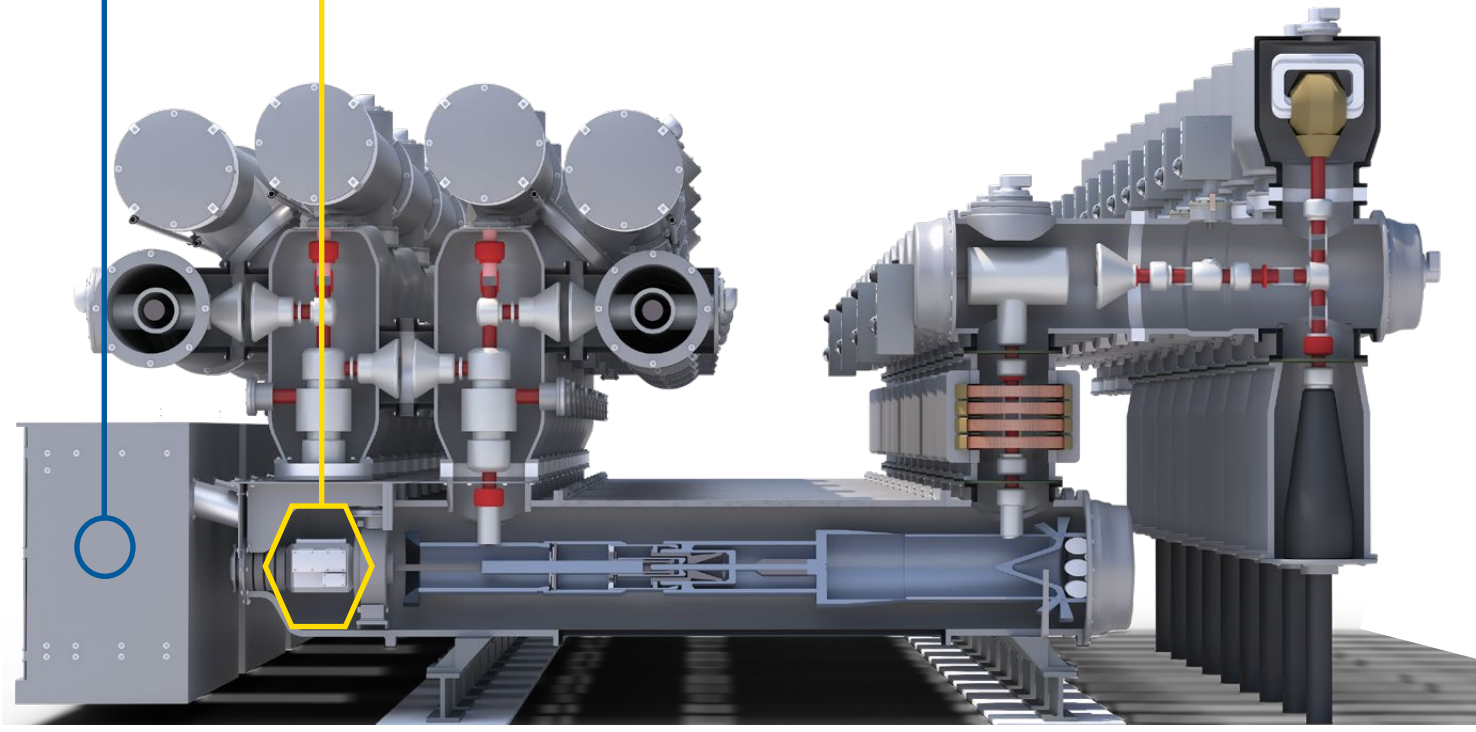
3 Dynamic contact resistance measurement
Perform a dynamic contact resistance measurement during open operation. (Pages 16-17)

4 Capacitance and TanDelta measurements
The capacitance measurement measures the charge stored at a given voltage. The TanDelta measurement measures the ratio between ohmic and capacitive leakage current. (Pages 18-19)

5 Partial discharge testing and monitoring
Measure partial discharge to determine deterioration of electrical insulation and detect developing insulation detects. (Pages 30-33)

HV switchgear parts and recommended diagnostic tests

Switchgear component	Subcomponent
Mechanism	Mechanical Linkage
	Operating rod
	Damper, Spring
	Motor
Control circuit	Trip and close coils
	Undervoltage coil
	Auxiliary contacts
	Power supply



Failure Mode	Condition indicator	Recommended tests						
Opening / Closing time out of tolerance	Main contact state over time	■						
Pole synchronism > threshold	Time differences of contacts	■						
Not open or close on command	Aux. contact state over time	■						
	Coil Current profile				■			
Mechanical problem	Main contact state over time	■						
Wear of damper or spring	Contact travel over time					■		
Not or insufficient charging	Motor current over time			■				
Electrical failure, mechanical friction issues	Coil current profile				■			
	Aux. contact state over time	■						
Mechanical friction issues	Release operating voltage						■	
Electrical failure	Supply voltage when tripping							■
Electrical or mechanical wear	Diff. to main contacts	■						
	Bounces	■						
Degrading batteries	Voltage during operation	■						
	Under-voltage condition	■						
		7	8	9	10	11	12	13

Recommended tests

7 Timing tests
Various methods for determining operating time, pole discrepancy and pre-insertion resistor timing on switchgear contacts. (Pages 12-15)

8 Capacitance and TanDelta measurements
The capacitance measurement measures the charge stored at a given voltage. The TanDelta measurement measures the ratio between ohmic and capacitive leakage current. (Pages 18-19)

9 Motor current measurement
Measure the current of the spring charging motor and evaluate the duration, the inrush current and the nominal current. (Pages 20-21)

10 Coil current measurement
Measure the current of the trip and close coil over time. Use graphical comparison to evaluate the typical shape of the captured current. (Pages 22-23)

11 Motion measurement
Apply a travel transducer to the mechanical linkage and record the motion during operation. (Pages 24-25)

12 Minimum pick-up test
Increase the trip/close coil supply voltage step-by-step until the switchgear operates. (Pages 26-27)

13 Undervoltage release test
Decrease the supply voltage of an undervoltage coil until the switchgear trips. (Pages 28-29)

The ideal solution for your HV switchgear testing needs

Recommended diagnostic tools

These testing solutions allow you to perform a thorough condition assessment of HV switchgear in order to quickly identify potential problems and risk of failure.

Diagnostic tests	CIBANO 500	CPX 200	COMPANO 100
	Dedicated circuit breaker test device with guided assistance	*Powerful, compact and lightweight primary asset test device*	*Lightweight, battery powered multi-pupose test device*
			
Guided workflows	■	■	–
Static contact resistance measurement	up to 200 A DC	up to 1000 A DC	up to 100 A DC
Timing tests			
Main Contact Timing	■	■	■
Contact synchronism	up to 15	up to 3	–
Contact Bounce Analysis	■	■	–
Auxiliary Contact Timing	■	■	■
Integrated power supply	up to 2400 VA (300 V)	up to 2500 VA (125 V)	up to 30 VA (220 V)
Both sides grounded	■	–	–
Pre-Insertion Resistor Timing	■	–	–
Test with current clamps (First Trip)	■	–	–
Dynamic contact resistance measurement	■	–	–
Capacitance and Tan Delta measurements	–	■	–
Motor current measurement	■	■	■
Coil current measurement	■	■	–
Motion measurement	■	–	–
Minimum pick-up test	■	–	–
Undervoltage release test	■	–	–

Legend: ■ = Performs test; – = Not available or applicable

CMC 500
Modular, multi-phase protection relay test set and commissioning tool

–
–
■
up to 10
■
■
up to 320 VA (600 V)
–
–
■
–
–
■
■
–
■
■

	MPD 800	UHF 800	PARADIMO 100
	Portable universal multichannel PD measuring system	*Dedicated UHF PD measuring system (MPD 800 compatible)*	*Designed for continuous PD monitoring and trending*
			
Partial discharge testing and monitoring			
According to IEC 60270	■	–	–
Ultra-High Frequency (UHF)	–	■	■
High Frequency Current Transformer (HFCT)	■	–	–

Legend: ■ = Performs test; – = Not available or applicable

Static contact resistance measurement

Areas tested

- ✓ Primary circuit
- ✓ Interrupter

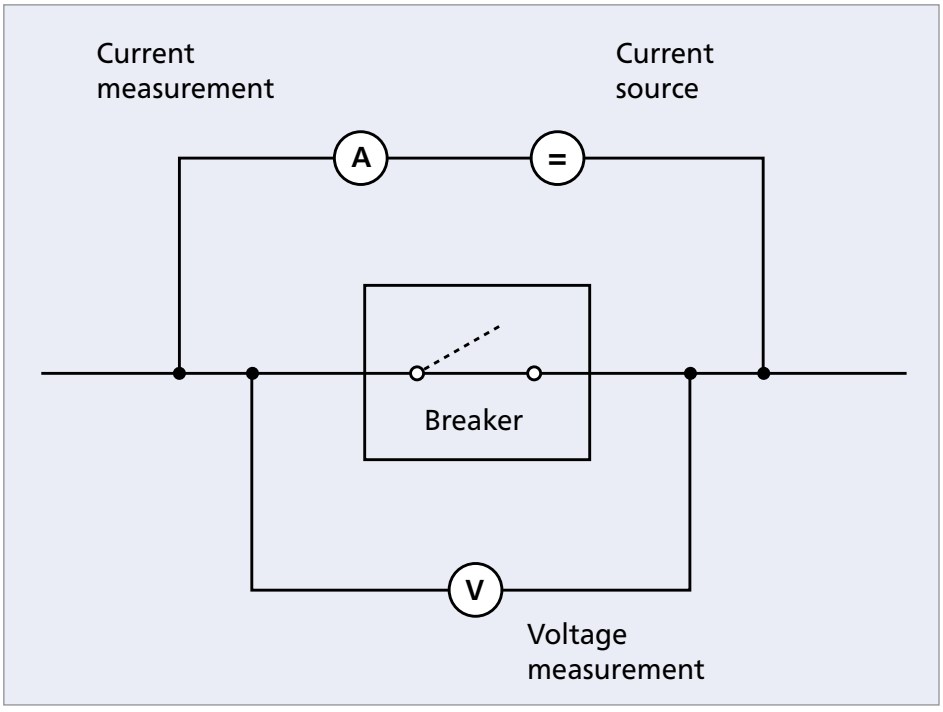
Why measure?

Static contact resistance tests serve to confirm if the resistance at the main contacts of a switch or connections in the primary circuit permits current to flow with minimal losses. Measurements of static contact resistance, often referred to as micro-ohm measurements, constitute one of the crucial tests for switchgear circuit breakers.

The test assesses whether the resistance in the contacts conducting current allows the flow of rated current with acceptable losses. Resistance is influenced by the properties of the contact surfaces, which are the connection points on a microscopic scale, along with the contact pressure and surface oxidation. An elevation in temperature beyond specified limits can alter these electrical contact surface characteristics, subsequently increasing the losses. This process can accelerate over time, potentially culminating in a sharp increase towards the end.

How does it work?

Usually a four-wire measuring method is used for static contact resistance measurements. Two wires are used to inject the current, and the voltage drop is measured with the other two wires. This measurement method is suitable for resistance measurements in the micro-ohm range. Typical resistances values are between 10 to 100 µΩ.



Apply Ohm's Law, expressed as R = V/I, to determine the contact resistance using the observed voltage drop and the supplied current. Evaluate the calculated resistance against the permissible limits or norms for the particular switchgear type. Document the measurement outcomes for subsequent reference and evaluation.

Good to know ...

> Insufficient contact pressure can lead to higher resistance.

> Using the Grounded Contact Resistance (GCR) measurement method allows the contact resistance measurement on both sides grounded gas insulated switchgear.

Recommended solutions

CIBANO 500

> **All-important tests on circuit breakers:** CIBANO 500 combines a micro-ohmmeter, timing analyzer, and a coil and motor supply. All-important tests on all types of circuit breakers can be carried out even when a station battery is not available.

> **Powerful integrated power supply:** Enables a highly accurate, digitally generated output signal of up to 2.4kW.

> **High measurement accuracy:** Four measurement ranges allow you to accurately determine contact resistances with an accuracy of better than 1 µΩ.

CPX 200

> **High current output:** Generates up to 1000 A AC/DC combined with the High Current Module, making it more suitable for resistance measurement on contacts that are prone to having a thin layer of byproducts from the arc extinguishing process.

> **High accuracy and reliability:** Utilizes a 4-wire measurement method for highly accurate resistance measurements, even in the micro-ohm range. This accuracy is crucial for detecting even minor deviations.

> **Guided testing and reporting:** Guided workflows, wiring instructions, as well as procedures for automated testing and reporting, save time, reduce the potential for human error and eliminate manual data recording and report writing.

COMPANO 100

> **Basic checks on breakers:** Performs micro-ohm measurements, basic timing measurements and motor current measurements.

> **High measurement accuracy:** Precise timing and micro-ohm measurements with an typical accuracy of better than 1 µΩ at 100 A DC.

> **Battery powered operation:** The integrated battery allows users to perform basic checks fast and efficient, even if no mains supply is available.

> **Versatility:** Can also be used for many other basic tests like CT/VT ratio, polarity and wiring checks and testing basic protection relays.

Timing tests

Areas Tested

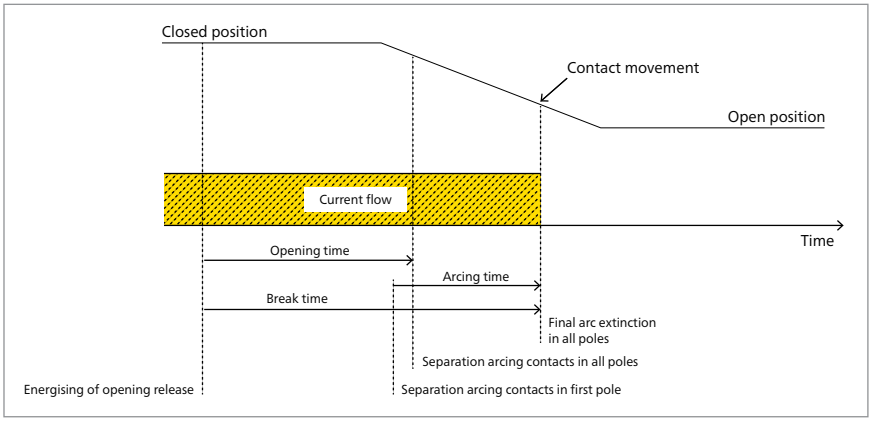
- ✓ Interrupter
- ✓ Mechanism
- ✓ Control circuit

Why measure?

The primary function of every switching device is to control the electrical flow by connecting and disconnecting high voltage lines. For any applied grid protective mechanisms to work properly, it is crucial that these devices operate within specified boundaries. If the devices do not perform within these specified parameters, it could imply a potential issue in one of the areas within the switchgear. To ensure the safety and reliability of the switching device, further testing is usually performed to identify and resolve the root cause of any deviation in performance.

How does it work?

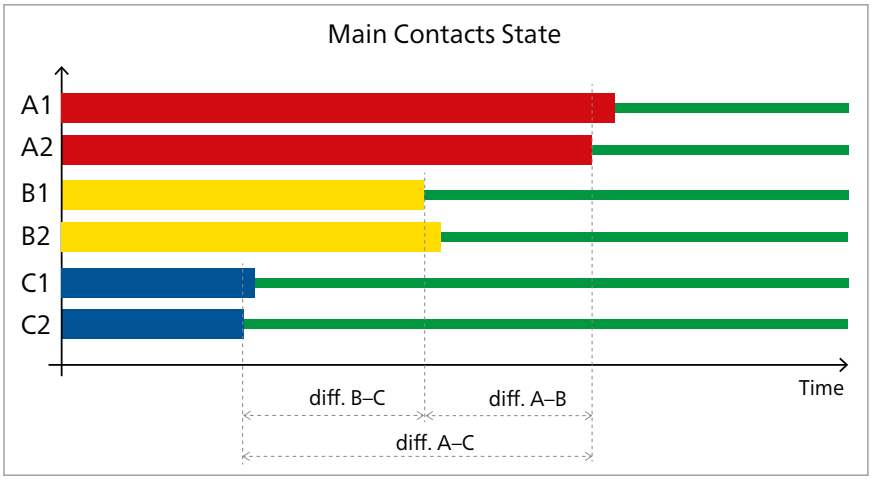
There are a variety of switchgear timing testers that differ from each other by their set of features. The feature set and thus the device that a tester needs depend on their specific area of application and the associated requirements. The following Timing Test feature are available:



Opening time definition according IEC 62271-100

1. Main Contact Timing

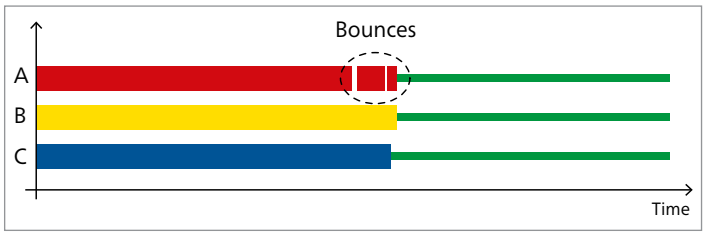
Test devices with this feature measure the operation time of the main contacts of the switchgear according to the IEC 62271-100 standard. Switchgear manufacturers are widely accepting this standard and utilize it to define their product specifications. Therefore, any test device that aims to verify or compare manufacturer specifications with actual measurements taken in the field will follow this standard. This ensures consistency and accuracy in assessing whether the switchgear operates within the designated time constraints.



Time differences between phases

2. Contact synchronism

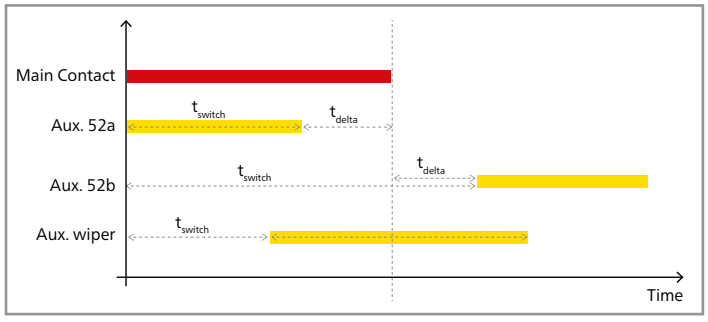
This feature assess the time differences between phases (synchronism). Significant deviations can harm three-phase inductive machines such as generators, power transformers, and motors. According to the IEC 62271-100 standard, there are defined limits for allowable discrepancies. Additionally, in a phase with multiple interrupters, maintaining similar switching times is essential.



Graphical representation of contact bounces

3. Bounces

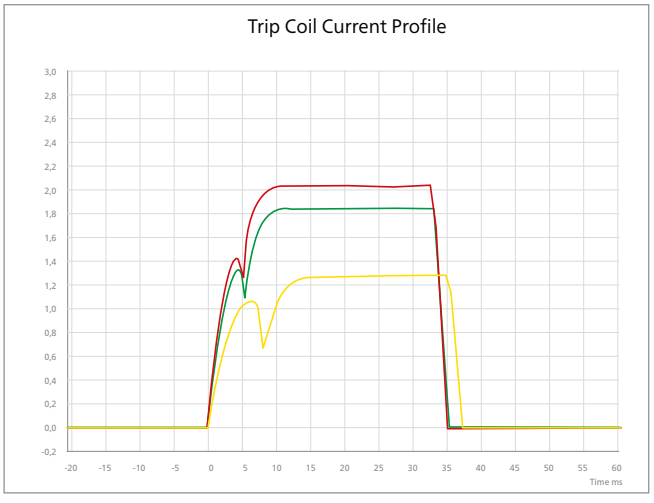
Binary traces serve as graphical representations to evaluate contact bouncing, illustrating the main contact state. The amount of bounces that occur in switching devices is influenced by the contact mechanism and the speed at which they open or close. This undesirable effect generates significant transients that can cause over voltages and damage other components of the electrical network.



Timing relationship of auxiliary contacts 52a, 52b and wiper to main contact

4. Timing of auxiliary contacts

The coordination of timing between main and auxiliary contacts in switchgear control systems is essential. Main contacts are responsible for handling the main circuit flow, whereas auxiliary contacts enable supplementary operations, such as initiating a spring-charging motor, in a sequence aligned with primary actions like circuit closure. Manufacturers supply detailed specifications of these timing relationships, which are crucial for optimal system functionality.



Influnce of supply voltage on coil current

5. Timing test with integrated power supply

The power supply built into the test device enables a complete separation between the switchgear control voltage and the substation's power source. This improves safety for operators and makes it easier to assess switching times at different voltage levels, including the station's minimum, standard, or maximum defined operation voltage.

Operating times

		Opening time
	Breaker	**39,30 ms**
+	**A**	**38,40 ms**
+	**B**	39,30 ms
+	**C**	38,90 ms

Coil characteristics

	Peak current
Trip A	1,28 A

0,7U$_n$

Operating times

		Opening time
	Breaker	36,90 ms
+	A	36,00 ms
+	B	36,90 ms
+	C	36,40 ms

Coil characteristics

	Peak current
Trip A	1,85 A

U$_n$

Operating times

		Opening time
	Breaker	**36,60 ms**
+	**A**	**36,60 ms**
+	**B**	**36,60 ms**
+	**C**	36,20 ms

Coil characteristics

	Peak current
Trip A	2.04 A

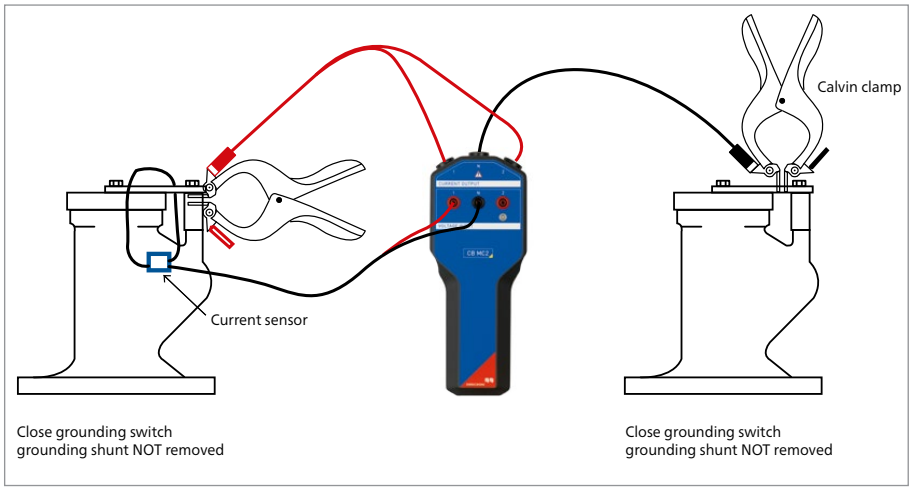
1,1U$_n$

Different control voltage results in different timing measurements

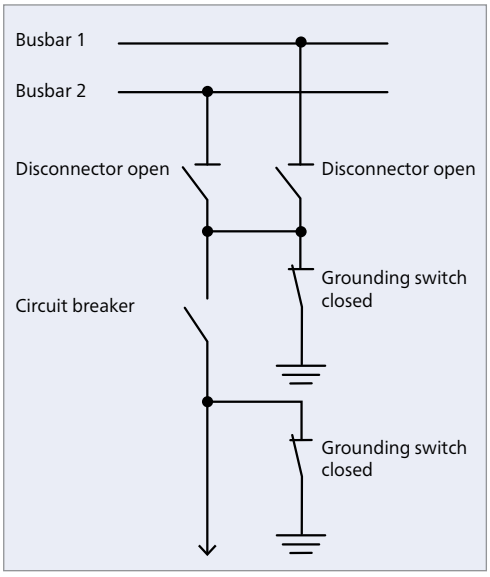
Timing tests

6. Both sides grounded timing test

During field tests, nearby feeders or neighboring busbars can generate strong electric fields. These fields result in the induction of high voltages within the metallic parts of the switchgear. To address this problem, grounding is implemented on both sides of the switching device. For timing tests on a High Voltage GIS grounded on both sides, a current sensor, specifically a Rogowski coil, is attached to the grounding switch of the switch bay. These sensors are flexibly designed, allowing easy installation on various isolated grounding switches, making them perfect for on-site applications in GIS setups. The breaker remains grounded on both sides throughout the duration of the timing measurement.



Wiring setup with current sensor



Single line diagram of a both sides grounded GIS with isolated grounding switches

Recommended solutions

CIBANO 500 (Timing tests 1-8)

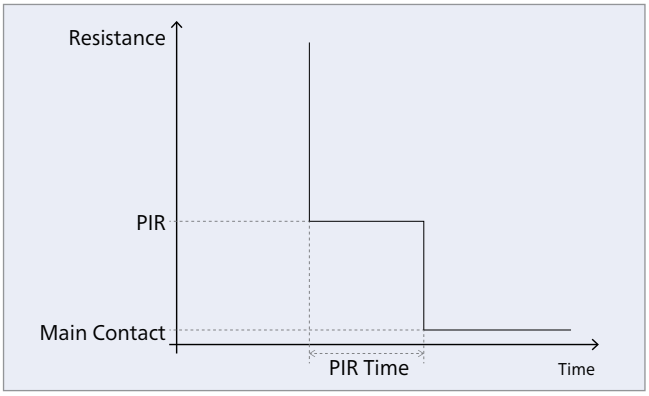
- **Personnel safety:** Test personnel safety can be increased when the test is performed with both sides of the breaker safely grounded.
- **Decreased interferences:** The CB MC2 connection modules decrease interferences as they are mounted close to the breaking elements with short cables offering minimized cable length for interferences from other live substation elements.
- **Guided workflows:** Save time and reduce the potential for human error.

CPX 200 (Timing tests 1-5)

- **Accurate and reliable timing measurements:** Designed for precision, allowing accurate measurement of timing parameters, ranging from opening and closing times of main and auxiliary contacts according to IEC 62271-100 to graphical evaluation of bounces to measuring the synchronism between phases.
- **Integrated power supply:** The integrated power supply ensures high repeatability and easy adaption to minimal, nominal and maximal control voltages.
- **Guided testing and reporting:** Guided workflows, wiring instructions, as well as procedures for automated testing and reporting, save time, reduce the potential for human error and eliminate manual data recording and report writing.

7. Timing test of pre-insertion resistors

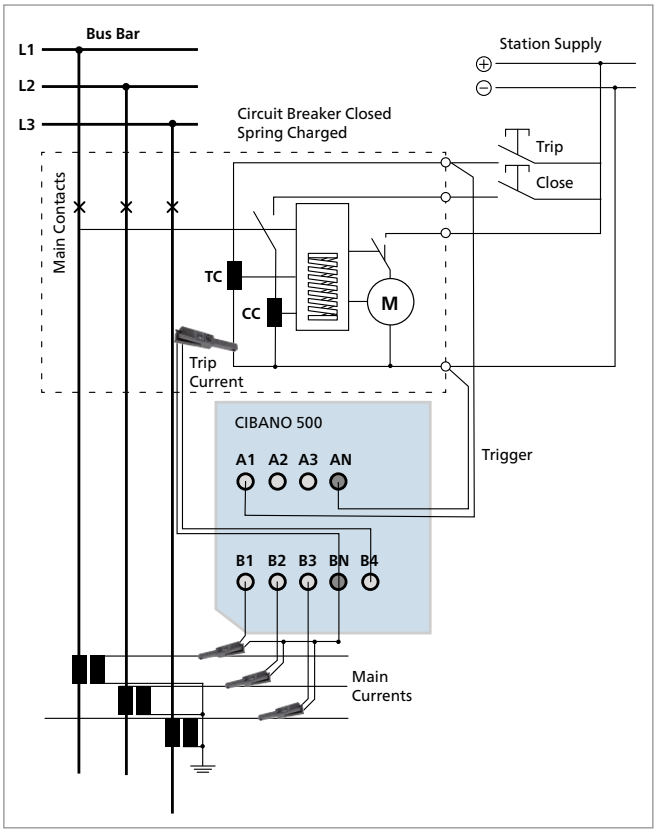
Pre-insertion resistors (PIR) are occasionally employed to mitigate transients produced during switching, providing an alternative to point-on-wave switching. These resistors channel the main circuit current through an ohmic resistor for a brief duration upon activation. It is crucial to ensure this PIR activation time is kept short to avoid overheating.



Pre-Insertion Resistor (PIR) timing measurement

8. Timing test with current clamps (First Trip)

The first trip test aims to evaluate the operational duration of a switching device that has been closed and in service for an extended period. This test seeks to determine whether there is any significant difference in operation time compared to a switching device that undergoes regular operation. For this test, current clamps are attached to the secondary side of current transformers to measure the trip time, ensuring that the device stays connected to the grid until its first trip following a long service period.



In-service timing test wiring setup with CIBANO 500

COMPANO 100 (Timing tests 1, 4 & 5)

- **Simple timing checks:** The versatile QUICK and FLEX modules in combination with the flexible timer function allows to perform a large variety of timing checks.
- **Accuracy and reproducibility:** Designed for precise and reproducible measurements.
- **Versatility:** The COMPANO 100 can also be used for many other basic tests like CT/VT ratio, polarity and wiring checks and testing basic protection relays.

CMC 500 (Timing tests 1-5 & 8)

- **Simple timing checks:** Several Test Universe modules in combination with the real-time measurement and signal recorder EnerLyzer allows users to perform a large variety of timing checks with graphical visualization.
- **Accuracy:** Measurement accuracy minimizes the risk of incorrect settings or faulty operation of the circuit breaker.
- **Troubleshooting:** The user-friendly software makes troubleshooting easier and faster, which is especially beneficial during commissioning or after a fault.

Dynamic contact resistance measurement

Areas tested

- ✓ Primary circuit
- ✓ Interrupter

Why measure?

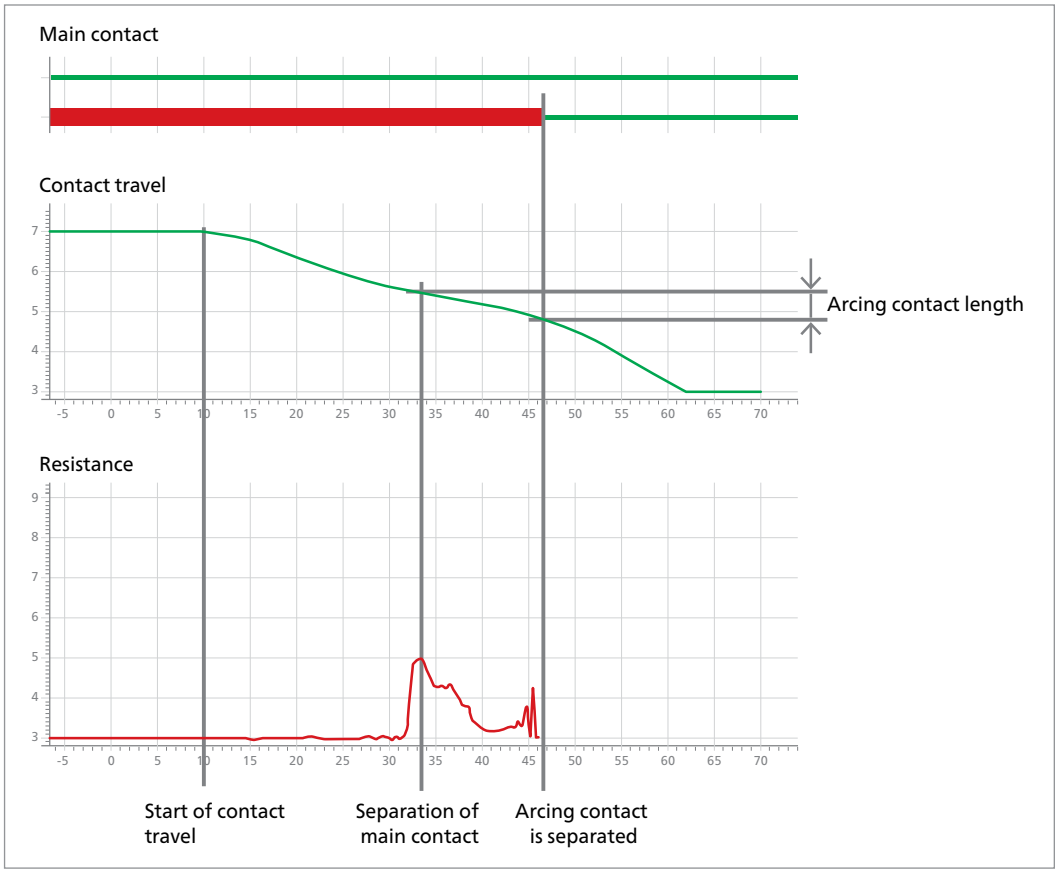
During the switching operation, the curves of the dynamic contact resistance (DRM) are recorded, providing valuable information about wear-related changes to the main and arcing contacts within the interrupter chambers. This measurement method enables the early detection of issues such as erosion, dimensional changes, or damage to the arcing contact—without the need to dismantle the circuit breaker.

When the contact movement is recorded simultaneously, the length of current carrying part of the arcing contacts can be measured. This allows for the assessment of contact condition and wear, including the detection of arcing contact failures.

By identifying problems early, DRM can help prevent costly repairs or failures, making it a valuable tool for switchgear maintenance programs, helping to ensure equipment reliability and safety.

How does it work?

The dynamic contact resistance measurement (DRM) is a highly accurate four-wire measurement in which a constant current is injected through the contacts, and the resistance is simultaneously measured during the switching operation.



DRM records contact resistance during breaker operation (resistance over time). If combined with a travel measurement, the arcing contact length can be determined.

Good to know ...

> DRM is commonly used in SF_6 circuit breakers to assess the condition of arcing contacts, which are made for instance of tungsten/copper alloy and tend to erode with each interruption of current.

> The CIBANO 500 uses the CB MC2 Accessory to measure DRM.

Recommended solutions

CIBANO 500 + CB MC2 + CB TN3

> **All-important tests on breakers:** CIBANO 500 combines a micro-ohmmeter, timing analyzer, and a coil and motor supply. All-important tests on all types of circuit breakers can be carried out even when a station battery is not available.

> **Powerful integrated supply:** The integrated power supply can output a highly accurate, digitally generated output signal of up to 2.4kW.

> **High measurement accuracy:** Using four measurement ranges, CIBANO 500 can accurately determine contact resistances with an accuracy of better than 1 µΩ.

Capacitance and Tan Delta measurements

Areas tested

- ✓ Primary circuit
- ✓ Interrupter
- ✓ Mechanism

Why measure?

Changes in capacitance can indicate deterioration of insulation materials or damaged grading capacitors. By documenting capacitance changes over time, maintenance teams can predict when equipment may need to be replaced or repaired, minimizing downtime. Post-repair capacitance measurements can ensure the effectiveness of repairs and prevent future failures.

The Tan-Delta measurement in high-voltage switchgear, also known as a dissipation factor test or loss angle test, calculates the ratio of resistive to capacitive leakage current and is used to assess the condition of insulation and predict its remaining life. This test provides insights into the electrical losses within the insulation system, which can indicate the presence of damage or deterioration.

Tan-delta measures the ratio of resistive current (losses) to capacitive current in the insulation, revealing how well the insulation is performing its role of isolating and storing energy. By observing Tan-Delta values over time, potential insulation problems can be identified before they lead to major failures.

Elevated Tan-Delta values can indicate accelerated aging or degradation of the insulation, allowing for better planning of maintenance or replacement. Ensuring the health of insulation in high-voltage switchgear is crucial for preventing breakdowns, safety hazards, and unexpected outages.

How does it work?

The Tan-Delta value, along with capacitance, is measured using specialized high voltage accessories. The measured Tan-Delta value is compared to previous measurements, manufacturer specifications, and established guidelines to assess the insulation health. Higher Tan-Delta values typically indicate increased degradation of the insulation system.

No.	Measurement	Breaker position	Test mode	Sweep	V test	Freq.	V out	I out
1	C1G	Open	GST	None	10.00 kV	60.00 Hz	10.00 kV	0.55 mA
2	C2G	Open	GST	None	10.00 kV	60.00 Hz	10.00 kV	0.37 mA
3	C3G	Open	GST	None	10.00 kV	60.00 Hz	10.01 kV	0.53 mA
4	C4G	Open	GST	None	10.00 kV	60.00 Hz	10.00 kV	0.36 mA
5	C5G	Open	GST	None	10.00 kV	60.00 Hz	10.01 kV	0.54 mA
6	C6G	Open	GST	None	10.00 kV	60.00 Hz	10.01 kV	0.36 mA
7	C12	Open	UST-A	None	10.00 kV	60.00 Hz	10.01 kV	0.01 mA
8	C34	Open	UST-A	None	10.00 kV	60.00 Hz	10.01 kV	0.01 mA
9	**C56**	**Open**	**UST-A**	**None**	**10.00 kV**	**60.00 Hz**	**10.01 kV**	**0.01 mA**

Good to know ...

> For devices with low capacitance, such as high-voltage SF_6 breakers, it is typically suggested to evaluate losses in watts rather than using power factor measurements, as outlined in IEEE C57.152-2013.

Wat losses	Cap. meas	PF meas
1.68 mW	141.9 pF	0.0306 %
1.40 mW	69.3 pF	0.0379 %
1.67 mW	138.5 pF	0.0316 %
1.41 mW	93.5 pF	0.0392 %
1.64 mW	139.2 pF	0.0303 %
1.37 mW	93.4 pF	0.0380 %
0.05 mW	3.4 pF	0.0459 %
0.06 mW	3.0 pF	0.0587 %
0.05 mW	**3.0 pF**	**0.0519%**

Power factor and capacitance results obtained from a dead tank SF_6 breaker

Recommended solutions

CPX 200

> **High accuracy and reliability:** The CPX 200 provides precise dissipation/power factor measurements, which are crucial for assessing the condition of high-voltage switchgear insulation.

> **Variable frequency testing:** The ability to test with an extended frequency range from 1Hz up to 600Hz with the system component HVX10 allows for effective suppression of mains interference and provides valuable insights into the insulation's behavior at various frequencies.

> **Guided testing and reporting:** Guided workflows, wiring instructions, as well as procedures for automated testing and reporting, save time, reduce the potential for human error and eliminate manual data recording and report writing.

> **Compact and portable:** Designed to be the most compact and lightweight solution in the industry, making it easy to transport and ideal for on-site testing.

Motor current measurement

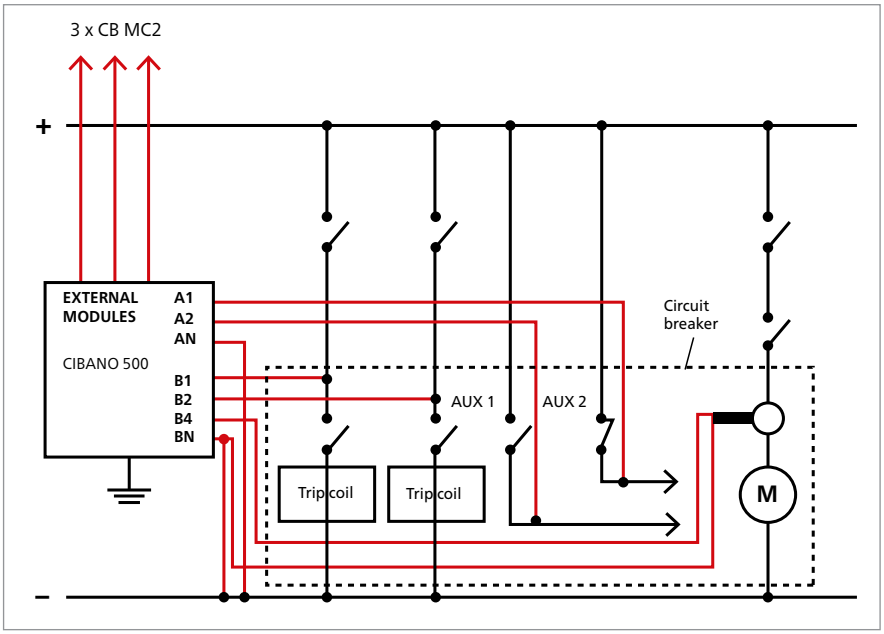
Area tested

✓ Mechanism

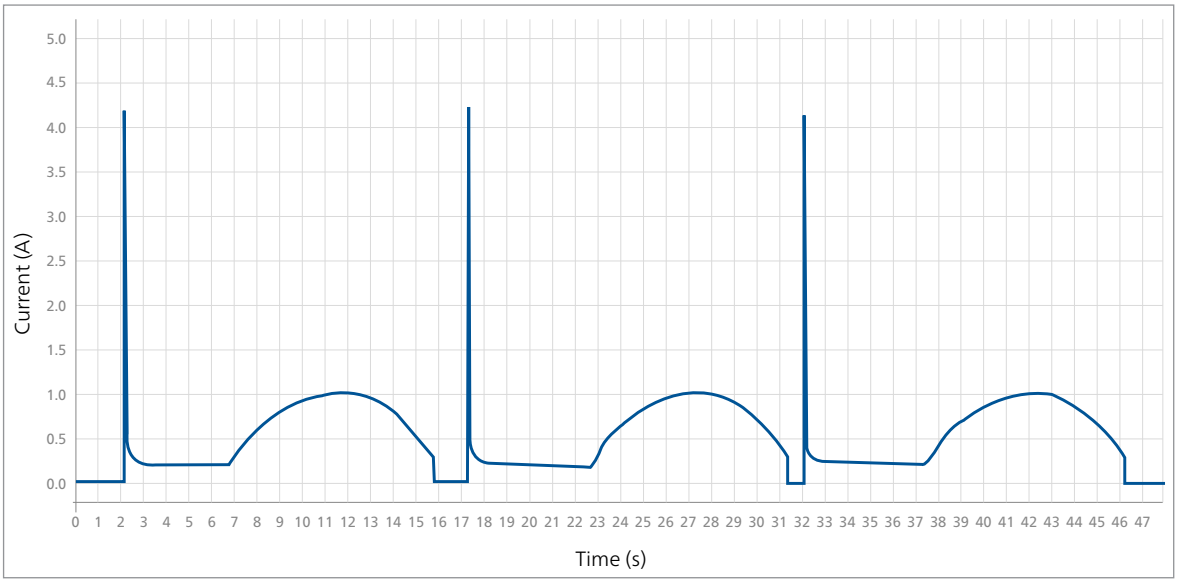
Why measure?

Motor Current Signature Analysis is a non-intrusive diagnostic technique that analyzes the current waveform and run-time of a motor to detect variations from the expected waveform. It involves breaking down the current waveform into inrush-currents and continuous currents drawn from the station supply.

Early detection of potential issues through motor current measurements can optimize maintenance strategies as well as prevent costly breakdowns and outages.



Motor current test on an HV circuit breaker



How does it work?

The test involves measuring the current drawn when the motor is charging the spring of the operating mechanism or increasing the hydraulic or air pressure. Analysing this current helps to verify the adequacy of lubrication in the operating mechanism or any electrical issues of the drives.

Good to know...

> On a spring operated mechanism, the motor starts right after a close operation. Therefore it is useful to combine them with a close timing test.

> On a independent pole operated circuit breaker it is important to monitor the inrush current of the motors.

> It is very handy to use current clamps to avoid any re-wiring.

Recommended solutions

CIBANO 500

> **All-important tests on breakers:** CIBANO 500 combines a micro-ohmmeter, timing analyzer, and a coil and motor supply. All-important CB tests on all types of CBs can be carried out even when a station battery is not available.

> **Powerful integrated supply:** The integrated power supply can output a highly accurate, digitally generated output signal of up to 2.4kW.

> **High measurement accuracy:** CIBANO 500 can accurately determine DC currents of up to 55 Amps or AC currents of up to 40 Amps with high accuracy.

CPX 200

> **Accurate and reliable measurements:** The CPX 200 uses digital filtering and a high sampling rate up to 40kHz to provide highly accurate current measurements, even in the presence of interference from the power grid.

> **Guided testing and reporting:** Automated testing procedures and reporting optimize efficiency and streamline the testing process, saving time, reducing the potential for human error and eliminating manual data recording and report writing.

COMPANO 100

> **Basic current measurements:** The COMPANO 100 allows to measure the motor current using a currnt clamp or a shunt. It can record up to 100 results in the FLEX sequencer, allowing to manually trace the current over time.

> **Versatility:** The COMPANO 100 can also be used for many other basic tests like CT/VT ratio, polarity and wiring checks and testing basic protection relays.

CMC 500

> **Basic current measurements:** The CMC 500 allows to measure the motor current using a current clamp or a shunt with the real-time measurement and signal recorder EnerLyzer with graphical visualization.

> **Accuracy:** The CMC 500's precision and reliability ensure accurate measurements, minimizing the risk of incorrect settings or faulty operation of the circuit breaker.

> **Troubleshooting:** The CMC 500's user-friendly software makes troubleshooting easier and faster, which is especially beneficial during commissioning or after a fault.

Coil current measurement

Areas tested

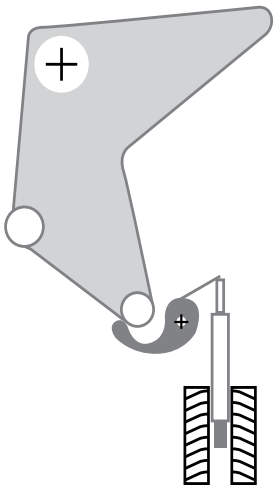
- ✓ Mechanism
- ✓ Control circuit

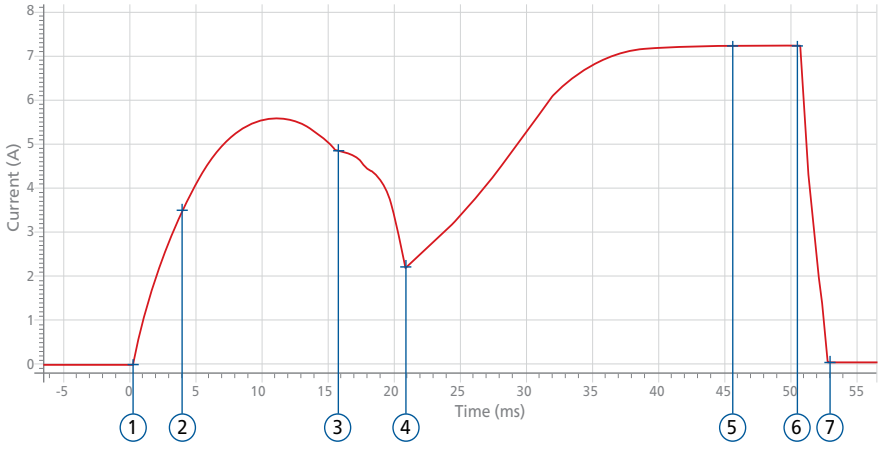
Why measure?

Coil current measurements record the current signature curve of trip and close coils during breaker operation to detect potential mechanical and electrical issues. They help identify problems like lubrication issues, latch operation problems, and the quality of the control voltage supply before they manifest as actual faults. This allows you to identify potential issues before they escalate, preventing costly outages and repairs. It also enables proactive maintenance based on the measured coil current, ensuring the proper functioning of the circuit breaker's operating mechanism and control circuit for reliable and efficient operation and extended lifespan of the HV circuit breaker.

How does it work?

During a coil current analysis, the current flow in the trip or close coil during the closing or opening operation of the switchgear is measured and displayed in a chart over time. Resulting curve deviations from the electrical coil properties that are expected (time constant), the necessary driving force (proportional current), and the correct timing sequence of the auxiliary contacts are indicators for electrical or mechanical problems within the trip and close mechanism of the circuit breaker.





1–2	Coil energized	4–5	Armature comes to stop	6–7	Auxiliary contact interrupts coil supply
2–3	Armature induces back	5	Current overcomes inductance		
3–4	Armature hits trigger releases spring	6	Auxiliary contact opens		

Detection of potential problems in actuating coils – Comparison is the best method of analysis.

Good to know ...

- The ability to do graphical comparison is a very useful feature when comparing test results.
- Using a stable power source guarantees that the measured coil current curves are repeatable as different control voltages will influence the shape of the curves.
- Advanced test devices combine these measurements with the timing test to increase efficiency.

Recommended solutions

CIBANO 500

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- **Troubleshooting:** The CMC 500's user-friendly software makes troubleshooting easier and faster, which is especially beneficial during commissioning or after a fault.

Motion measurement

Area tested

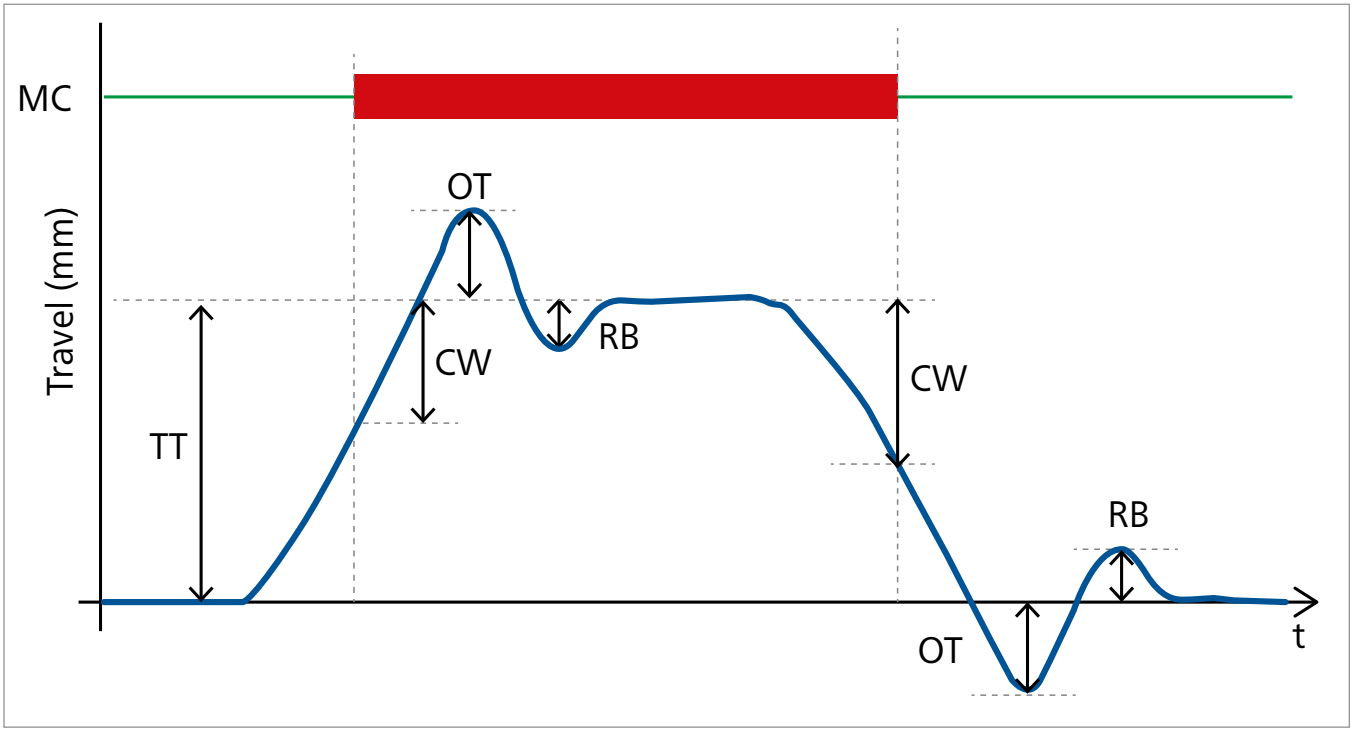
- ✓ Mechanism

Why measure?

Motion measurements on high-voltage switchgear, specifically circuit breakers, are vital for assessing their operational condition and ensuring reliable performance. These measurements provide data on the mechanism's performance, including closing and opening times, contact travel, and velocity, ensuring the breaker operates within specified limits. They also help detect early signs of wear and tear, allowing for preventative maintenance to ensure the reliability and longevity of high-voltage switchgear, minimize the risk of costly outages and optimize the safety of personnel and equipment.

How does it work?

The procedure involves attaching a linear or rotary transducer to the operating mechanism. Ideally, it should be positioned at the same location where the manufacturer places it for factory acceptance tests. If this is not feasible, place it as near as possible to the main contact, ensuring consistent placement for any repeat tests.



Motion measurements check the overall mechanism performance as well as to detect defects of the kinematic chain.

Good to know ...

> The tests are usually done together with timing or dynamic contact resistance tests.

> There is a big selection of motion sensor mounting videos on OMICRON's youtube channel.

Recommended solutions

CIBANO 500 + CB TN3

> **High-precision measurements:** The CIBANO 500 offers high accuracy in timing measurements, contact resistance testing, and coil/motor current analysis.

> **Condition Indicators:** It computes various condition indicators for the breaker's motion, including total travel, contact wipe, velocity, and rebound.

> **Combined measurements:** CIBANO 500 can perform various tests, including timing tests (main and auxiliary contacts, pre-insertion resistors), static and dynamic contact resistance measurements (DRM), coil and motor current analysis, and motion/contact travel analysis.

> **Automated testing:** The system, combined with the Primary Test Manager (PTM) software, allows for automatic test execution and result evaluation, further boosting efficiency.

Minimum pick-up test

Areas tested

- ✓ Control circuit

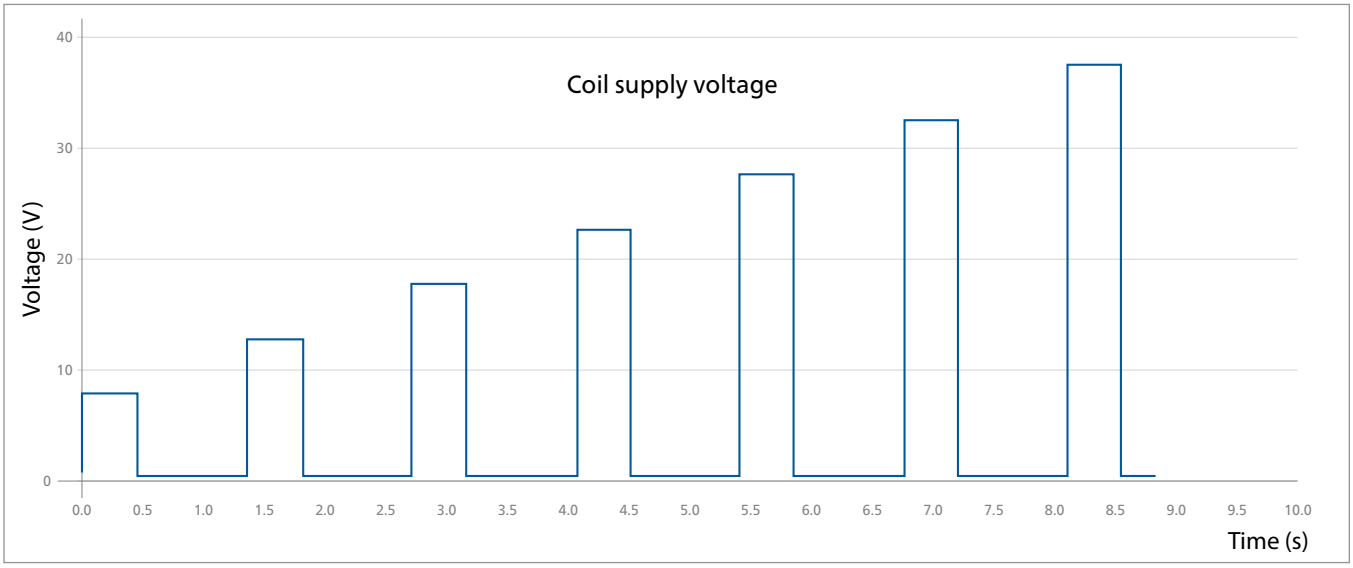
Why measure?

The minimum pick-up voltage test on HV switchgear determines the lowest voltage at which the circuit breaker's trip or close coil reliably activates the latch mechanism and initiates switching. This ensures proper operation even under low voltage conditions and helps prevent equipment damage and safety hazards during faults. By verifying the trip coil's response to minimal voltage, the test confirms the breaker will operate when needed, maintaining system integrity and protecting personnel from arc flash risks. As a preventative measure, it supports the safe and reliable performance of the electrical system.

How does it work?

To perform the test, the supply voltage applied to the circuit breaker coil is gradually increased, while monitoring the current draw. The minimum trip voltage is recorded when the circuit breaker actuates and trips. Repeat the test multiple times to ensure consistency and accuracy of the measured minimum trip voltage.

Keep detailed records of the test results, including the measured minimum trip voltage and any observed discrepancies. For example, a high pick-up voltage can indicate problems with the trip coil, control wiring, or other components, allowing for timely repairs or replacements before a fault occurs.



The coil voltage is consequently ramped up in defined voltage steps. With every further ramp the magnetic field increases until it's enough for the latch to hit the trigger and releases the energy stored in the spring, causing the circuit breaker to open. This procedure is done separately to find out the minimum pick-up voltage required to trip (open) and close the circuit breaker.

Good to know ...

> The test voltage range should be chosen based on the circuit breaker's rated voltage and current.

> The test procedure may vary slightly depending on the specific standards and regulations applicable to the switchgear.

Recommended solutions

CIBANO 500

> **Efficiency:** By using short, controlled voltage pulses instead of continuous voltage, the CIBANO 500 minimizes the risk of overheating the trip coils during the test, allowing for quicker and more frequent testing without damage.

> **Accuracy:** The CIBANO 500's integrated power supply provides a stable and precise output, ensuring consistent and reliable test results.

> **Comprehensive testing:** The CIBANO 500 allows for a complete assessment of the circuit breaker's performance under various voltage conditions, ensuring reliable operation, even during low DC supply scenarios.

> **Combined test reports:** The CIBANO 500 can combine the results of timing, contact resistance, coil currents, and motion tests into a single, comprehensive report, simplifying analysis and interpretation.

CMC 500

> **Simple minimum pick-up voltage release test:** The Test Universe Ramping module in combination with the real-time measurement and signal recorder EnerLyzer allows to perform minimum pick-up tests with graphical visualization.

> **Accuracy:** The CMC 500's precision and reliability ensure accurate measurement of the minimum pick-up voltage, minimizing the risk of incorrect settings or faulty operation of the circuit breaker.

> **Troubleshooting:** The CMC 500's user-friendly software makes troubleshooting easier and faster, which is especially beneficial during commissioning or after a fault.

Undervoltage release test

Area tested

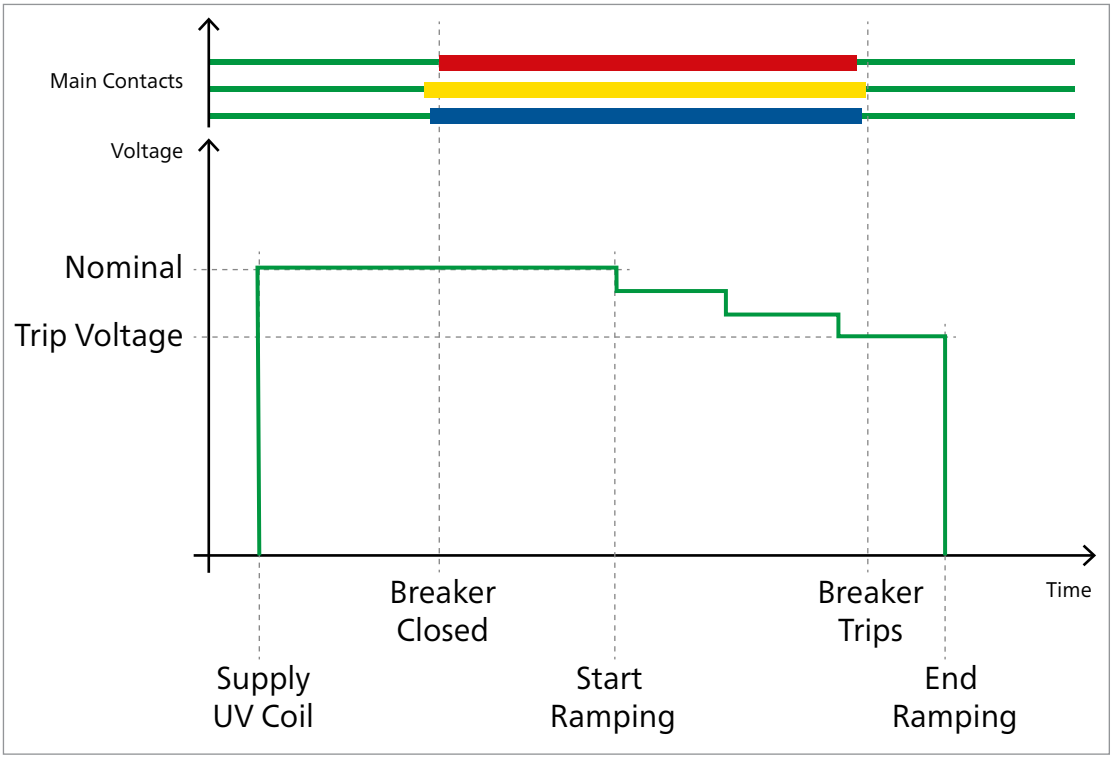
✓ Control circuit

Why measure?

Switchgear that does not have a redundant power supply can be equipped with an undervoltage release system. This system opens the circuit breaker as soon as the supply voltage drops below a defined threshold. The undervoltage release test is performed to determine the voltage level at which the undervoltage coil triggers the circuit breaker to open.

How does it work?

To test the undervoltage coil, a clearly defined sequence of tasks must be performed. Before the test starts, the system must be disconnected from the grid, meaning the switch is de-energized and the contacts are open. Then the test begins by applying the control voltage, closing the switch, and then ramping down the control voltage for the undervoltage coil. This continues until the threshold voltage is reached and the undervoltage coil opens the switch. Document the trip voltage and any other relevant observations.



Test sequence for UV coil testing

Good to know ...

> Due to the complexity of the test process, a guided test is very beneficial. Prevents errors and leads to more efficient test execution.

Recommended solutions

CIBANO 500

> **All-important tests on breakers:** CIBANO 500 combines a micro-ohmmeter, timing analyzer, and a coil and motor supply. All-important CB tests on all types of CBs can be carried out even when a station battery is not available.

> **Guided workflow:** The user interface Primary Test Manager (PTM) provides a guided workflow for various tests.

> **Testing breakers without a close coil:** For circuit breakers without a close coil and as a result the time calculation according to IEC standard cannot be applied, CIBANO 500 can use the motion/ contact travel as measurement start reference.

CMC 500

> **Simple undervoltage release test:** The Test Universe Ramping module in combination with the real-time measurement and signal recorder EnerLyzer allows to perform undervoltage release tests with graphical visualization.

> **Accuracy:** The CMC 500's precision and reliability ensure accurate measurements and minimizing the risk of incorrect settings or faulty operation of the circuit breaker.

> **Troubleshooting:** The CMC 500's user-friendly software makes troubleshooting easier and faster, which is especially beneficial during commissioning or after a fault.

Partial discharge testing and monitoring

Areas tested

- ✓ Primary circuit
- ✓ Interrupter

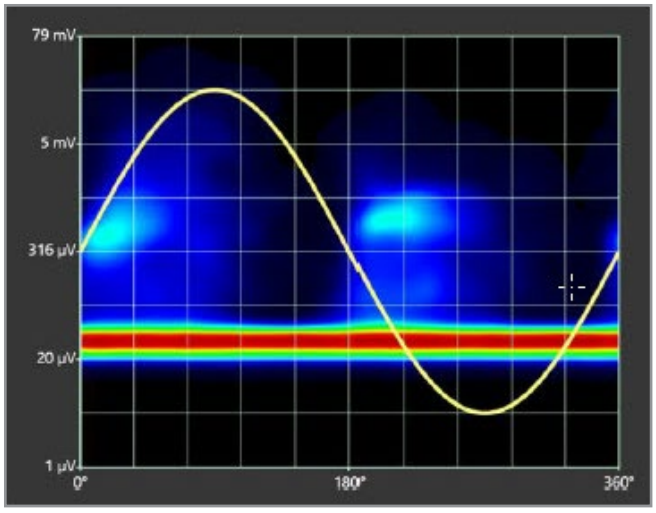
Why measure?

Partial discharge in high-voltage Gas-Insulated Switchgear (GIS) is a critical issue as it indicates insulation degradation and potential failures. Detecting and monitoring partial discharge (PD) is essential for maintaining the reliability and safety of GIS equipment. PD is a leading indicator of developing faults, so its detection and monitoring are crucial for timely intervention and maintenance.

PD in GIS can be initiated by various factors, including floating particles, metal protrusions, voids, or surface discharges. PD can accelerate insulation aging and deterioration, potentially leading to equipment failure and even catastrophic incidents. Continuous monitoring and diagnostic measurements help to identify insulation aging, degradation and defects early on to prevent catastrophic failures.

How does it work?

Online PD measurement and monitoring in GIS involves employing specialized sensors to detect the PD signals generated by defects, analyzing these signals to pinpoint the location and severity of the defects, and continuously monitoring the equipment to identify and address potential issues before they lead to equipment failure. There are various methods for detecting PD activity in high-voltage switchgear, including:

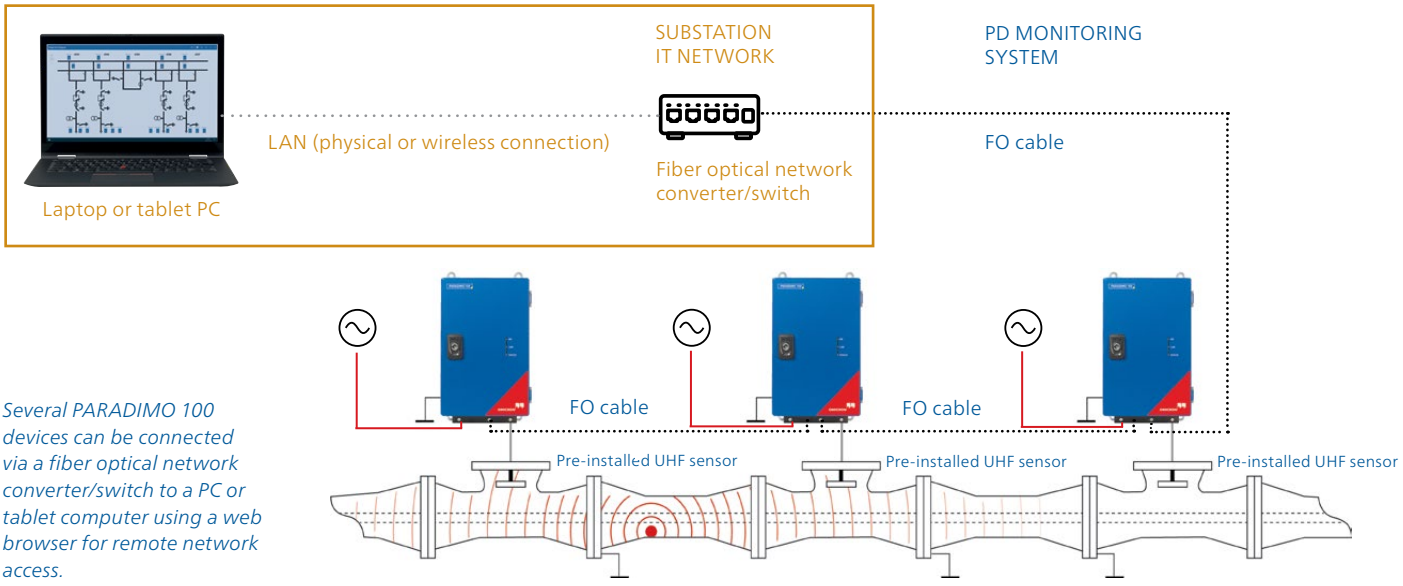


PRPD Diagram -- The Phase-Resolved Partial Discharge (PRPD) diagram is an established tool to analyze PD activity in relation to the phase angle of the applied voltage. Characteristic PRPD patterns correspond to specific types of defects, which can be used to identify the nature of the PD.

1. **IEC 60270 Measurement:** To perform a PD measurement according to the IEC 60270 standard at a HV substation, a typical setup involves using a coupling capacitor. This capacitor is generally connected via a bushing or termination of the GIS or is directly mechanically mounted to the GIS. The measurement is conducted offline, with the test voltage supplied by an external source brought to the site. These measurements are typically carried out during commissioning and are valued for their comparability to factory measurements. However, it's important to consider challenges such as external noise and the overall effort required.

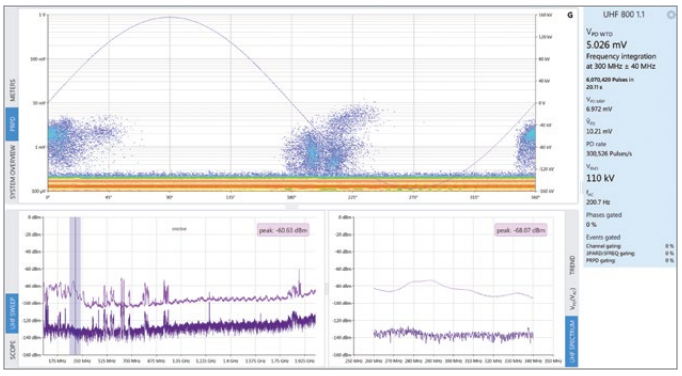
UHF PD monitoring on GIS

PARADIMO 100 monitoring devices communicate via standard network protocols. Multiple monitoring points facilitate trending, defect detection, and classification for reliable risk assessment in GIS and GIL.



Several PARADIMO 100 devices can be connected via a fiber optical network converter/switch to a PC or tablet computer using a web browser for remote network access.

Partial discharge testing and monitoring



Different measurement modes allow you to achieve a high signal-to-noise ratio and perform sensitive UHF PD measurements on GIS/GIL.

2. **UHF Detection:** Ultra-high frequency (UHF) sensors are used to detect the high frequency signals generated by PD. PD measurements in the UHF range offer an optimized measurement sensitivity in environments with high levels of external noise. UHF measurement sensors are often pre-installed in the latest GIS technology. These permanent sensors can be connected to a terminal box, which allows safe plug-and-play connections of PD measurement and monitoring equipment, which collects and analyses the data from the sensors.

HFCT (High-frequency current transformer)

3. **Cable Termination:** HFCTs (High-frequency current transformers) are typically connected to the ground straps or earth connections of HV cables within switchgear. The HFCTs can be often clamped around the cable's grounding braid. The HFCT then detects the high-frequency current pulses generated by partial discharges in cable termination and in some extent also from GIS and cable, allowing for PD detection without needing to directly access the high-voltage conductors.

The collected data from the sensors is analyzed to identify patterns and trends in PD activity. This analysis can help to pinpoint the location and severity of the PD source. Thresholds are set to trigger alarms when PD activity exceeds acceptable levels. The data can also be used to observe the overall health of the GIS equipment and predict potential failures.

The results are compared with established standards and historical data to determine if PD levels are within acceptable limits. Any detected PD activity is evaluated to determine if it indicates potential insulation issues or defects. If PD levels are excessive, further investigation is needed to identify the cause and take corrective action, which may include repairs, replacements, or improved maintenance practices.

Good to know ...

> The tightly sealed SF_6 compartments in GIS affect some of the detection methods. In this case, it is best to use the built-in UHF sensors for UHF detection.

Recommended solutions

MPD 800

- **High sensitivity:** The MPD 800 is designed for highly sensitive PD measurements, which is crucial because PD signals can be weak and easily masked by noise.
- **Industry standard compliance:** Adheres to the IEC 60270 standard for PD measurement, ensuring reliable detection of PD activity in switchgear.
- **Accurate detection and localization:** The system accurately detects and locates insulation defects in switchgear, enabling users to assess the risk of failure and plan maintenance based on the condition of the insulation.

UHF 800

- **Broad UHF PD measurement range:** Ensures very sensitive PD measurements in the UHF range from 100 to 2000 MHz. Using the Spectrum Evaluation feature and adjustable measurement filters, operators can easily select the best signal-to-noise ratio for sensitive PD measurements and reliable PD detection despite high levels of external noise.
- **Synchronous, scalable UHF PD testing system:** The system can be easily expanded by connecting several UHF 800 or MPD 800 data acquisition devices for synchronous, multi-channel PD measurements on GIS and GIL.

PARADIMO 100

- **Highly reliable PD monitoring:** Simultaneously monitors PD activity in different UHF frequency ranges using wideband and medium-band filters for optimal signal-to-noise ratios in noisy environments.
- **Convenient web user interface:** The Web user interface allows easy access for configuring measurement and alert settings and viewing real-time PD data and recorded trends.
- **Built-in PD know-how:** The system detects and automatically classifies all PD-related defects for reliable risk assessment.

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Quality

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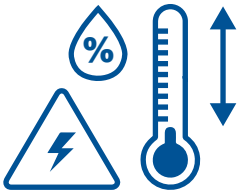
hours burn-in tests before delivery



100%

routine testing for all test set components

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ISO 27001
TÜV & EMAS
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OHSAS 18001

Compliance with international standards

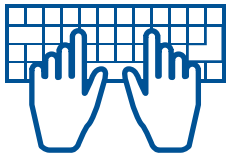
Innovation

... a product portfolio tailored to my needs

More than

200

developers keep our solutions up-to-date



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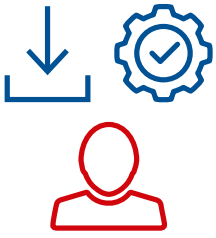
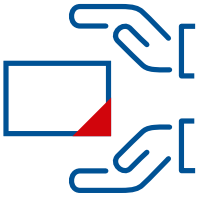


Easy access to software downloads, services, and certificates via the Customer Portal

Comprehensive repair and calibration services for reliable measurements



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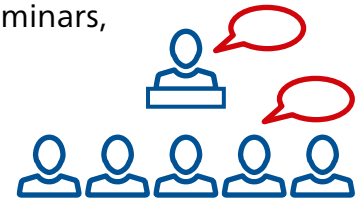
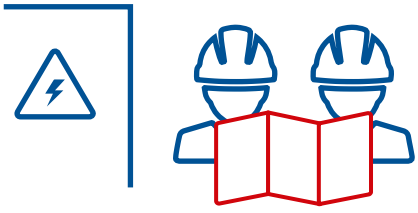


to thousands of technical papers and application notes



Extensive expertise in consulting, testing and diagnostics

OMICRON is an international company that works passionately on ideas for making electric power systems safe, secure, and reliable. Our pioneering solutions are designed to meet our industry's current and future challenges. We always go the extra mile to empower our customers: we react to their needs, provide extraordinary local support, and share our expertise.

Within the OMICRON group, we research and develop innovative technologies for all fields in electric power systems. Customers worldwide rely on the accuracy, speed, and quality of our reliable, user-friendly solutions for electrical testing of medium- and high-voltage equipment, protection systems, digital substations, and cybersecurity.

Founded in 1984, OMICRON draws on their decades of profound expertise in the field of electric power engineering. A dedicated team of more than 1,300 employees provides solutions with 24/7 support at 23 locations worldwide and serves customers in more than 170 countries.

Emotions are energy. Our energy moves.

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