

# DIRANA

Dielectric response analysis and moisture in oil-paper dielectrics

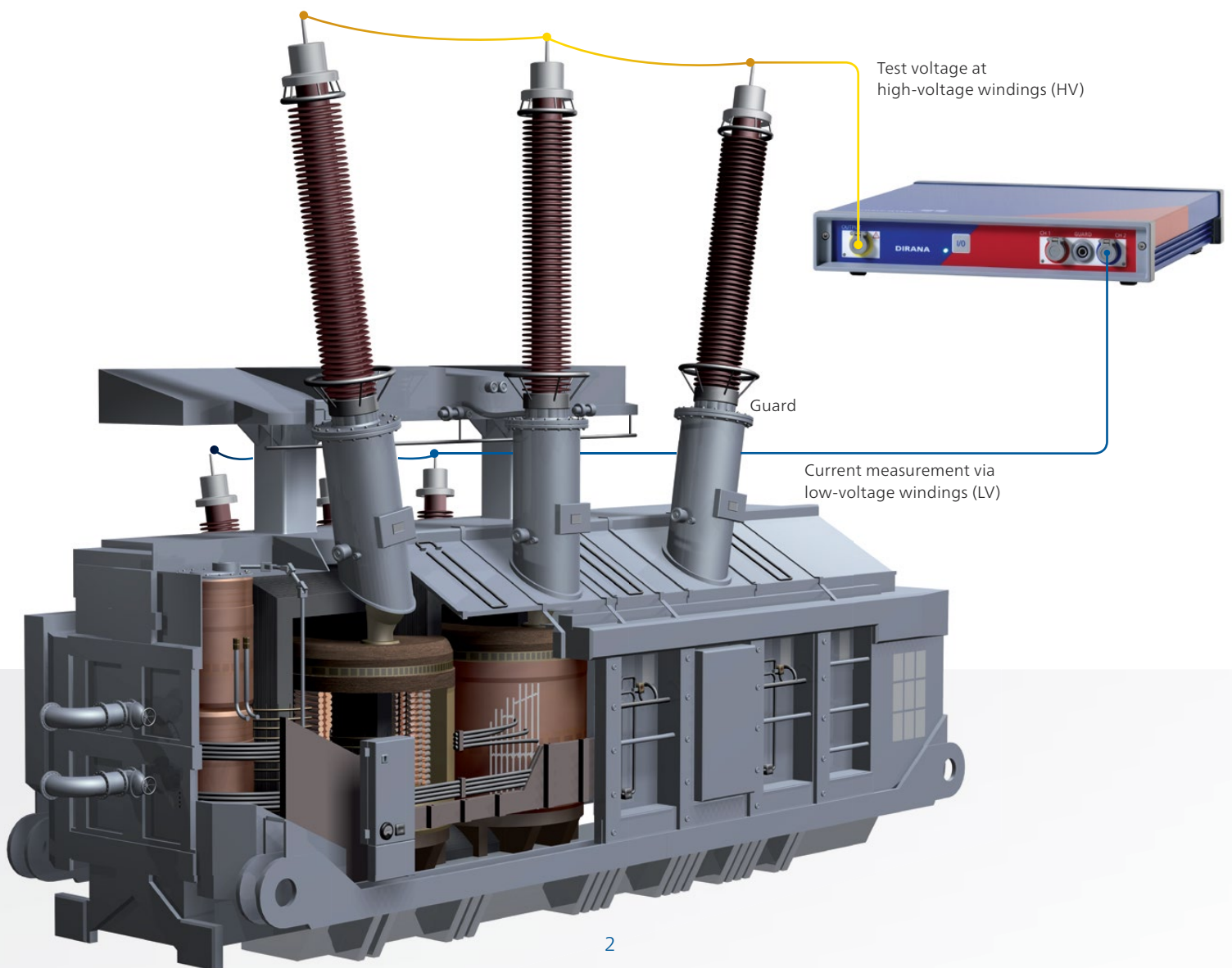


# Dielectric measurements

## Why dielectric response measurements?

Valuable information about the condition of high-voltage insulation may be obtained by measuring its dielectric response. A typical measurement at mains frequency may provide limited results. Exposing the insulation to a wide band of frequencies and measuring its dielectric response at various frequencies results in a more comprehensive condition assessment. The effects of moisture and ionic contamination on the dielectric properties of the insulation are more pronounced at lower frequencies.

Polarization effects and dielectric losses are affected by various properties of the dielectric material at different frequencies. These properties include moisture content, contamination, byproducts and temperature effects.



## Applications

The DIRANA determines the dielectric properties as a function of frequency. It measures the dissipation factor and capacitance of insulation systems like rotating machines.

It is used to determine the moisture content in oil-paper insulation for the following applications:

- > Power transformers
- > Paper-mass insulated cables
- > Bushings
- > Instrument transformers (CTs/PTs)

DIRANA supports these applications by a large number of selectable connection diagrams. This is helpful for the user during on-site measurement.

## Measurement steps

The dielectric response is measured by a three-terminal measurement that includes the output voltage, the measurement current and a guard to prevent disturbances due to current paths caused by dirty bushings or electromagnetic fields.

For e.g. a two-winding transformer which has been disconnected from the network:

- > Apply the test voltage to the HV windings
- > Current measurement via LV windings
- > Connect the guard to the bushing flange (ground)

Unlike the conventional equilibrium method, the measurement can be taken right away. There is no requirement to allow the transformer to cool, or wait until moisture equilibrium between paper and oil has been reached.

## Two channels = 50 % time savings

OMICRON's DIRANA is the first dielectric response analyzer which comes equipped with two input channels. By utilizing two channels, significant time savings can be achieved. For example, in the case of a three-winding transformer, the test voltage can be applied to the LV winding while the input channels are connected to the HV and the tertiary windings. This may result in a time savings of up to 50 %.



## Your benefits

- > Wide frequency range provides a high degree of accuracy and precise measurements at all temperature levels never possible in the past
- > Various insulation systems can be evaluated
- > Large number of connection diagrams to support the user
- > DIRANA's special guarding technique protects against measurement interference
- > Two input channels significantly reduce testing time

 [www.omicronenergy.com/DIRANA](http://www.omicronenergy.com/DIRANA)



# Moisture in oil-paper insulation

## Cost-effective maintenance

In the electric power supply, oil-paper insulation is used in numerous apparatus, as for example in transformers, bushings and instrument transformers. Due to the cost pressure of a de-regulated energy market, utilities have shifted maintenance from a time based to a condition based approaches. This development requires reliable diagnostic tools.

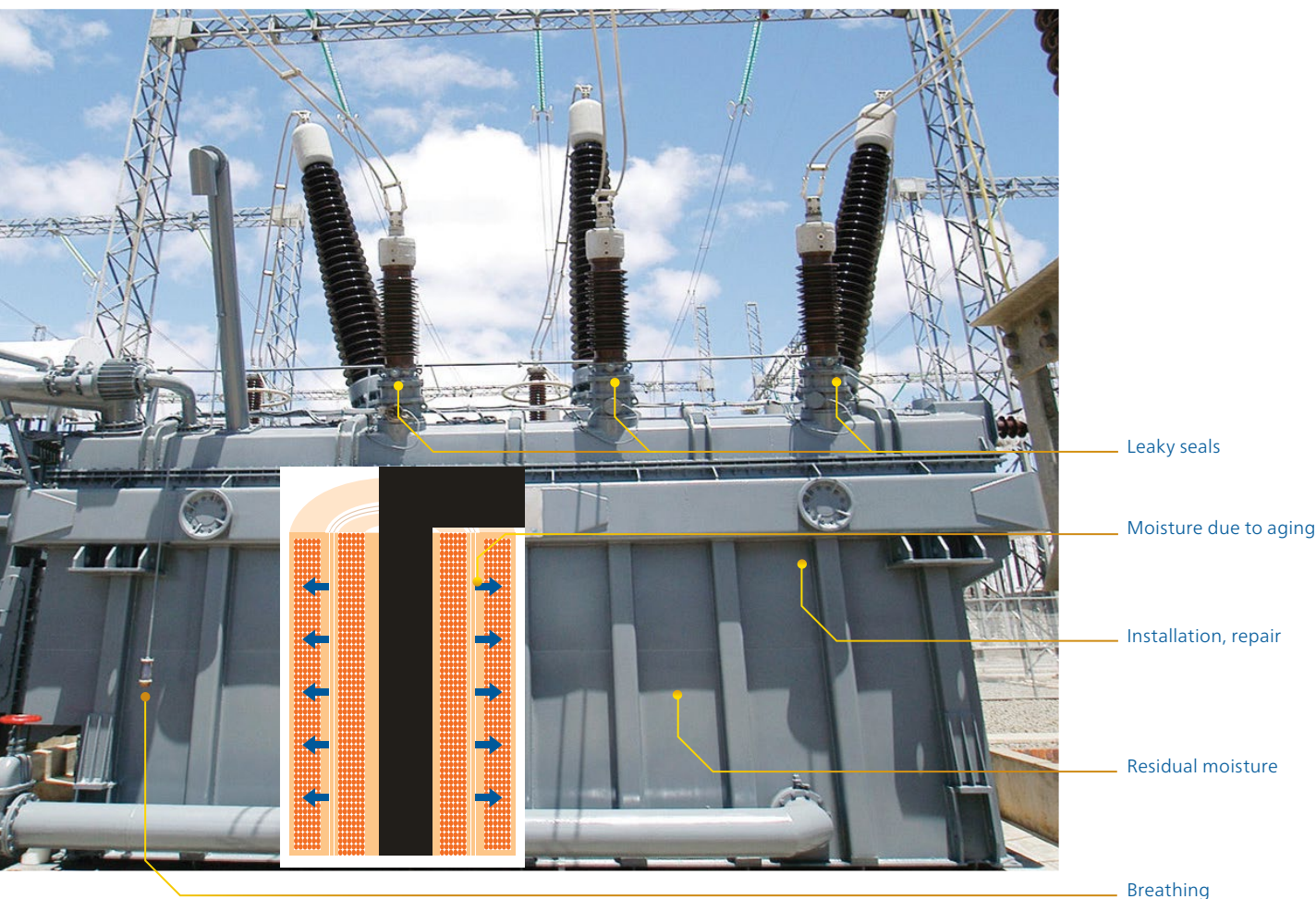
For example, DIRANA helps you to prioritize the maintenance of your transformer fleet by analyzing the moisture content of the oil-paper insulation. The test result provides a water content of the paper that can be compared to other moisture analysis techniques.

## Moisture in oil-paper insulation

Water in transformers comes from four sources: residual water after drying, water from cellulose and oil aging (oxidation), water through leaky seals or repairs, and water due to breathing. Therefore, even in the case of a non-breathing transformer the moisture can reach a critical level.

Moisture entering in oil-paper insulations can cause three dangerous effects: it decreases the dielectric withstand strength, accelerates cellulose aging (de-polymerization) and causes the emission of gas bubbles at high temperatures.

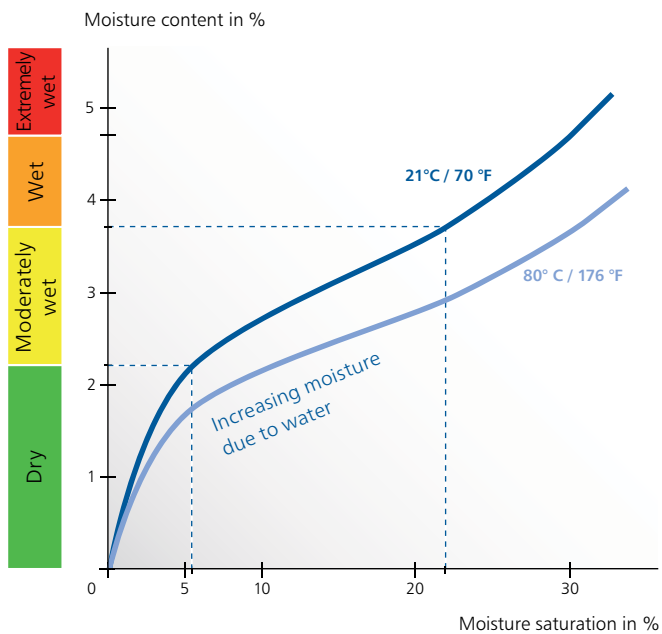
Typically the solid part of the insulations e.g. pressboard, paper and wood holds the majority of the water, i.e. 2000 times more than the oil. Thus the moisture concentration in the paper insulation is much more important than that in the oil.



## Why moisture determination?

An accurate assessment about the actual moisture content is required in order to decide if further corrective action, such as drying, is necessary.

The graph below shows the temperature dependent relationship between moisture content and moisture saturation to allow conversion of the measured values.



Moisture content relates water mass to the material mass, whereas moisture saturation relates water mass to the maximum water mass a material can adsorb.

## How to assess the results?

IEC 60422 categorizes moisture saturation of more than 6 % as “moderately wet”, which is equivalent to a moisture content of approximately 2.2 %. At this level the dangerous effects caused by water can affect the insulation. Based upon this, corrective action should be taken for e.g., a drying process. Below is the moisture assessment used per IEC 60422.

Moisture Categories				
Dry:	below	2.2 %		
Moderately wet:	2.2 %	to	3.7 %	
Wet:	3.7 %	to	4.8 %	
Extremely wet:	above	4.8 %		

Assessment Result		
Moisture Content:	2.2 %	dry
Oil Conductivity:	5.3 pS/m	good
Data Quality:	perfect	

## Your benefits

- > Determination of moisture content in oil-paper insulations for a more accurate condition assessment
- > Reliable quantitative data for an efficient condition-based maintenance program
- > Moisture assessment is based upon international standards

# Moisture assessment

## Why dielectric measurements for moisture determination?

Traditional oil sampling methods requires the use of an equilibrium diagram for evaluating moisture in transformers and can result in errors in the assessment. The application of conventional equilibrium charts causes inaccurate results due to the uncertainties during the sampling and water-in-oil measurement. Together with very long time constants for equilibrium processes, it leads to a very poor accuracy.

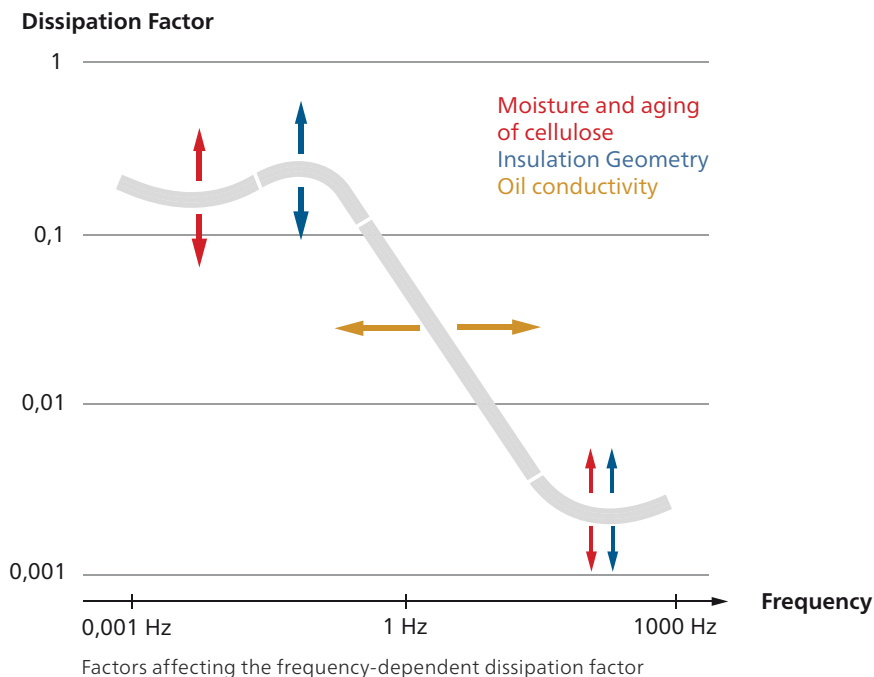
The dielectric response method, in contrast, is a very reliable method providing a high degree of accuracy in assessing the moisture content in the paper insulation.

## How does it work?

DIRANA derives the moisture content in paper or pressboard from properties such as polarization current, complex capacitance, and dissipation factor. Each of these parameters is strongly affected by moisture.

The dissipation factor plotted against frequency shows a typical S-shaped curve. With increasing moisture content, temperature or aging the curve shifts towards the higher frequencies. Moisture influences the low and the high frequency areas. The linear, middle section of the curve with the steep gradient reflects oil conductivity. Insulation geometry conditions determine the "hump" which is located to the left side of the steep gradient.

DIRANA's moisture determination is based on a comparison of the transformers dielectric response to a modeled dielectric response. A fitted algorithm compares the measured data with the model data and calculates the geometry data, the moisture content as well as the oil conductivity. Only the oil temperature needs to be entered.



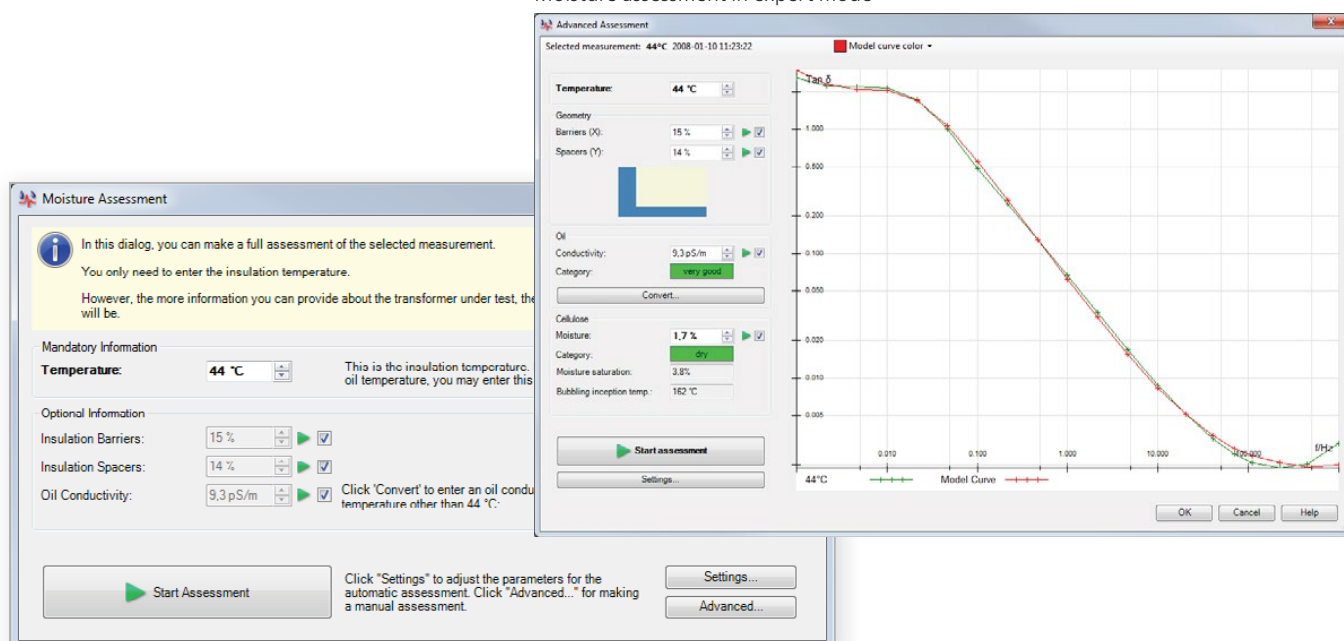
## Easy-to-use and efficient software

The software combines expert knowledge with an intuitive user interface. You can select between basic and extended moisture assessment (basic and expert mode). If necessary, a software wizard is available which helps to perform the assessment.

## Reliable results even for aged oil-paper-insulation

DIRANA compensates for the influences of conductive aging byproducts such as acids. These substances increase the dielectric losses in the same way as water and may therefore lead to an overestimated water content. DIRANA's software uses a compensation algorithm that provides reliable results even with aged oil-paper-insulations.

Moisture assessment in expert mode



Moisture assessment in basic mode

## Your benefits

- > Scientifically proven interpretation scheme
- > Automated analysis of moisture content and oil conductivity
- > Compensation for temperature and insulation geometry
- > Reliable results even for aged oil-paper-insulations

# Innovative measurement with OMICRON

OMICRON's DIRANA determines the dielectric properties of insulation within a wide frequency band. Based upon dissipation factor and capacitance, the system analyzes the moisture content in oil-paper-insulation. DIRANA also lends itself well to other high voltage insulation systems e.g. transformers, bushings, instrument transformers, cables and generators.

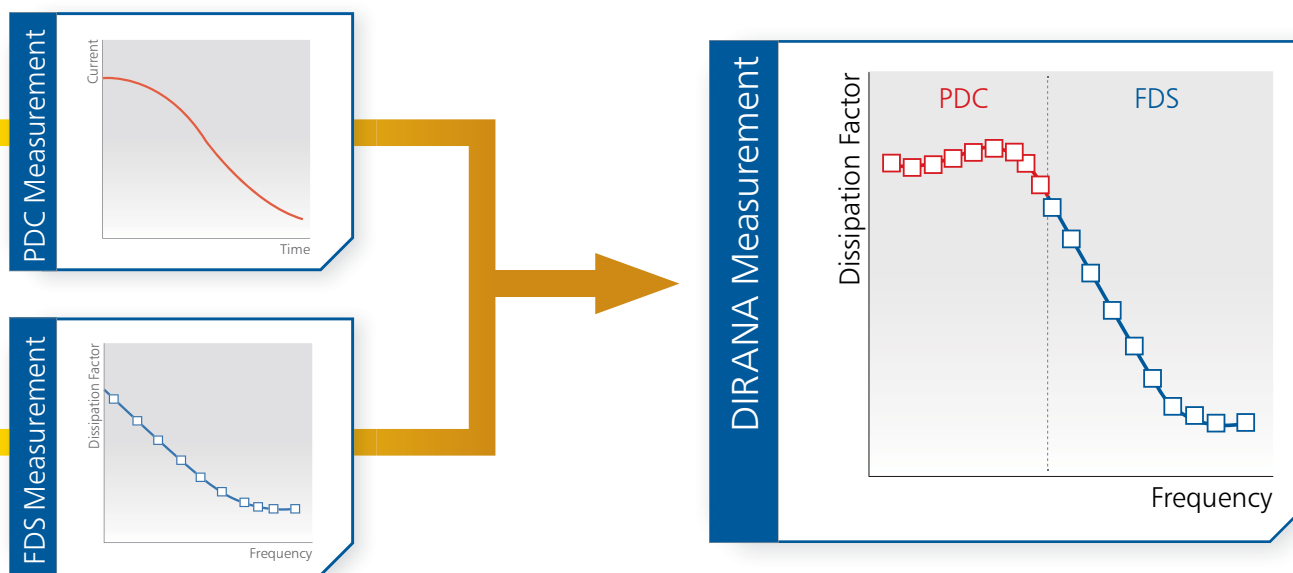
## Time and frequency domain method combined

DIRANA combines the polarization current measurement (PDC) method in time domain with the frequency domain spectroscopy (FDS) and thus significantly reduces the testing time compared to existing techniques. Essentially, time domain measurements can be accomplished in a short time period but are limited to low frequencies. In contrast, frequency domain measurements are feasible for high frequencies but take very long time at low frequencies.

DIRANA's patented technique combines the advantages of both principles. It acquires data in the time domain from

10  $\mu$ Hz to 0.1 Hz and in the frequency domain from 0.1 Hz to 5 kHz. This reduces the measuring duration by up to 75 % compared to exclusive frequency domain measurements.

For instance, data acquisition for a typical frequency domain measurement from 1 kHz down to 0.1 mHz will take 11 hours, DIRANA will acquire this data in under 3 hours. DIRANA transforms the time domain currents into the frequency domain for subsequent evaluation.



12 h	FDS	100 $\mu$ Hz ... 1 kHz
5.5 h	PDC	100 $\mu$ Hz ... 1 Hz
3 h	DIRANA	100 $\mu$ Hz ... 1 kHz

Test duration

Frequency band



## Reliable moisture assessment with DIRANA

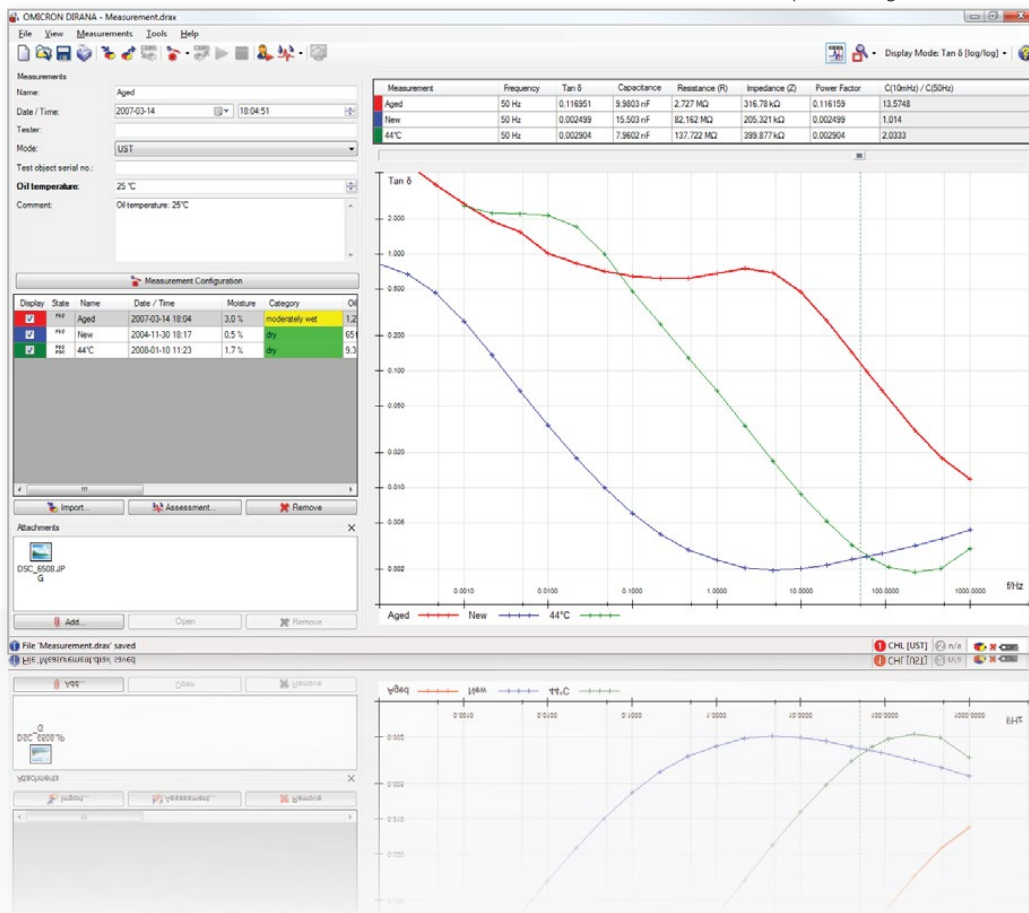
Water can cause dangerous effects for oil-paper insulation, it decreases the dielectric withstand strength, accelerates aging of the paper insulation and causes the emission of gas bubbles at high temperatures. Thus knowledge about the moisture concentration is of utmost importance for the equipment operator.

DIRANA analyzes the dielectric response for determination of the moisture content in the paper of oil-paper insulation. For this purpose, the software uses a scientifically proven database to compare the measure values. This is

done completely automatically, only the oil temperature needs to be entered.

The automated assessment compensates influences such as temperature, insulation geometry, oil conductivity and aging byproducts. Conductive aging byproducts appear as water and cause an overestimation of the moisture content leading to unnecessary drying. However, DIRANA compensates for this influence and thus reliably detects moisture even in aged oil-paper insulation.

Intuitive user interface for performing measurements



# Technical data

## Technical data

---

### Voltage source

Measurement voltage	200 V <sub>peak</sub>
Max. continuous output current	50 mA <sub>peak</sub>

### Dissipation factor, capacitance

Dissipation factor range, resolution	0...10, 10 <sup>-6</sup>
Accuracy for:	
1 mHz < f < 100 Hz	1 % + 3 × 10 <sup>-4</sup>
f < 1 mHz and f > 100 Hz	2 % + 5 × 10 <sup>-4</sup>
Capacitance	10 pF ... 100 µF
Accuracy	0.5 % + 1 pF

### Time domain current measurement (PDC)

Range, resolution	20 mA, 0.1 pA
Input resistance	10 kW
Accuracy	0.5 % ± 1 pA

### Frequency Domain Spectroscopy (FDS)

Measurement voltage	200 V <sub>peak</sub>
Measurement current	50 mA <sub>peak</sub>

### Ranges for combined FDS and PDC measurement

Frequency	5 kHz ... 50 µHz (using approximation: 10 µHz)
-----------	---

### Measuring time (based on frequency)

2 mHz ... 1 kHz	approx. 15 min.
100 µHz ... 1 kHz	< 3 h
10 µHz ... 1 kHz	< 6 h

### Mechanical data / supply voltage

Dimensions (w × h × d)	260 × 50 × 265 mm/ 10.25 × 2 × 10.5 inch
------------------------	---

#### Weight

Instrument	2.3 kg / 5 lbs
Complete case	20 kg / 44.1 lbs

Supply voltage	100 V ... 240 V
----------------	-----------------

Frequency	50 Hz ... 60 Hz
-----------	-----------------

### Calibration

Optional calibration every two years

### PC requirements

Operating system	Windows XP, Windows Vista, Windows 7
CPU / RAM	Pentium 1 GHz / 512 MB
Interface / Drives	USB 2.0 / CD-ROM drive

### Environmental conditions

Ambient temperature	
in operation	-10 °C ... +55 °C / -31 °F ... 131 °F
for storage	-10 °C ... +65 °C / 31 °F ... 149 °F
Relative humidity	20 % ... 95 %, non-condensing
Air-pressure (storage/operation)	70 kPa ... 106 kPa

### Software tests

GST (Grounded Specimen Test)	Measurement with grounded test object
GSTg (Grounded Specimen Test, inkl. Guard)	Measurement with grounded test object and guard
UST (Ungrounded Specimen Test)	Measurement with ungrounded test object

## DIRANA ordering information

Packages	Description	Ordering No.
Complete DIRANA set	DIRANA comes in a rugged case which contains all necessary accessories like connection cables with clamps, drums etc.	VE000670



### Get your DIRANA training!

OMICRON Academy offers well-known training courses to answer any individual question you might have. The training "Moisture Determination and Dielectric Diagnostics of Power Transformers" covers:

- > Methods of moisture determination and theory of dielectric frequency response
- > Operating concept of DIRANA and its accessories
- > Practical sessions with DIRANA on a power transformer
- > Interpretation of the dielectric response curves

📄 [www.omicronenergy.com/training](http://www.omicronenergy.com/training)

OMICRON is an international company serving the electrical power industry with innovative testing and diagnostic solutions. The application of OMICRON products allows users to assess the condition of the primary and secondary equipment on their systems with complete confidence. Services offered in the area of consulting, commissioning, testing, diagnosis and training make the product range complete.

Customers in more than 140 countries rely on the company's ability to supply leading-edge technology of excellent quality. Service centers on all continents provide a broad base of knowledge and extraordinary customer support. All of this together with our strong network of sales partners is what has made our company a market leader in the electrical power industry.

For more information, additional literature,  
and detailed contact information of our  
worldwide offices please visit our website.