POWER TRANSFORMER MAINTENANCE

▶ ETP SYSTEM

ETP SYSTEM

Condition-based maintenance of power transformers

The predictive and condition based maintenance is nowadays accepted as the most efficient solution to guarantee the proper operation of critical assets. In both electrical power generation, T & D and industry applications, power transformers are essential and require the right maintenance policy.

Due to the high cost of the on-line monitoring systems and the need of performing scheduled shutdowns for other different reasons as mechanical revisions, the off-line tests provide a cost-efficient, safe way to proper transformer maintenance.

The ETP system will guide the operator with messages on the computer's screen, while an exhaustive set of measurements is performed on the analyzed transformer. Three-phase connection instructions are displayed, as well as wait messages while the secondary windings are discharged automatically.

Each transformer's technical parameters are saved into a database along with the results obtained during successive tests, in order to recall them in the future and to perform their evolution in the time.

Complete three-phase system

The ETP System is composed by four independent measurement modules controlled from a common measurement & analysis software in a PC. Diagnostics are performed by co-relating the measurements done by each module:

✓ **Turns Ratio:** three-phase measurement of the turns ratio and the excitation current in every position of the tap changer. Results are compared with the theoretical values and the error is shown graphically.
✓ **Recovery Voltage:** evaluation of the solid and liquid insulation condition through electrical measurements.
✓ **Winding Resistance:** three-phase measurement of the resistance values in every winding and for every position of the tap changer.
✓ **Short-circuit Impedance:** evaluation at low voltage of the short-circuit impedance and voltage.

The above measurements are used to evaluate the condition and then predict possible failures at the four main circuits in a transformer:

✓ **Electrical Circuit:** checking the continuity of the windings, the connections and the tap changer.
✓ **Geometrical Circuit:** checking the symmetry between the columns of the core, between the windings and the core and between these and the transformer's enclosure.
✓ **Magnetic Circuit:** checking the condition of the magnetic core (loose plates, short-circuits, detachment of the magnetic shunt, etc.).
✓ **Dielectric Circuit:** checking the degradation and the ageing of the solid and liquid insulation.

Testing is a simple, automatic and fully software-guided task. The operation is divided into to main steps: 1) Measurement, wich guides the operator to the connections and wait operations, eliminating human errors and ensuring repeatability, and 2) Analysis, by immediately displaying the measured values on the screen as they are acquired by the software. The information can be immediately converted into a complete report and interpreted by an expert to determine whether maintenance operations should be planned or not.

ETP Trends software will produce an evolutive view of the transformer's condition by collecting results from successive tests within any two dates.

ETP Diaghelp will apply an expert algorithm to the test results to provide a direct, concise diagnostic of the transformer including alerts, warnings and service recommendations.

Independent modules

The four modules that compose the ETP System can also be used separately. For example, you can use the ETP-2 if you only need to evaluate the condition of the liquid isolation (paper & oil). The software will automatically detect the connected module and will enable the corresponding measurement functions only.

The more different modules you connect, the more complete and accurate analysis you will get, naturally. This is particularly important if you also want to use the DiagHelp software for expert diagnostics.

Please note that measurement results determined as 'suspicious' by one of the modules can, in most cases, be confirmed by using other –complementing- module.

Every ETP combination (one or more modules) is delivered with the necessary test leads, calibration certificates and a transport bags, as well as the ETP software and the communications cables.

The characteristics of the individual modules are described along the following pages in this brochure.

The following table provides a brief listing of the failures typically detected by each module:

Failure	Detected Damage	ETP-1	ETP-2	ETP-3	ETP-4
Core	General status	● ●	—	—	● ●
Connection	Tap changer breakdown	● ●	—	● ●	—
	Connection slakening	●	—	● ●	●
Windings Integrity	Windings displacement	—	—	—	● ●
	Open Winding	● ●	—	● ●	● ●
	Winding hot spot	—	—	● ●	—
	Short circuit between turns	●	—	● ●	● ●
	Winding partial short circuit	● ●	—	● ●	● ●
Liquid and Solid Insulation	Degradation of solid dielectric	—	● ●	—	—
	Degradation of liquid dielectric	—	● ●	—	—
	Contamination of the insulation	—	● ●	—	—
	Anomalous aging	—	● ●	—	—

Complete ETP System
(ETP-1, ETP-2, ETP-3, ETP-4 and test software)

Understanding the results

All the measured and calculated parameters are defined, contrasted and delimited by the main international standards (IEEE, IEC). The experience in the diagnostics and the help brought by our diagnostics software ETP DiagHelp allow relating all these parameters quickly, and then determining the issues in the transformer's condition. However, the basis of the condition based maintenance is the trend analysis. The ETP Trends software provides a quick, graphical view of all the results: every results from successive tests performed in the same transformer is shown in a table and a graph. Thanks to this feature, we can optimize the scheduling of the shutdowns and revisions to be performed on the machine, so reducing intervention cost and downtime.

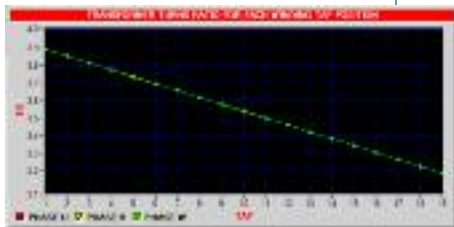## Surge Protection Multi-socket

This optional accessory provides additional protection to your ETP equipment and to the user. It features an interference filter, an overvoltage protection, supply voltage display, thermal-magnetic breaker and an indicator of defective or non-existent ground connection.

ETP-1

Turn Ratio Measurements

Turn Ratio Graphics

Three-phase Turn Ratio and Excitation Current Meter

The ETP-1 module determines the turn ratio on the three phases of power and distribution transformers and autotransformers of any type by applying a test voltage on the high-voltage winding and measuring the resulting voltage on the low-voltage winding. This method also provides the evaluation of other parameters:

- Excitation current I_1
- Phase angle between the test voltage V_1 and the excitation current I_1
- Phase angle between the test voltage V_1 and the measured V_2

The test is performed at low voltage and at the supply's frequency, which makes the ETP-1 adequate for field testing and for quality assessment in production lines.

The following problems can be detected with the ETP-1:

- Shorted turns
- Interrupted windings
- Magnetic core problems
- Dirty or damaged tap changer

Database storage of results enables individual tracking of each transformer.

SPECIFICATIONS

Power supply	230V ac ± 10%, 50Hz ± 5% or 60Hz ± 5% 115V ac ± 10%, 50Hz ± 5% or 60Hz ± 5% 350 VA max
Test signal	Voltage: 115V rms Current: < 2A rms
Measurement ranges	Turn ratio: 0.9:3000, 7 scales Resolution: 4 ½ digits Accuracy: ± 0.3% reading ± 2 digits Current: 3.1:2000 mA rms, 6 scales Resolution: 3 digits Accuracy: ± 1% reading ± 2 digits Phase angle: -180° +180° Resolution: 3 digits Accuracy: ± 0.15°
Measurement time	Single-phase: 20 to 35" depending on mode Three-phase: 60 to 90" depending on mode
Measurement modes	High to Low ratio High to Tertiary ratio
Environmental conditions	Temperature: 5° - 35° C / 40° - 95° F Humidity: 10 - 80% non-condensating
Storage	Temperature: 5° - 75°C / 40° - 165° F Humidity: 10 - 80% non-condensating
Physical dimensions	Depth: 40 cm / 16" - Width: 45 cm / 18"- Height: 13.5 cm / 5" Weight: 13 Kg. / 28 lb.
Test leads	Length: 2 x 8 m / 2 x 26 ft. Weight: 2 x 6 Kg. / 2 x 13 lb.

ETP-2

Recovery Voltage, Time Constant, and Insulation Resistance Meter
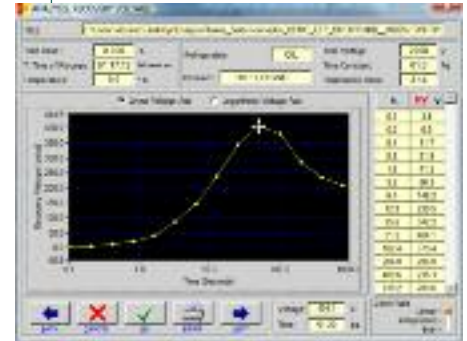
The ETP-2 module measures the recovery voltage (polarisation spectrum) on power and distribution transformers and autotransformers of any type with oil-paper dielectric, calculating the degree of humidity contained in the paper and evaluating the overall condition of the oil-paper system.

These calculations are performed by applying various DC voltage levels through a programmable output during specific time intervals. Calculated parameters are:

- Recovery voltage and Time Constant
- Insulation Resistance
- Polarisation index

The following problems can be detected with the ETP-2:

- Solid dielectric degradation
- Liquid dielectric degradation
- Contaminated insulation

Recovery Voltage Analysis
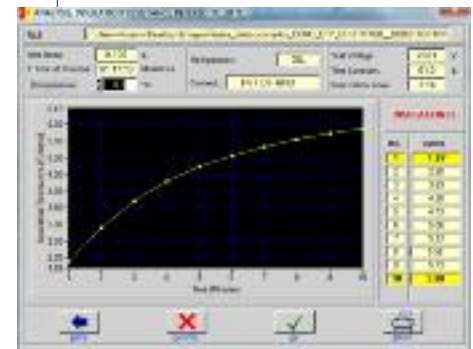
Insulation Resistance Analysis

SPECIFICATIONS

Power supply	230V ac ± 10%, 50Hz ± 5% ó 60Hz ± 5% 115V ac ± 10%, 50Hz ± 5% ó 60Hz ± 5% 60 VA max
Test signal	Range: 500V / 1000V / 1500 V / 2000V Current: maximum 5 mA. Resolution: 1 V Accuracy: ± 1% ± 1 digit
Measurement ranges	Recovery Voltage: 0 – 1000V Test Voltage: 0 – 2000V Insulation:

Scale 1	@2000V	1 MΩ - 100 GΩ
Scale 2	@2000V	100 GΩ - 200 GΩ
Scale 3	@2000V	200 GΩ - 2TΩ

Accuracy	Recovery Voltage: ± 3% ± 3 digits Test Voltage: ± 1% ± 3 digits Insulation:

Scale 1	1 MΩ - 100 GΩ	± 3% ± 3 digits
Scale 2	100 GΩ - 200 GΩ	± 5% ± 3 digits
Scale 3	200 GΩ - 2TΩ	± 20% ± 3 digits

Used parameters	**Recovery Voltage** **Insulation Resistance** **Polarisation Index** **Time Constant**
Environmental conditions	Temperature: 5º - 35º C / 40º - 95º F Humidity: 10 - 80% non-condensating
Storage	Temperature: 5º - 75ºC / 40º - 165º F Humidity: 5 - 80% non-condensating
Physical dimensions	Depth: 40 cm / 16” - Width: 45 cm / 18”- Height: 13.5 cm / 5” Weight: 10 Kg. / 22 lb.
Test leads	Length: 2 x 8 m / 2 x 26 ft Weight: 2 x 4 Kg. / 2 x 9 lb.

ETP-3

Three-phase Winding Resistance Meter

The ETP-3 is designed to measure very low resistance values on transformer windings or on any load with a strong inductive component. The unit applies the necessary DC current to magnetize the winding and stabilize the current, in order to provide an accurate, repeatable measurement.

The software takes into account the connection group and the temperature to calculate simple (u, v, w) and compound (uv, uw, vw) ohmic resistance values referenced to a normalized temperature (temperature-corrected). The ohmic values obtained allow verifying the correct insulation between turns, and to assess the transformer's specified electrical and mechanical characteristics.

The following problems can be detected with the ETP-3:

- Loose connections
- Tap changer malfunction
- Shorted turns
- Hot spots on the windings

Winding Resistance Values
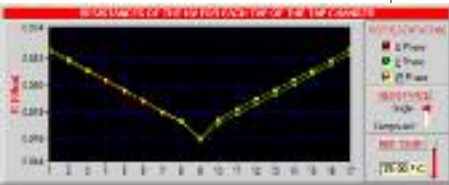
Winding Resistance Graphics

SPECIFICATIONS

Power supply	230V ac ± 10%, 50Hz ± 5% ó 60Hz ± 5% 115V ac ± 10%, 50Hz ± 5% ó 60Hz ± 5% 450 VA max
Test signal	Voltage: 24 Vdc max Current: 0 – 20A ± 5%
Used parameters	**Compound winding resistance** **Simple winding resistance** **Temperature-corrected**

Measurement ranges				
Current	**Range**	**Accuracy**	**Resolution**	
20A	10mΩ	±0.5% ±2 digits	1µΩ 4 digits	
20A	100mΩ	±0.5% ±2 digits	10µΩ 4 digits	
5A	1Ω	±0.5% ±2 digits	100µΩ 4 digits	
500mA	10Ω	±0.5% ±2 digits	1mΩ 4 digits	
50mA	100Ω	±0.5% ±2 digits	10mΩ 4 digits	
5mA	1000Ω	±0.5% ±2 digits	100mΩ 4 digits	

Measurement modes	**Manual**: The user stops the test when the Reading is accepted as reliable. **Automatic**: The software determines when to finalise the measurement. **By phase**: Allows accelerating the measurement on transformers greater than 100 MVA
Environmental conditions	Temperature: 5º - 35º C / 40º - 95º F Humidity: 10 - 80% non-condensating
Storage	Temperature: 5º - 75ºC / 40º - 165º F Humidity: 5 - 80% non-condensating
Physical dimensions	Depth: 40 cm / 16" - Width: 45 cm / 18"- Height: 13.5 cm / 5" Weight: 11.7 Kg. / 26 lb.
Test leads	Length: 8 m / 26 ft Weight: 14.15 Kg. / 32 lb.

ETP-4

Three-phase Short Circuit Impedance and Short Circuit Voltage Meter

The ETP-4 module measures the short-circuit impedance in distribution and power transformers by applying a test voltage on the high voltage winding and measuring the resulting current and phase angle. The reading is automatically compensated by the transformer's temperature value and normalized to 75º C / 165º F.

The following problems can be detected with the ETP-4 module:

- Shorted turns
- Interrupted winding
- Tap changer dirt or damages
- Magnetic core problems

Short-circuit impedance values

SPECIFICATIONS

|	
Power supply	230V ac ± 10%, 50Hz ± 5% ó 60Hz ± 5% 115V ac ± 10%, 50Hz ± 5% ó 60Hz ± 5% 880 VA max
Test signals	Voltage: 12, 24, 48, 108 or 216 Vrms Current: 4 Arms max. Frequency: supply
Measurement modes	Impedance in primary with short-circuited secondary Impedance in primary with short-circuited tertiary
Measurement ranges	Short-circuit Impedance: 2,5 Ω - 4000 Ω in 8 Scales
Measurement times	Single-phase: 28 seconds Three-phase: 1 min. 28 seconds
Accuracy	Short-circuit Impedance: ± 1% ± 2 digits Phase angle: ± 25% between 0 and 10º ± 2% between 10 and 360º
Used parameters	Primary current on each phase Primary & secondary voltage on each phase Phase angle between voltage and current on primary and secondary windings Phase angle between primary and secondary voltages Short-circuit impedance and voltage
Environmental conditions	Temperature: 5º - 35º C / 40º - 95º F Humidity: 10 - 80% non-condensating
Storage	Temperature: 5º - 75ºC / 40º - 165º F Humidity: 5 - 80% non-condensating
Physical dimensions	Depth: 40 cm / 16" - Width: 45 cm / 18"- Height: 13.5 cm / 5" Weight: 16 Kg. / 35 lb.
Test leads	Length: 8 m / 26 ft Weight: 14.15 Kg. / 32 lb.

Expert analysis software

The Diaghelp and Trends software packages complete the EDA III and ETP systems, facilitating results analysis and subsequent decision-making.

The ETP DiagHelp program makes it possible to perform an initial estimate of the status of the transformer, applying diagnosis criteria to the calculations and measurements carried out by the ETP system. These criteria are based on various standards, theoretical principles and more than 10 years of experience of numerous experts. After entering the transformer's serial number, DiagHelp will analyze the results from any of the saved tests and will display the transformer's critical elements on a chart with green, yellow and red indicators, alerts and recommendations as appropriate.

The efficiency and accuracy of DiagHelp diagnostics will be optimum when the four ETP modules are used for testing.

ETP Trends is designed to collect the results from a series of consecutive tests performed on a specific transformer between any two given dates, in order to track the evolution of the machine with time, establishing trends for each of the parameters considered. In this way, it is possible to detect when a transformer enters a risk zone and to schedule the most appropriate maintenance actions. A report including tracking graphics can be generated instantaneously.
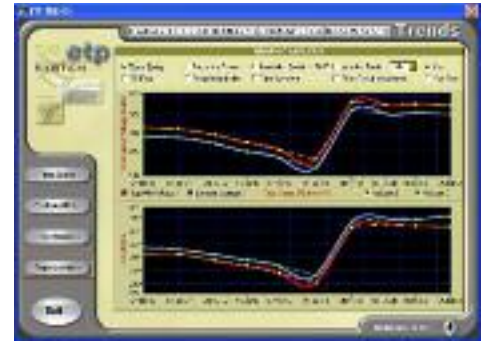
ETP Trends: tap changer failure, tracked before and alter servicing

ETP DiagHelp: shorted turn alert

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