

Transformer Diagnostic Testing

Performing Winding Resistance and Turns Ratio Tests



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Power transformers play a vital role in power transmission. They are used to raise or lower the voltages in the power delivery system. High voltage (HV) power transformers are very expensive to manufacture and require long lead times since they are very labor intensive. A failed transformer is not only costly to replace but also causes loss of revenue to the utilities. Due to this reason, proper maintenance to ensure reliable performance and longevity is of utmost importance.

In operation, all transformers are subjected to internal as well as external fault current. Transformers will see more external than internal fault. Fault current imposes high mechanical stresses on the transformer's windings and its mechanical structure. These high stresses weaken and alter the mechanical structure of the transformer. Hoop buckling of windings and winding deformations are typical effects of high stresses caused by a short circuit in the system. Also the heat generated during normal operation and during a fault, oxidizes the transformer oil. Over time, the interaction of the insulation paper (used for conductor wrapping) with the hot transformer oil weakens the dielectric strength of the transformer.

In current operational environments, getting the required long outage to test transformers is not that common. So when the outage is planned, all the required tests need to be performed quickly. Although all tests need to be performed during the short outage time, personnel safety should never be overlooked or compromised. For transformer maintenance, personnel safety and speedy testing are the two most important factors. Several different tests can be performed on a transformer to analyze its condition. The transformer winding integrity can be verified by using the Sweep Frequency Response Analyzer test. The transformer bushing and overall insulation integrity can be analyzed using the Tan-delta (or Power Factor) test. Chemical analysis of the transformer oil should be conducted to detect moisture and determine the dielectric strength of the oil. Additionally, transformer turns ratio and winding resistance tests are used to detect shorted windings and possible connection issues. The focus of this application note is on winding resistance and turns ratio tests.

Winding resistance tests can verify the winding connections to the transformer bushings, or the winding contact resistance (as in the case of the load tap changer and voltage regulator). A properly-designed winding resistance meter can obtain fast and accurate resistance readings when performing an HV transformer winding resistance test.

A typical transformer winding resistance meter employs a high DC power supply (20Vdc to 60Vdc) to drive the winding into saturation. The use of a high DC voltage will quickly drive the winding into saturation and reduce the waiting time for stable readings. A high test current also delivers more accurate readings in noisy environments.

Since the transformer winding is highly inductive, it will store the energy injected into it during testing. This energy must be safely discharged in a controlled way to avoid the risk of injury to test technician as well as damage to the test instrument. For operator safety, this discharge circuit should be built into a transformer winding resistance meter. The test equipment should also provide clear audio and visual warnings to the user.

Vanguard Instruments offers the economical WRM-10, a 10A/36Vdc winding resistance meter that features dual resistance reading channels. The WRM-10 is capable of measuring winding resistance of transformers up to 200MVA. For higher test currents, Vanguard offers the TRM-20 (20A) and TRM-40 (40A). Both devices employ a 60Vdc voltage source that can quickly saturate very large HV transformer windings, providing fast and stable readings. Dual resistor reading channels can simultaneously read the HV and LV winding resistances (Figure 1). This feature further reduces the measurement time by at least 50%

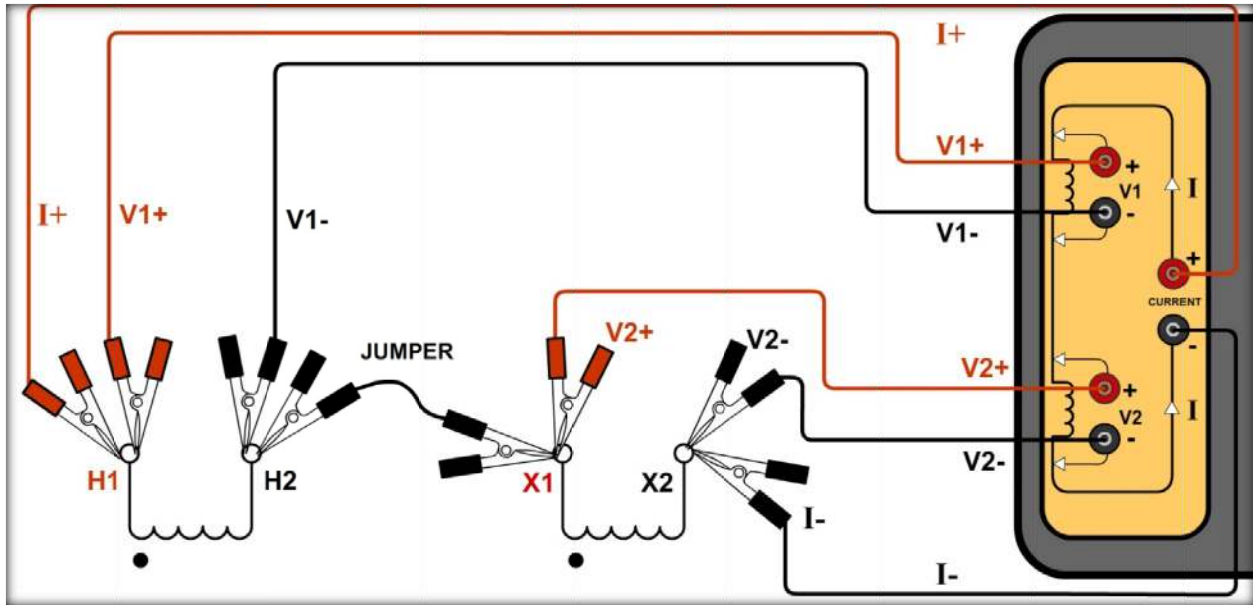


Figure 1. Dual winding Connection

Vanguard also offers three-phase winding resistance meters, the TRM 203 (20A) and TRM 403 (40A). The test terminals from these devices can connect to all the transformer HV or LV bushings. The device will then inject the DC test current to each of the phases and measure the resistance value. This feature reduces the testing time by making connections to the transformer only once (Figure 2).

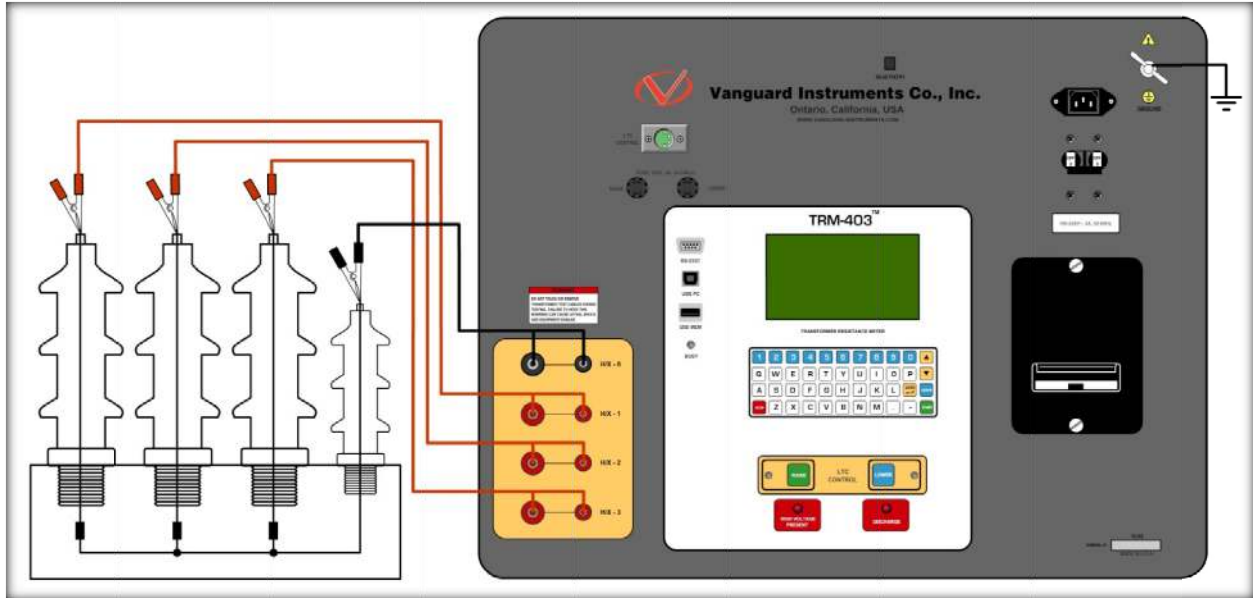


Figure 2. Three-phase Winding Connection

Since a DC test current is passed through the transformer winding during the DC resistance test, the transformer core will be magnetized. When a magnetized-core HV transformer is energized the first time, the excessive in-rush current may trip the protection relays. Steps should be taken to eliminate this remnant magnetism.

Both the TRM-20/40 and TRM-203/403 have built-in transformer demagnetization capabilities. This feature minimizes the remnant magnetism in the transformer core after a DC resistance test.

For high voltage transformers with a load tap changer, it is a very desirable feature that the DC winding resistance meter also verify the continuity and correct operation of the load tap changers (LTC's). These are the only moving parts of a transformer, and like all mechanical devices, they are susceptible to wear and tear. In fact, LTC's result in more failures and outages than any other transformer component, so regular testing to ensure reliable and safe operation is essential.

The Vanguard LTCA-10 and LTCA-40 Load Tap Changer Analyzers offer dynamic resistance testing capability on the Load tap changer on the transformer. The test current used for LTCA-10 and LTCA-40 are 10A and 40 A, respectively. A typical LTCA-10 test connection diagram is shown in figure 3. A DC test current is injected through the LTC contact. The LTC is then operated through all taps while the Vanguard LTCA records the test current and voltage drop across the LTC contact. The LTCA can produce a high resolution resistance waveform of the LTC contact during operation as shown in figure 4. The user can observe the LTCA contact resistance reading/graph transitioning from one position to another. This is a powerful diagnostic tool for analyzing LTC and voltage regulator contact issues.

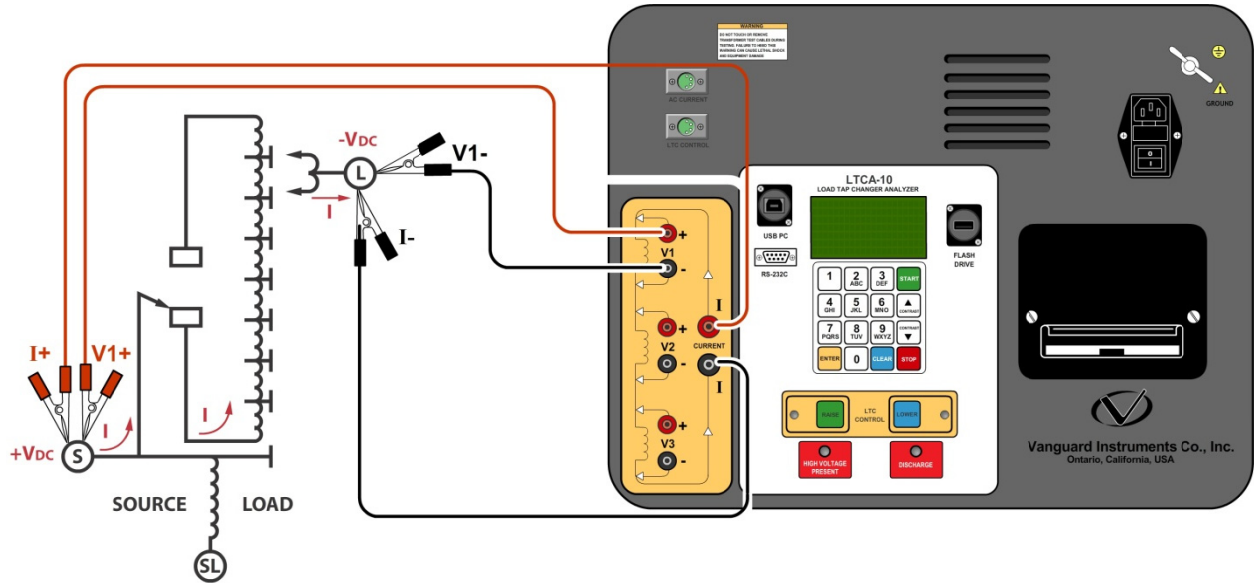


Figure 3. Dynamic Resistance Test Connections

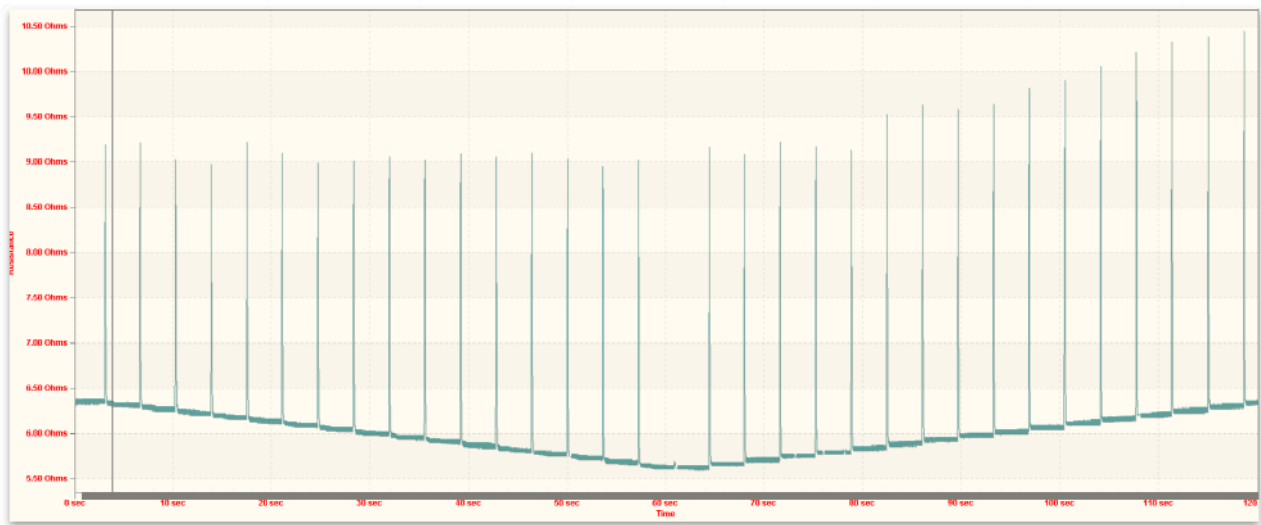


Figure 4. Dynamic Resistance Waveform of a Voltage Regulator

The IEEE C57.12.90 standard provides the guidelines for measuring transformer turns ratios using the voltage method. Turns ratio tests verify the transformer winding configuration, winding turns ratio, and excitation current. A typical 3-phase turns ratio tester applies a single phase excitation test voltage on the HV side of the transformer winding. The induced voltage on the corresponding phase is then measured on the secondary side. The turns ratio reading and excitation current is then displayed. Vanguard Instruments offers three 3-phase transformer turns ratio testers: ATRT-03 S2, TRF-100 and TRF-250. The TRF-250 provides the highest test voltage in the industry (250Vac).

A built-in thermal printer conveniently prints the test reports on site for instant analysis. All Vanguard Turns Ratio Testers can be used in stand-alone mode or can be PC-controlled with the provided software.

TRANSFORMER TEST RESULTS																					
DATE: 03/03/16	TIME: 07:15:55																				
COMPANY: VANGUARD INSTRUMENTS																					
STATION: FACTORY																					
CIRCUIT: 120V																					
MFR:																					
MODEL:																					
S/N:																					
KVA RTG: 500																					
OPERATOR: HAI																					
TEST VOLTAGE = 8 V																					
TYPE: YNd1																					
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X TAP: _____	X VOLTAGE: 100																				
CALCULATED RATIO: 10.000																					
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Figure 5. Thermal Printout from ATRT-03 S2

The ATRT-03 S2 and TRF-250 are also available as battery-operated models (ATRT-03A S2 and TRF-250A, respectively). This allows users to test transformers at a construction site when an AC supply is not available.

Vanguard Instruments also offers single phase transformer turns ratio tester models ATRT-01 S3 (AC power) and ATRT-01B S3 (AC/Battery powered).

Phase-shifting transformers are special transformers that require a 3-phase test voltage for the turns ratio test. Vanguard Instruments offers the Tri-Phase turns ratio tester for this application. The Tri-Phase generates its own 3-phase test voltage (8Vac, 40Vac, 100Vac) to test the transformers. This device accurately measures the turns ratio and the phase shift relationship between the HV and LV of the transformer. Sample test results are shown below in figure 6.

	Phase	H Voltage	H Tap	X Voltage	X Tap	Calc. Ratio	Meas. Ratio	Deviation	P/F	I[mA]	Angle
1	A	12000		208		57.6923	57.739	0.08		1.800	30.030
	B	12000		208			57.747	0.09		2.500	150.030
	C	12000		208			57.739	0.08		3.100	269.990
2	A	12000		208		57.6923	57.755	0.11		1.800	30.010
	B	12000		208			57.745	0.09		2.400	150.000
	C	12000		208			57.723	0.05		3.100	270.020
3	A	12000		208		57.6923	57.736	0.08		1.800	30.020
	B	12000		208			57.723	0.05		2.500	150.020
	C	12000		208			57.755	0.11		3.100	270.020

Figure 6. Typical Tri-Phase report showing the phase relationship

To get the most out of the limited time available during a transformer outage, a user typically performs as many tests as possible. The Vanguard Trip Saver Box (TSB) provides a convenient way to perform winding resistance tests as well as turns ratio tests in one go. The TSB eliminates the need to change test cables between the winding resistance meter (heavy gauge conductors to carry current) and the lighter gauge cables of the Turns Ratio tester as shown in figure 7. The TSB allows the same TRM cables to be used with the turns ratio tester.

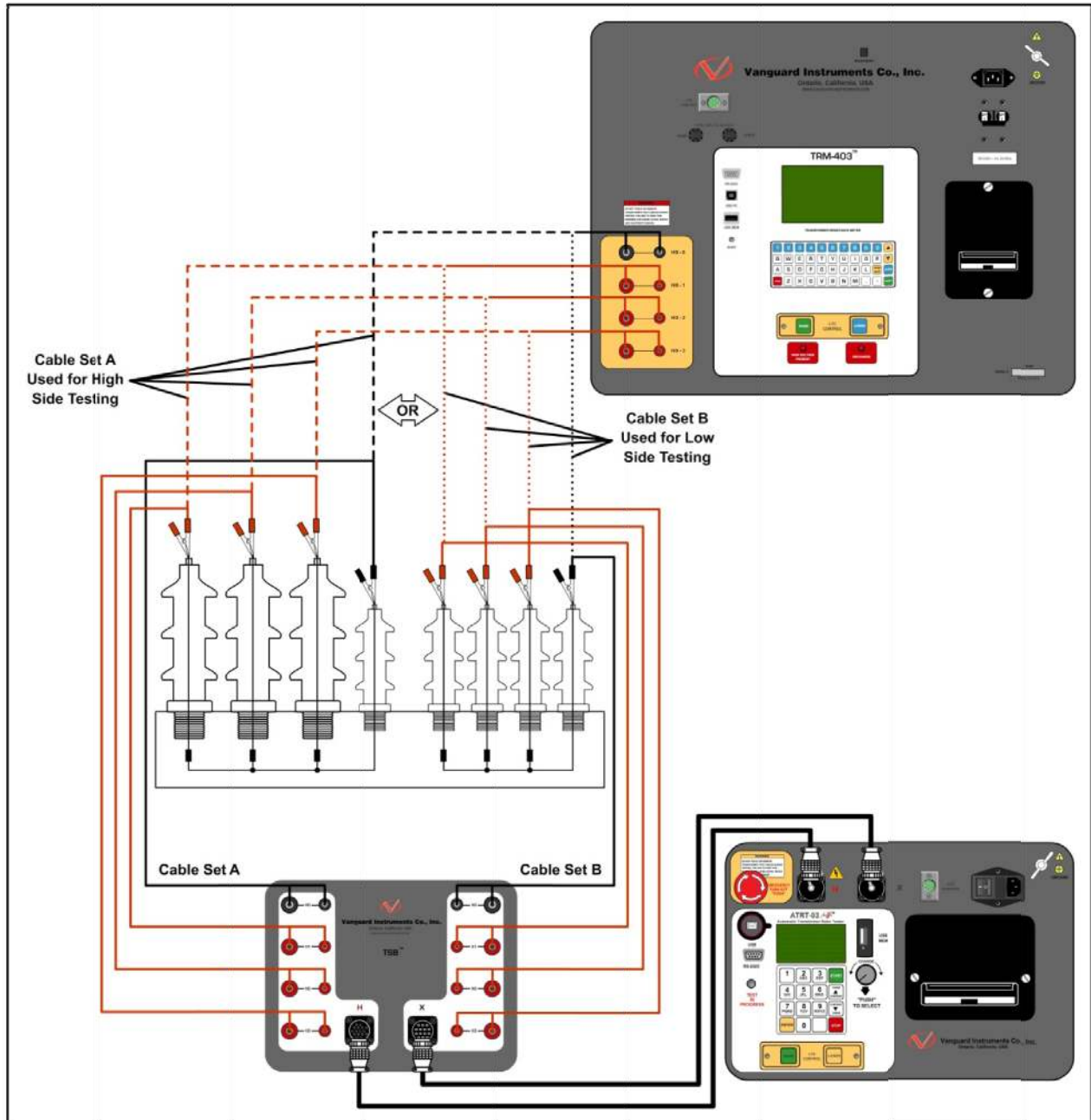


Figure 7. Trip Saver Connections to TRM-403 and ATRT-03 S2

The table below shows the Vanguard offerings for DC winding resistance measurement

Model	DC Test Current	# Windings Tested	Demag Routine
TRM-20	Up to 20A	Test two windings	Yes
TRM-40	Up to 40A	Test two windings	Yes
TRM-203	Up to 20A	Test three phases	Yes
TRM-403	Up to 40A	Test three phases	Yes
WRM-10	Up to 10A	Test two windings	No
LTCA-10	Up to 10A	Test three phases + LTC diagnostics	No
LTCA-40	Up to 40A	Test three phases + LTC diagnostics	No

The table below shows the Vanguard offerings for turns ratio testing

Model	Description	Test Voltages	Turns Ratio Range
ATRT-01 S3	Single phase	4, 40V	0.8 – 15,000 to 1
ATRT-01B S3	Single phase, Battery Powered	4, 40V	0.8 – 15,000 to 1
ATRT-03 S2	3-phase	8, 40, 100V	0.8 – 15,000 to 1
ATRT-03A S2	3-phase, Battery Power	8, 40, 100V	0.8 – 15,000 to 1
TRF-100	3-phase	4, 40, 100V	0.8 – 50,000 to 1
TRF-250	3-phase	4, 40, 100, 250V	0.8 – 50,000 to 1
Tri-Phase	True 3-phase	8, 40, 100V	0.8 – 15,000 to 1

Vanguard Instruments Winding Resistance Meters and Transformer Turns Ratio Testers are housed in field-rugged enclosures and feature rugged membrane keypads for convenient data entry and control. Optional built-in thermal printers are available for field use. All devices can be used in stand-alone mode or can be computer-controlled with the included software.

For further information on Vanguard Instruments' offerings for current transformer testing, please contact our local channel partner or visit our web site at www.vanguard-instruments.com.



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