TTRU3 Application Note

Factory Ratio Testing of Power Transformer

Introduction

Ratio Testing Transformers under Construction

Transformer equipment manufacturers (OEMs) have a critical need to measure true ratio, as they must confirm proper manufacture of their transformers during construction and final assembly. Improper construction has consequences of higher cost, late delivery, and poor quality. The ability of a ratio instrument to be used for all steps involved makes it a practical value to OEMs because only one instrument is purchased and used throughout each stage. Only the most reliable and accurate instruments make it to the factory floor.

Winding stack under construction

re used: Art Mandigo Winding Service

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Testing Winding Stacks (incomplete transformers)

Problem

When an individual winding stack is built, it is often tested on a universal test core prior to placing the winding stacks on the final core. The ratio measurements during this testing validate proper winding turns. The universal test core is critical for preliminary ratio testing of a winding during construction, but it produces ratio errors due to

1) reluctance in the flux path at the butt joint
2) a wide air gap between the universal test core and the winding

With poor coupling and high magnetic reluctance, the ability to measure ratio within the required +/-0.5% of nameplate ratio becomes difficult and is not reflective of the final ratio measurements.

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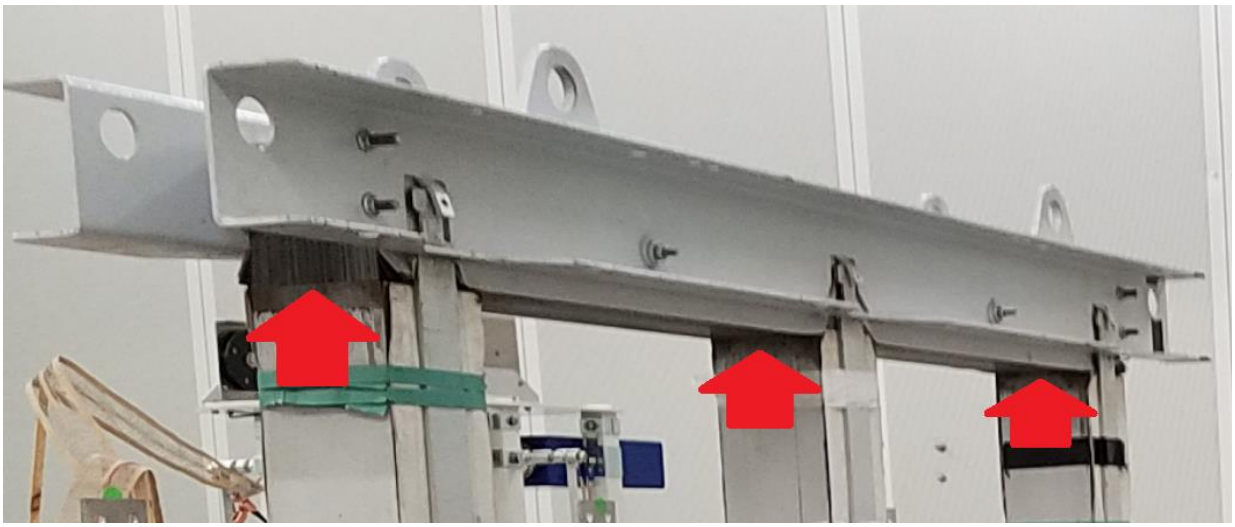

Universal test core with a “butt” joint

High reluctance and a poor flux path - Increased ratio error

Universal test core with a large air gap

Reduces magnetic coupling, resulting in higher flux leakage – increased ratio error

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Solution

To overcome ratio measurement problems, OEMs use instruments with higher test voltages on the primary winding. This reduces the errors due to voltage dependence recorded at lower test voltages. A higher test voltage (single phase, three phase switched) improves ratio results, but comes with higher purchase price, more weight and is less safe than lower test voltage units.

An alternate method to resolving high measurement errors is an instrument which steps up test voltage by exciting the secondary winding. This method resolves high measurement errors seen when traditional step down method deliver poor results. The TTRU3 uses a true 3Ø step up ratio method where a calculated input AC voltage is applied to the secondary winding which results in an induced voltage up to 250V on the primary winding.

Testing from the low side provides a number of benefits, including:

- Overcomes low impedance issues when applying test voltage from the high side. High impedance may result in voltage dependence issues.
- Injects test voltage to the low side providing better magnetic coupling to the core due to a smaller air gap compared to high side injection, which improves results
- Applies all 3 phases of test voltage simultaneously – reducing the load effects of delta winding when tested singled phase

The TTRU3 delivers results closest to nameplate ratio, even when test voltage is lower than traditional ratio instruments.

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Dyn5 3Ø

	Nameplate Voltage			Megger TTRU3 – 3 Phase Simultaneous -235V					
Tap	HV	LV	Calculated V Ratio	Phase A V Ratio	% Error	Phase B V Ratio	% Error	Phase C V Ratio	% Error
1	16538	400	71.61164	71.59276	-0.026%	71.61666	0.007%	71.60020	-0.016%
2	16144	400	69.90557	69.89067	-0.021%	69.91301	0.011%	69.89673	-0.013%
3	15750	400	68.1995	68.18685	-0.019%	68.20781	0.012%	68.19274	-0.010%
4	15356	400	66.49343	66.48303	-0.016%	66.50399	0.016%	66.48840	-0.008%
5	14962	400	64.78736	64.77973	-0.012%	64.79913	0.018%	64.78441	-0.005%

Expected results using an accurate ratiometer on a universal core

Tap Pos	Rated Voltage [V]		Design Ratio	Measured Ratio			Ratio Deviation	
	HV	LV		Phase A	Phase B	Phase C	Phase A	Phase B
5	6615	1902	3.478	3.480	3.480		0.060	0.060
2.5	6458	1902	3.395	3.403	3.402		0.225	0.195
0	6300	1902	3.312	3.324	3.327		0.353	0.444
-2.5	6142	1902	3.229	3.246	3.243		0.519	0.426
-5	5985	1902	3.147	3.167	3.164		0.646	0.550
				67 V	250V			

Poor TTR performance on a universal core

Is the winding the issue, or the instrument???

In this case it is the instrument

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Assembly Test

Problem

Once a core and windings are assembled a series of tests are conducted to ensure the transformer is mechanically sound and built to specifications. Whether large or small, most transformers undergo this testing prior to solid epoxy or liquid insulation application. This is done so that time and material costs are not put at jeopardy. This is the last opportunity to correct issues, and testing accuracy is critical to ensure that specifications are met.

Three-Phase winding assembled with the final core

Picture from LinkedIn – Manuel Bolotinha – Dec 2017

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Solution

The TTRU3 provides accuracy equal to the best competitors on the market. Where our previous TTR units were satisfactory for routine testing, the new TTRU3 provides guaranteed accuracy of **±0.05%**. The results are repeatable by any user, with any line input voltage, and under varying temperature conditions – which can reach 45°C in many transformer factory floors in hot climates.

The TTRU3 provides the fastest 3 phase ratio results on the market. This makes assembly line testing of smaller transformers both accurate and efficient. With the TTRU3, test time is reduced by more than 66% (from 40 seconds to 10 seconds), allowing for lower manufacturing cost and high quality transformers.

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Final Test and Commissioning

Problem

When completing a transformer, manufacturers must report results to their customers. There is a need for the instruments used to provide both accurate results as well as a professional report. Only instruments which provide this ability are considered, and until recently, Megger TTRs were not considered.

Solution

The quality of the transformer construction is reflected in test results, and the TTRU3 delivers results in both the level of accuracy, and the look of the report provided. Reports are available as PDF or as CSV files, allowing customers to choose a format, or integrate our results into their database and reporting formats.

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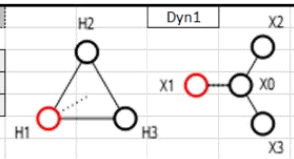
Test & Asset Details							
Asset ID		Job #	0	TTR SN	M874949-3613-LF	Turns RatioAllowed Error %	
Substation		Date of Test		Tester			0.5
Position		Date of Report					

Transformer Test Conditions					
Ambient Temp	20°C	Weather	Cloudy	Oil Temp	20°C
Humidity	0%	Reason	Acceptance	Winding Temp	

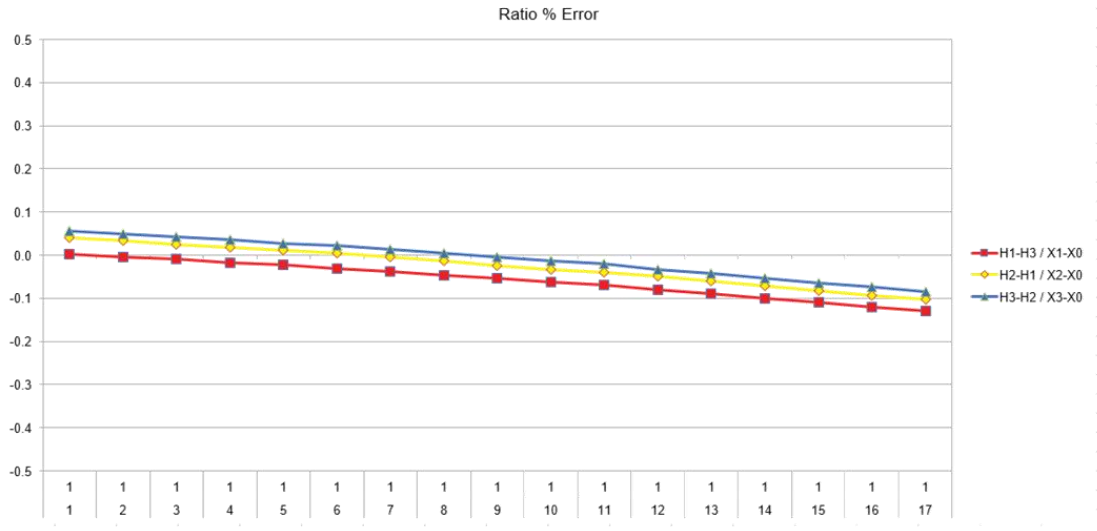
Transfomer Nameplate					
MFR		Weight	0lb	Oil Volume	1L
Serial #		Class	AN	Coolant	OIL & WATER
Year		BIL	0kV	Impedance	0%
Type	Sealed	Core Design	Unknown		



	Voltage		kVA	Rated I	# Taps	Nominal	Tap Changer	Tap Setting	First Tap Voltage	Last Tap Voltage
	L-L	L-G								
Primary	161000		0		19	9	OLTC		177100	144900
Secondary	22800	13164	0		1	1	DETC		22800	22800

Turns Ratio

						H1-H3 / X1-X0				H2-H1 / X2-X0				H3-H2 / X3-X0			
Tap		Voltage		Test V	Calc TTR	ctual Ratio	% Error	I excmA	Phase(Deg)	ctual Ratio	% Error	I excmA	Phase(Deg)	ctual Ratio	% Error	I excmA	Phase(Deg)
Pri	Sec	Pri	Sec														
1	1	177100	22800	250	7.7675	7.7678	0.00	0.022	0.009	7.7707	0.04	0.022	-0.022	7.7719	0.06	0.024	0.002
2	1	175088	22800	250	7.6793	7.6790	0.00	0.022	0.011	7.6820	0.03	0.021	-0.018	7.6830	0.05	0.024	0.003
3	1	173075	22800	250	7.5910	7.5903	-0.01	0.022	0.014	7.5930	0.03	0.021	-0.017	7.5942	0.04	0.024	0.005
4	1	171063	22800	250	7.5028	7.5015	-0.02	0.022	0.017	7.5042	0.02	0.021	-0.016	7.5054	0.04	0.024	0.007
5	1	169050	22800	250	7.4145	7.4128	-0.02	0.022	0.017	7.4153	0.01	0.021	-0.013	7.4165	0.03	0.024	0.010
6	1	167038	22800	250	7.3262	7.3240	-0.03	0.022	0.021	7.3265	0.00	0.021	-0.012	7.3278	0.02	0.024	0.013
7	1	165025	22800	250	7.2379	7.2352	-0.04	0.022	0.022	7.2377	0.00	0.021	-0.009	7.2390	0.01	0.024	0.014
8	1	163013	22800	250	7.1497	7.1464	-0.05	0.021	0.024	7.1488	-0.01	0.020	-0.007	7.1501	0.00	0.024	0.018
9	1	161000	22800	250	7.0614	7.0577	-0.05	0.021	0.028	7.0597	-0.02	0.021	-0.004	7.0611	0.00	0.024	0.019
10	1	158988	22800	250	6.9732	6.9689	-0.06	0.021	0.028	6.9709	-0.03	0.020	-0.002	6.9722	-0.01	0.023	0.024
11	1	156975	22800	250	6.8849	6.8801	-0.07	0.021	0.036	6.8822	-0.04	0.020	0.004	6.8834	-0.02	0.023	0.032
12	1	154963	22800	250	6.7966	6.7912	-0.08	0.021	0.037	6.7932	-0.05	0.020	0.007	6.7944	-0.03	0.023	0.034
13	1	152950	22800	250	6.7083	6.7024	-0.09	0.021	0.042	6.7043	-0.06	0.020	0.009	6.7055	-0.04	0.023	0.039
14	1	150938	22800	250	6.6201	6.6135	-0.10	0.020	0.042	6.6154	-0.07	0.019	0.013	6.6166	-0.05	0.023	0.043
15	1	148925	22800	250	6.5318	6.5247	-0.11	0.021	0.048	6.5264	-0.08	0.020	0.016	6.5277	-0.06	0.023	0.047
16	1	146913	22800	250	6.4436	6.4358	-0.12	0.020	0.048	6.4375	-0.09	0.019	0.022	6.4388	-0.07	0.023	0.052
17	1	144900	22800	250	6.3553	6.3471	-0.13	0.020	0.053	6.3488	-0.10	0.019	0.026	6.3499	-0.09	0.022	0.058



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