Accurate Measurement of High Voltage Transformer Losses at Lower Power Factors

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***Abstract*— The losses of power system equipment, such as transformers, motors and generators have traditionally amounted to a very large value every year. These losses are becoming increasingly significant with the increasing cost of electricity. In this paper we are concerned with transformer losses. Therefore, it is very important for an electrical equipment manufacturer to quantify these losses at the development and production level to come up with acceptable efficiency for their equipment and then to confirm the efficiency by actually measuring the losses. Here an attempt has been made to measure losses at lower power factors(PF)and calibration of the Transformer loss measuring system.**

***Index Terms*— Transformer losses, Energy efficiency, measurement system.**

I. Introduction

The Transformer Loss Measurement System (TLMS) is the system used for the accurate measurement of power losses of single phase or

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poly phase power and distribution transformers. This is essential so that the ultimate measurement of energy by an energy meter [3] is meaningful. The TLMS provides high accuracy over a very wide range of voltage, current and power factors. The measurement of electrical power [3] at high voltage and high current [1], [2] is becoming increasingly important so that the transformer losses can be calculated for the better economy of the industries. The power utilities are who buy the high voltage and high current transformers are very much vigilant about the losses of the transformers and are imposing penalty for f transformer and are imposing penalty for higher losses that occur in load and no-load conditions. To keep these penalties as low as possible, it is important that the manufacturer accurately measure these losses and keep them below the specified threshold values.The measurement of power losses is only possible if the TLMS offers accurate measurement of power losses at low power factors, and over a very wide operating range of voltage and current. Measurement accuracy, linearity, consistency and repeatability are also very important factors while measuring the power at lower power factors. These combined with variety of other significant factors like the adjustments for accurate power factor measurement should be incorporated in the design of the TLMS to facilitate the calibration of the system. The three phase TLMS comprises of, in general, 3 loss free gas (SF6) filled capacitor for test voltage measurement and 3 current transformer to measure the currents which can be read by a power analyzer or can be displayed on the screen of a computer system through software. In between the voltage divider and power analyzer, voltage channel is shown in Fig. 1. The purpose of this voltage channel is to provide the correct ratio and the measurement by the power Analyzer. The function of the current channel is to provide the filters to suppress spikes etc. for the correct measurement by the power Analyzer.

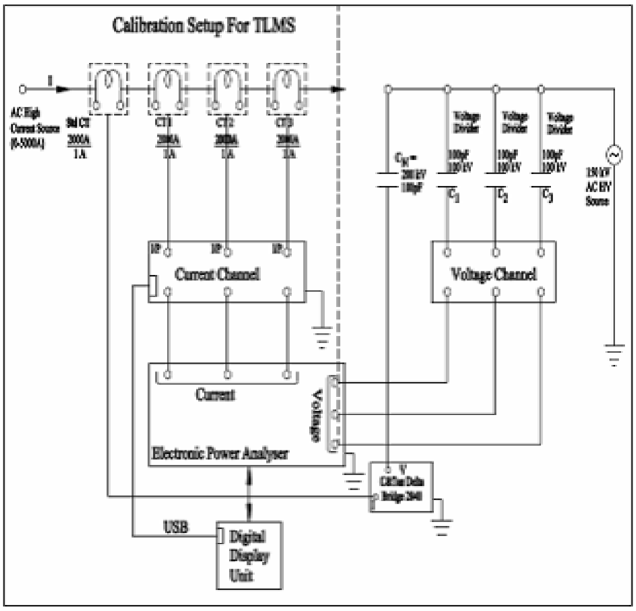

Fig. 1 Calibration Setup for Transformer Loss Measurement System

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Fig. 2 Three Potential Dividers and Three Current Transformer

II. CALIBRATION OF TLMS:

The TLMS is configured to allow convenient calibration that contains three potential dividers along with three current transformers. High voltage is applied to potential dividers to get the voltages at measurement levels of the power analyzer. In the same way the high currents are transformed to lower level and are applied to the power analyzer. As a typical example, one can set the divider at 100kV/100V and current transformers at 2000/1A. The power Analyzer measures the voltages, currents and power factors. The "test windings" is incorporated to adjust the voltage and current ratios correctly. The loading of auxiliary circuits can be monitored and can be corrected.

During calibration of TLMS in laboratory one uses three voltages in parallel and three currents in series from phase to phase (say R-Y). The voltage input from R to Y phase is given and a tapping is taken from in between and then the input to the high voltage transformer is given from this tapping and B phase as shown in Fig. 4 and the three currents are given in series (Fig. 5)

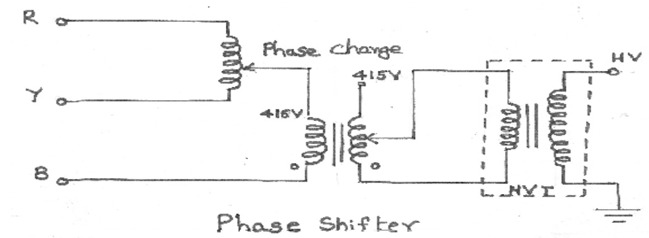

Fig. 3

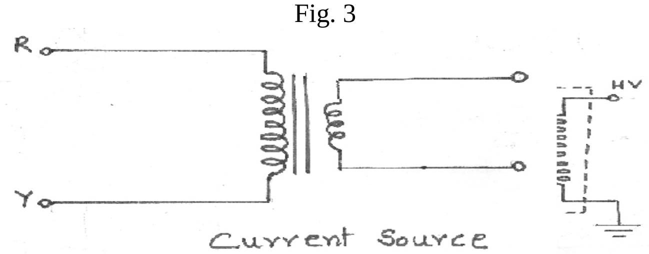

Fig. 4

The TLMS does not use instrument transformers that would power conventional instruments with nominal voltages (100 volts) and nominal current (1 amperes), but rather converts the measuring voltage and current to a low voltage signals that are directly suitable for digital converters (ADC) and digital signal processors (DSP). This reduces the complexity of the measuring system, increases its reliability and improves accuracy [4].

For the testing of the TLMS voltage and current were fixed at 100kV and 2000A and at power factors varied from 0.2 to 0.02.

III. RESULTS:

The Transformer Loss Measuring System (TLMS) have been calibrated along with the HV Dividers and Current Comparators. High Voltage is applied parallel both on the Std. and on the HV Dividers (Device Under Calibration) High voltage (1kV – 20kV) and high current (1A – 2000A) is applied on the TLMS at different Power Factors (0.02, 0.05, 0.1 & 0.2). The C & tan delta bridge has been used for recording the values and for comparison and the results are given in table I , II and III for voltage , current and power factor values:

Table – I
Range: 1kV – 100kV

Sl. No.	Measured Value by C & Tan δ Bridge (kV)	Indicated Value voltages by Transformer Loss Measuring System (TLMS) in kV		
		R - Phase	Y - Phase	B - Phase
1.	1.000	1.0017	1.0018	1.0019
2.	2.000	2.0014	2.0018	2.0018
3.	5.000	5.004	5.004	5.000
4.	10.000	10.009	10.010	10.015
5.	20.000	19.993	20.997	20.001
6.	40.000	40.041	40.046	40.062
7.	60.00	60.06	60.07	60.10
8.	80.00	80.06	80.08	80.13
9.	100.00	100.09	100.11	100.15

Table – II
Range: 1A – 2000A

Sl.No.	Measured Value by C & Tan δ Bridge (A)	Indicated Value of currents by Transformer Loss Measuring System (TLMS) in Amperes		
		R - Phase	Y - Phase	B - Phase
1.	1.0000	0.9955	0.9979	0.9992
2.	2.0000	1.9926	1.9942	1.9988
3.	10.000	9.993	9.990	9.990
4.	20.000	20.007	20.007	20.015
5.	30.000	30.010	30.004	30.009
6.	50.000	50.039	50.025	50.039
7.	80.000	80.063	80.044	80.077
8.	100.00	100.08	100.06	100.08
9.	150.00	150.12	150.07	150.13
10.	200.00	200.11	200.06	200.13
11.	350.00	350.05	349.96	350.01
12.	500.00	500.02	499.85	499.97
13.	700.00	699.81	699.65	699.65
14.	1000.00	999.37	999.12	999.20
15.	2.0000k	2.0001k	2.0016k	2.0012k

Table – III
Voltage: 20kV, Power Factor (PF): 0.02 – 0.2

Sl.No.	Applied Current (A)	Measured value by C& Tan Bridge(PF)	Power Factor Indicated by		
			R - Phase	Y - Phase	B - Phase
1.	200	0.0200	0.0197	0.0200	0.0207
		0.0500	0.0498	0.0501	0.0510
		0.1000	0.0998	0.1000	0.1008
		0.2000	0.2000	0.2001	0.2010
2.	500	0.0200	0.0198	0.0200	0.0206
		0.0500	0.0497	0.0501	0.0509
		0.1000	0.0998	0.1002	0.1011
		0.2000	0.1997	0.2000	0.2013
3.	2000	0.0200	0.0202	0.0203	0.0206
		0.0500	0.0503	0.0502	0.0513
		0.1000	0.1002	0.1000	0.0990
		0.2000	0.2000	0.2000	0.2011

IV. Safety Instructions/ Precautions :

Whenever possible, balancing, maintenance and repair activities should be avoided with the instrument open and powered up. If such operations cannot be avoided, they must be performed only by experienced personnel familiar with the dangers involved.

Proper power cable connects the TLM System housing and the protective ground. Use only a line connector plug with a good protective ground contact. In this way, the instrument will not present a shock hazard.

Before connecting the TLM System to the high-voltage test system, the power outlet should be connected and only then high voltage should be switched on so that all safety requirements are fulfilled.

HV components can be electrically charged even if the high voltage is switched off. These components must be discharged with an earth rod without fail whenever anyone enters the high voltage area. The tools for this i.e earthing rod must always be available in the system. The earthing rod must be connected to the system earth. The earthing cable may not be touched or stepped in during the discharge.

Care is taken to give the voltage and currents from the same phases i.e., If the current and voltage transformers are to be connected from phase to phase supply. For instance the high current is applied from R-Y phase, the voltage transformer is given input from R-Y phase and a tap from this is taken and then the voltage is given from tap to B phase. This will give phase shift in the TLMS.

V. Conclusion:

The calibration of the Transformer Loss Measuring System (TLMS) is essential as the power loss can be accurately measured by the proposed system. In general voltage and currents are measured within ±0.15% and power factor uncertainties are ±0.7% at 0.02 ±0.35% at 0.05, ±0.2% at 0.1 and ±0.1% at 0.2 PF. The uniqueness of the system is that by giving two phase input say R – Y we can calibrate the three phase system.

References

[1] Technical Report on Transformer Loss Measurement System by M/S Eltel Industries, Bangaluru, India.
[2] Acculoss TM, Transformer Loss System from Measurement International, Canada.
[3] International Standard, Electricity metering equipment (AC) General requirements, tests and test conditions (IEC 62052-11:2003-2)
[4] Transformer Loss Measurement System TMS 580 from Tettex Instruments Switzerland.
[5] Calibration of Test Systems for Measuring Power Losses of Transformers, "S.P.Mitra Member IEEE and Oskars Petersons, "IEEE Transactions on Power Quality, VOl. PWRD-1, No. 4, October 1986

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