RESEARCH DIVISION REPORT

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To Mr. F.J. Simpson
Director of Research

CALIBRATION OF MAGNETIC AND CAPACITOR VOLTAGE TRANSFORMERS IN THE FIELD

O.W. Iwanusiw*

Equipment and procedures are described that have been found suitable for calibrating magnetic VTs and CVTs in service. The equipment, together with factory or previous test results, is suitable for identifying shorted capacitor rolls in CVT stacks.

The continuous, accurate measurement of high voltage at transmission stations is a requirement for power-system monitoring, control, and revenue metering. Magnetic voltage transformers and capacitor voltage transformers (CVTs) are used for this purpose.

The long-term accuracy of magnetic VTs has seldom been questioned, but it is nevertheless desirable to ascertain the in-situ errors of important installations. On the other hand, the accuracy stability of CVTs has seldom, if ever, been as good as that of magnetic VTs and routine measurements are needed to ensure that CVT errors are within reasonable limits.

To perform in-situ measurements of magnetic-VT and CVT errors, special equipment was procured. The equipment consists of an outdoor, SF_6-filled, trailer-mounted standard capacitor, a capacitance bridge, and an auxiliary low-voltage capacitor. The standard capacitor has a basic insulation level of 900 kV and can be connected and used for measurements on systems up to 230-kV class. The trailer-mounted capacitor is shown in Figures 1 and 2.

Measurement Procedure

In a typical application the standard capacitor is connected to one phase in the station. The errors of all magnetic VTs and CVTs connected to that phase are then measured by use of the

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* This work was performed while Mr. O.W. Iwanusiw was with Ontario Hydro in the Electrical Research Department.

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auxiliary capacitor and the capacitance bridge. Measurements are performed at terminal blocks for instruments and relays, at the normal station burden. Measurements are also made with additional single-phase and polyphase burdens on the secondary or tertiary windings. The station burden is also measured. The work is repeated for each of the other two phases.

All the field measurements are supplied as data to a computer program which calculates the zero-burden errors for the magnetic VTs or CVTs, the lead impedances, and the effect of voltage drops in leads. Comparisons of the no-load errors of CVTs are especially useful since they may indicate faulty capacitors.

Measured and Calculated Results

A portion of the test results obtained at Mississagi TS on three ASEA type CUFA-220 CVTs having dual secondaries, and installed on a three-phase 230-kV circuit, is shown in Table I. (The largest errors in Table I were found only on CVTs in two out of the six three-phase sets of CVTs, all of which were type CUFA-220.)* Portions of computer-calculated results are shown in Table II and later in Table IV and are based on data presented in Table I and on other field measurements made under various combinations of test and service burdens.

Interpretation and Discussion of Results

Table I reveals that the three CVTs have widely different ratio correction factors (RCFs) at the service burdens. The RCFs vary from a low of 0.9930 (winding Y of phase C) to a high of 1.0112 (winding Y of phase B). The phase angle (PA) errors at the service burdens are reasonably small and range from 0.0002 to 0.0011 radian. Two most likely reasons for large ratio discrepancies without PA errors are either incorrect capacitance values in the capacitor divider or incorrect connections of the intermediate transformer ratio adjustment taps. An incorrect capacitance value can result if one or more capacitor rolls have shorted.

The differences in the RCF and PA values in Table II due to the different burdens (0,0; Z,0; 0,Z; Z,Z) make it possible to ascertain whether the CVT is operating properly. The increase in RCF due to a Z burden is typically 0.009 on the measured winding and 0.003 on the unmeasured winding. The increase in RCF due to a Z,Z burden is about 0.012 (1.2 per cent), which is the sum of the above two values, approximately.

The unloaded (0,0) RCF values from Table II can be compared with the unloaded RCF values obtained from factory or previous tests. A comparison between original factory test results and values from Table II is shown in Table III.

Table III reveals that the RCF of the phase-A CVT has basically not changed. The change in the RCF of the phase-B CVT was traced to a failed capacitor which had been replaced with one

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* For complete test results, see Research Division report 77-159-K, "Capacitor-Voltage-Transformer Calibration Mississagi TS".

of an incorrect value. In this instance, one of ten capacitors having a value of 0.113 μF had been replaced with one of about 0.102 μF. The resulting decrease in the capacitance of the upper section resulted in the 1.2 per cent increase in the RCF. The change in the RCF of the phase-C CVT was similarly traced to a capacitor whose capacitance had increased from 0.114 μF to 0.123 μF because of a shorted capacitor roll.

Differences between Tables II and IV, for the same burden condition, give the errors due to lead impedance between the CVT and the relay building. The differences indicate that the RCF increases by about 0.012 for a single-phase Z burden and about 0.006 for a balanced 3-phase Z burden. The differences due to the single-phase burden are larger because of the added impedance of the neutral lead. In this example, the errors due to lead impedance are about equal to the burden regulation of the CVT. In some cases the errors due to lead impedance may be excessive. In such instances, heavier leads can be installed, or separate leads can be provided to the metering equipment where accuracy is of importance.

Conclusions

A portable test facility consisting of an outdoor gas capacitor and a capacitance bridge was found to be suitable for measuring the in-situ accuracy of VTs and CVTs. The measurements, together with a computer program, either verify proper operation of CVTs or facilitate the location of sources of errors.

Approved:

J.R. Leslie
Manager
Electrical Research Dept

Submitted:

Jhn Vanderleck
for

O.W. Iwanusiw, P.Eng

OWI/MMcP

TABLE I

RESULTS OF BURDEN AND ERROR MEASUREMENTS

Phase	Winding	Service Burden		Measurements in Relay Bldg	
		VA	PF (lag)	RCF	PA (rad)
A	X	43.4	0.66	1.0002	0.0009
	Y	58.7	0.86	1.0018	0.0004
B	X	35.4	0.87	1.0110	0.0002
	Y	55.8	0.64	1.0112	0.0009
C	X	52.8	0.84	0.9944	0.0011
	Y	41.0	0.71	0.9930	0.0009

TABLE II

CALCULATIONS FOR JUNCTION BOX IN YARD

Phase	Burden Designation		Calculated Values for Junction Box			
	Winding X	Winding Y	Winding X		Winding Y	
			RCF	PA(rad)	RCF	PA(rad)
A	O*	O	0.9966	-0.0006	0.9957	-0.0011
	Z	O	1.0053	0.0016	0.9990	-0.0026
	O	Z	0.9998	-0.0021	1.0068	0.0015
	Z	Z	1.0085	0.0001	1.0101	0.0000
B	O	O	1.0077	0.0000	1.0077	-0.0001
	Z	O	1.0146	-0.0004	1.0112	-0.0021
	O	Z	1.0111	-0.0020	1.0132	-0.0015
	Z	Z	1.0181	-0.0023	1.0167	-0.0035
C	O	O	0.9895	-0.0001	0.9895	-0.0003
	Z	O	0.9992	0.0011	0.9929	-0.0021
	O	Z	0.9929	-0.0019	0.9975	-0.0002
	Z	Z	1.0026	-0.0007	1.0010	-0.0016

* O indicates infinite impedance.

TABLE III

COMPARISON OF CALCULATIONS WITH FACTORY TESTS

Phase	Winding	RCF (Test)	RCF Factory	Difference
A	X	0.9966	0.9970	-0.0004
	Y	0.9957	0.9969	-0.0012
B	X	1.0077	0.9962	+0.0115
	Y	1.0077	0.9960	+0.0117
C	X	0.9895	0.9965	-0.0070
	Y	0.9895	0.9965	-0.0070

TABLE IV

CALCULATIONS FOR RELAY BUILDING

Phase	Burden Designation		Calculated Values for Relay Bldg			
	Winding X	Winding Y	Winding X		Winding Y	
			RCF	PA(rad)	RCF	PA(rad)
Single-phase burdens (other phases unloaded)						
A	Z	Z	1.0203	0.0067	1.0227	0.0068
B	Z	Z	1.0299	0.0043	1.0295	0.0034
C	Z	Z	1.0143	0.0059	1.0135	0.0052
Three-phase burdens (all phases loaded similarly)						
A	Z	Z	1.0142	0.0033	1.0161	0.0032
B	Z	Z	1.0238	0.0008	1.0228	-0.0001
C	Z	Z	1.0082	0.0024	1.0070	0.0017

FIGURE 1. Transportable test equipment for calibrating VTs and CVTs. The standard capacitor is braced to the trailer and wrapped with a protective shroud. Cables and measuring equipment are carried in the van.

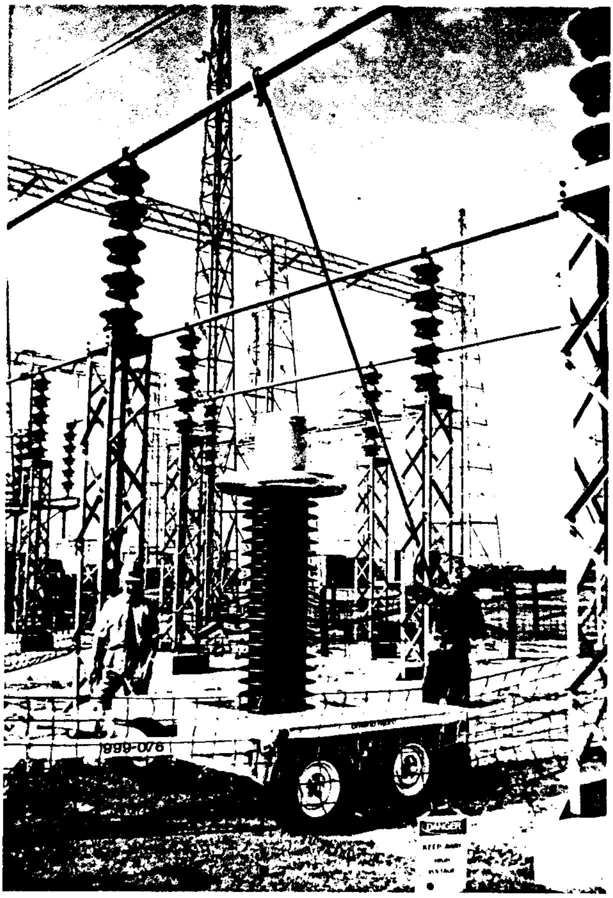

FIGURE 2. Standard capacitor being attached to an Ontario Hydro station bus for in-situ calibration of a CVT.