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RESEARCH DIVISION REPORT

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METERING CURRENT TRANSFORMERS FOR DISTRIBUTING STATIONS

The accuracy and burden requirements of metering current transformers in distributing stations have been studied and reviewed. Described are the advantages of various types of current transformers, and of their locations in a distributing station. Recommendations as to accuracy, burden, type and location of metering current transformers are made.

As requested by Mr. M. Fraresso in a memorandum dated January 26, 1962, the accuracy capabilities of bushing-type current transformers have been investigated. The aim was to determine whether bushing-type current transformers could be used in place of outdoor current transformers in distributing stations, because of difficulties encountered with existing outdoor current transformers. This report not only recommends certain bushing-type transformer applications, but also suggests other solutions to the difficulties experienced with outdoor current transformers.

It has been a standard Hydro practice to install external current transformers on the structures in distributing stations. These transformers were usually of the outdoor type, compound-filled, and had an accuracy rating of 0.3B0.9 and 0.6B(twice B0.9), as specified in Ontario Hydro Standard Specification for instrument current transformers M-160-56. Ontario Hydro's experience with these transformers has shown that moisture creeps into these transformers and causes electrical breakdown.

This report first reviews the accuracy and burden requirements of current transformers for metering the output power of distributing stations. This is followed by consideration of the location of the transformers in the power circuit.

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Next the ranges of application of bushing-type and wound-type current transformers are given, as determined by accuracy limitations. Recommendations are made regarding application of both types of transformer including the unsatisfactory compound-filled outdoor transformers.

ACCURACY AND BURDEN REQUIREMENTS

Research Division Report No. E62-50* describes the results of a survey conducted to determine the magnitude of burdens on metering current transformers in distributing stations as well as the number of current transformers of different ratios that are in service. Figure 1 was derived from Table I in Research Division Report No. E62-50 and shows that approximately 65 per cent of current transformers in service in distributing stations have a burden of 0.9 ohm (approximately CSA burden B0.9) or less imposed on them. It also shows that 90 per cent of current transformers have a burden of 1.8 ohms approximately CSA burden B(twice B0.9) or less imposed on them.

It can be concluded that if the magnitude of burden on the current transformers is to remain, in the future, according to Figure 1, the magnitude of the burden specified in M-160-56 should remain unchanged.

From the above-mentioned report, it can also be concluded that the application of AD ammeters and auxiliary current transformers, and the paralleling of current transformers are the chief reasons why the burden is high. In an effort to reduce this burden, consideration should be given to (a) single-phase thermal demand volt-ampere meters, calibrated in amperes, as replacements for the thermal AD ammeter; (b) the application of printing demand meters, operating from contacts on the watthour meter, as replacement for (1) SC graphic meter, (2) the necessity for using auxiliary current transformers; and (c) the use of dual ratio bushing current transformers.

The single-phase volt-ampere meter, calibrated in amperes, has an advantage of having a linear scale, as compared to the square-law scale of the present ammeter as well as having a lower burden.

Printing demand meters have several advantages over the SC graphic recorder. Their use will eliminate the need for auxiliary current transformers: (a) to change the range, all one has to do is to substitute the gear-train, coupling

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* Burdens on Current Transformers in Distributing Stations, Research Division Report No. E62-50, July 19, 1962, File 815.53.

the contact-device to the watthour meter disc, with one having a different ratio; (b) the number of pulses per kilowatt could be made the same for all stations, therefore simplifying the processing of tapes for billing and statistical purposes; (c) this system is more adaptable to automatic processing, which no doubt will have to be adopted sometime in the future.

The use of dual ratio bushing metering current transformers will facilitate the range changing of metering instruments without the use of auxiliary current transformers.

The accuracy of these transformers is specified in M-160-56 to be 0.3B0.2; 0.3B0.5; 0.3B0.9 and 0.6B(twice B0.9). On condition that burdens in the future will be normally limited to 0.9 ohm by applying restrictions suggested in Research Division Report No. E62-50 and also in Appendix II, accuracy requirements could be reduced to 0.6B0.2, 0.6B0.5 and 0.6B0.9. The transformers should also have a CSA accuracy of 1.2B(twice B0.9) in order to take care of isolated cases where the burden will exceed 0.9 ohm.

It is judged that the relaxation in accuracy from 0.3 accuracy class to 0.6 accuracy class will not substantially alter the mean error of power measurement of the ROA's as a group. For customer billing it is recommended that the above accuracy for current transformers will not be used. Instead, separate current transformers with accuracy specified in M-160-56 are recommended.

LOCATION OF THE CURRENT TRANSFORMERS

It is a standard practice to place metering current transformers on the load side of a generator or power transformer. In that position an instrument will respond to only the output or load current delivered by the transformer or generator. If the current transformers were placed on the neutral end of the windings, just before they are starred and grounded, the instrument would respond to stray capacitive currents as well as the load current.

From figures presented in Appendix I it can be concluded, that current transformers can be placed at the neutral end of the transformer windings without any danger of introducing errors in current, larger than 0.04 per cent of rated current, and power larger than 0.045 per cent of rated capacity of the transformer. Current transformers placed at the neutral can have inferior insulation because they operate at a lower voltage and are subjected to lower surges.

To enable the placement of external current transformers at the neutral ends of windings of 3-phase transformers, it is

required to bring out the neutral ends through additional bushings. The star connection would then be made outside the transformer. No additional bushings are required when placing them in stations where three single-phase transformers are employed.

TYPES OF CURRENT TRANSFORMERS

For the purpose of this report, current transformers are divided into two categories, bushing and wound types.

The bushing current transformer differs from the wound type by having no primary winding, and therefore the primary ampere turns are equal in value to the primary current.

The wound current transformer may have any number of turns on the primary, and therefore the ampere turns can be varied by putting more or less turns on the primary and on the secondary to maintain ratio.

The accuracy of a current transformer at a fixed burden depends chiefly on the primary ampere turns at rated primary current and the physical size and magnetic quality of the core. The errors in a current transformer are proportional to the value of the burden and inversely proportional to the weight of the core, the permeability of the iron, and the square of the primary ampere turns, with the other variables remaining constant.

$$\text{Error (accuracy class)} \approx \frac{\text{burden}}{(\text{ampere turns})^2 \times (\text{weight} \times \text{permeability}) \text{ of core}}$$

In our earlier discussion we have limited the magnitude of the error and burden. The primary ampere turns are limited by the rated current for a bushing current transformer. It follows, therefore, that a transformer can be built almost to any specification by using a core of suitable size and permeability. In practice, the physical size and the price of current transformers, with small errors and small rated ampere turns, make their use prohibitive.

By studying literature and talking to manufacturers, it is felt that most suppliers should be in a position to offer bushing current transformers rated at 400 to 5 amperes (400 ampere turns) and having CSA accuracy class of 0.6B0.2, 0.6B0.5, 0.6B0.9. The price of these transformers should be competitive to wound current transformers of same accuracy.

Some manufacturers will prefer to supply bushing current transformers having ratios as low as 200 to 5 amperes, if they are

supplying the power transformer. The ease of mounting the bushing transformer makes it more economical for them, than the wound transformer.

For currents below 200 amperes, wound current transformers must be used.

CONCLUSIONS AND RECOMMENDATIONS

The accuracy and burden requirements of metering current transformers for distributing stations have been considered. Ideas on ways in which the burden can be reduced and a new transformer location in the power circuit have been discussed.

It is recommended that:

(a) the accuracy of metering current transformers for distributing stations be 0.6B0.2; 0.6B0.5; 0.6B0.9. The transformers should also have an accuracy of 1.2B(twice B0.9);

(b) bushing metering current transformers with dual ratios be specified when ordering power transformers for distributing stations, if the ratio required is 400 to 5 amperes or larger;

(c) a choice between the bushing- and the wound-type transformers be given to the supplier, when ratios smaller than 400 to 5 are required;

(d) wound-type current transformers be installed on the neutral ends of windings;

(e) the compound-filled current transformers, on hand, be used up by connecting them on the neutral end of the windings in stations where three single-phase power transformers are used.

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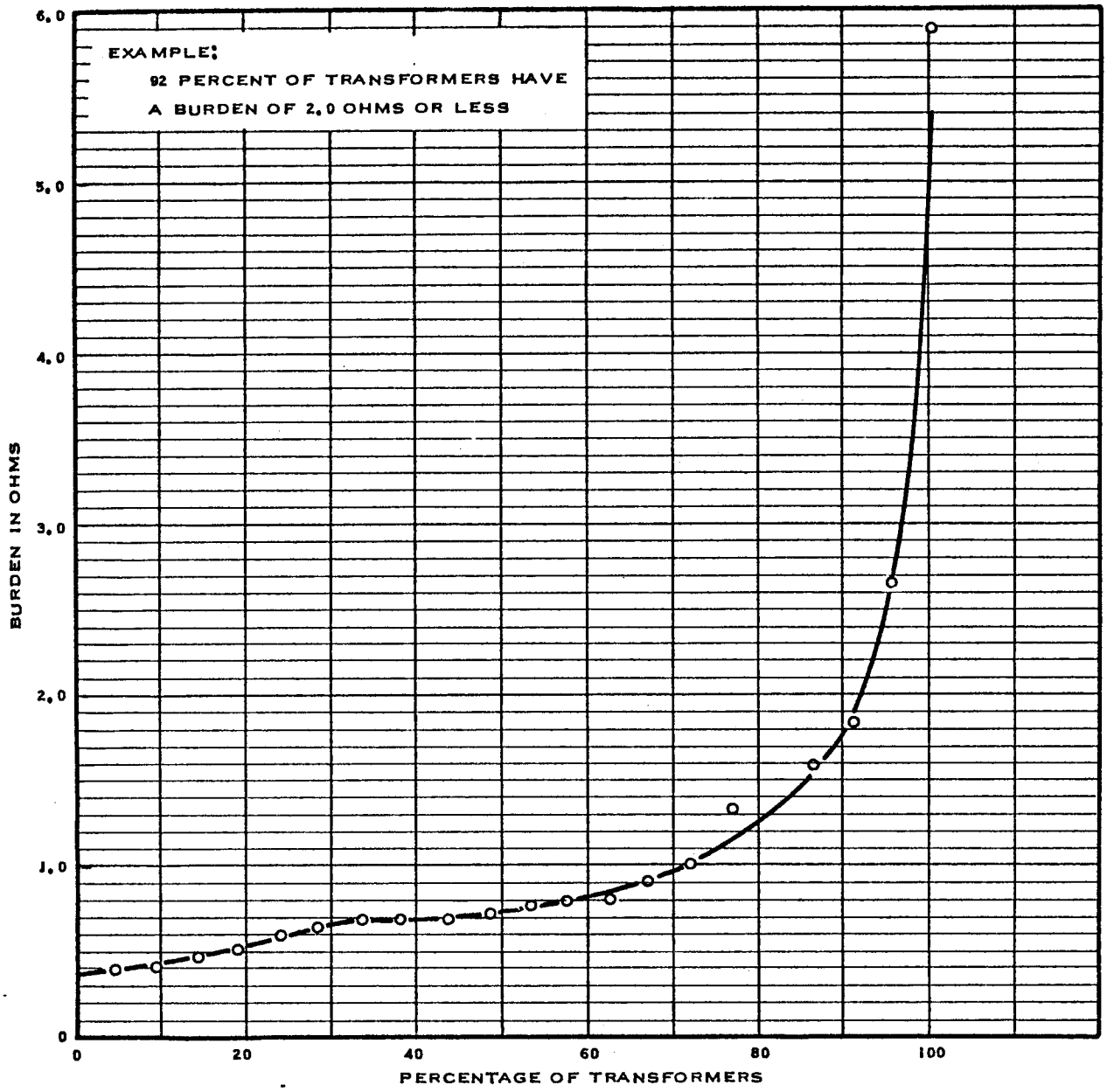

FIGURE 1

MAGNITUDE OF BURDENS ON METERING
CURRENT TRANSFORMERS IN DISTRIBUTING STATIONS

A P P E N D I X I

ERRORS IN THE MEASUREMENT OF CURRENT AND POWER OUTPUT OF A TRANSFORMER DUE TO THE PLACEMENT OF CURRENT TRANSFORMERS AT THE NEUTRAL ENDS OF WINDINGS

Transformer considered is a 5-mva, 27.6- to 4.14-kv (delta-star) power transformer.

Rated low-voltage current - 700 amperes per phase.

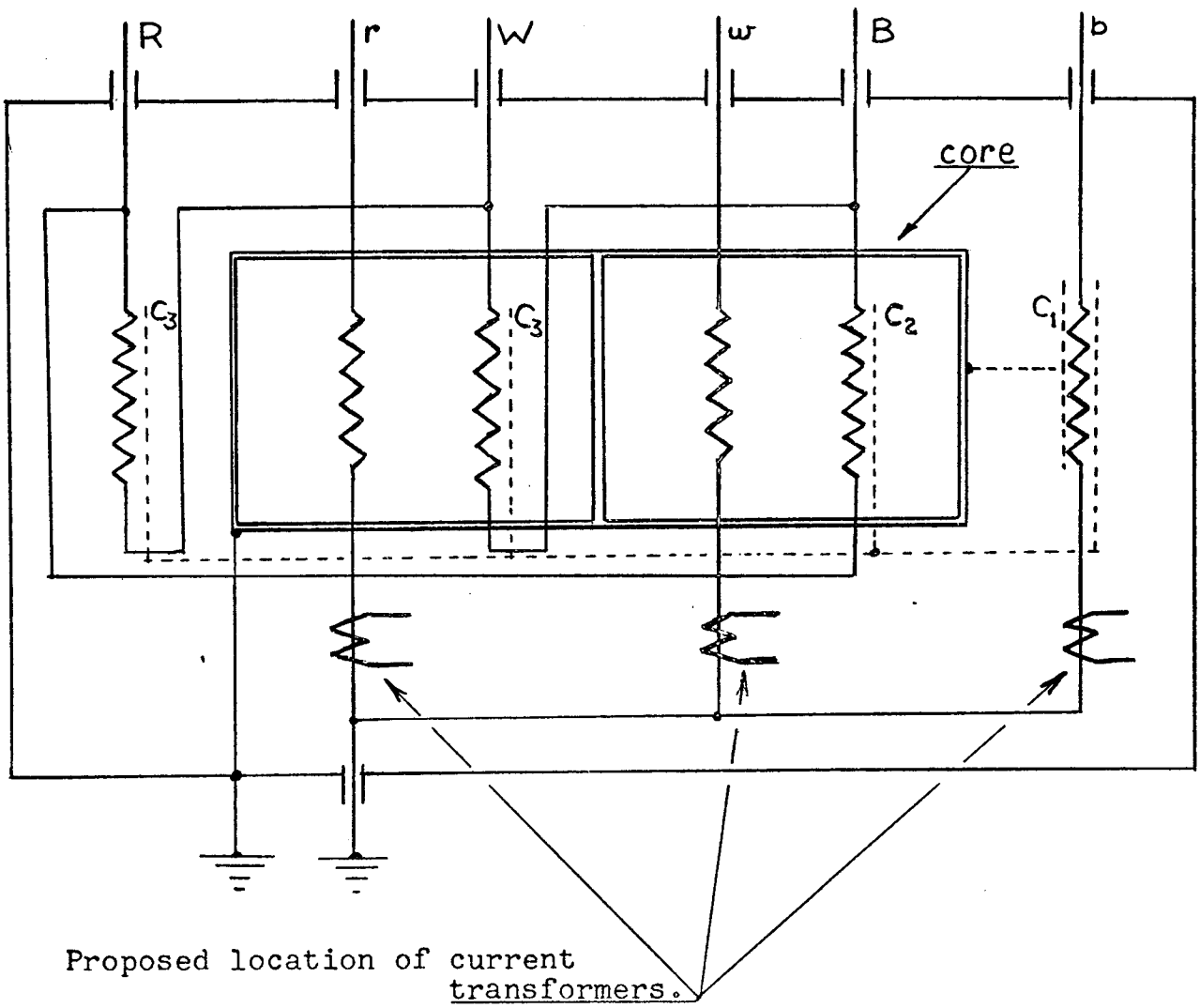

FIGURE 1

Inter-winding Capacitances in a Three-Phase Power Transformer

(a) Maximum values of stray capacitances expected: (refer to Figure 1).

C_1 - low-voltage winding to core and ground, 0.1 microfarad,

C_2 - low-voltage winding to high-voltage winding, 0.05 microfarad,

C_3 - low-voltage winding to high-voltage windings of the other two phases, 0.001 microfarad.

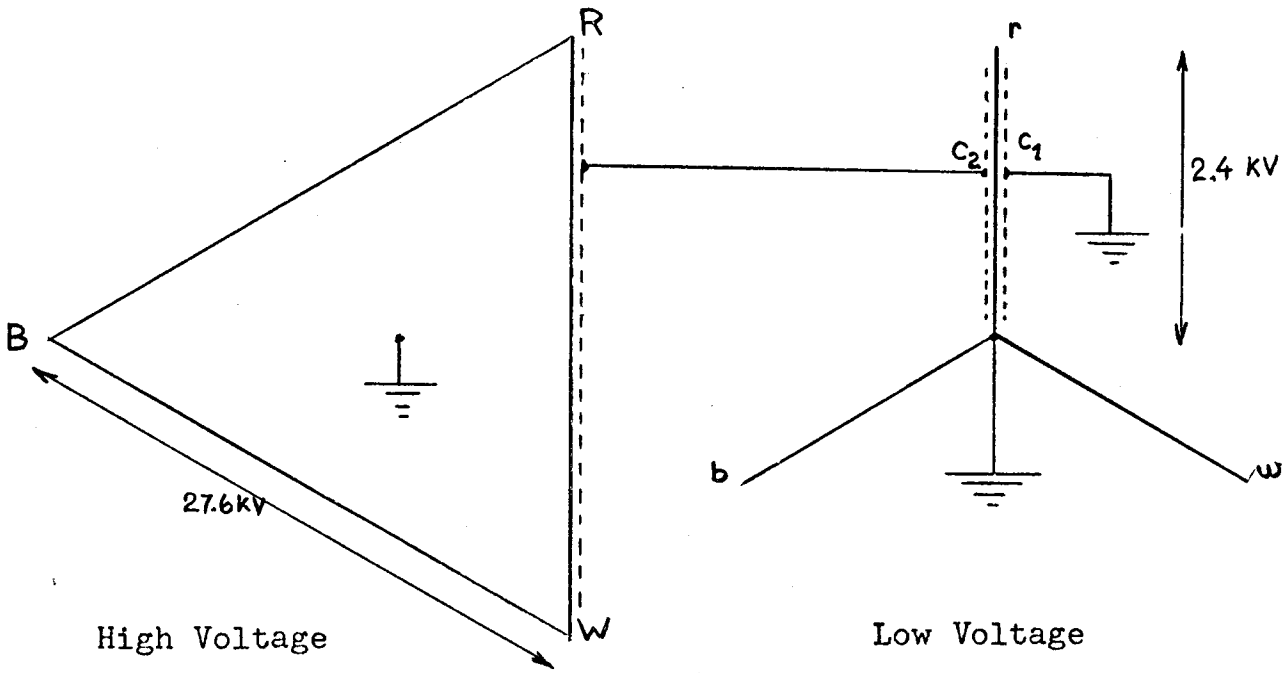

FIGURE 2

Diagram of Inter-winding Capacitances

(b) Maximum value of stray currents expected (per phase values):

Current due to C_1 (assuming capacitor is distributed along the winding)	= 0.045 amp
Current due to C_2 (assuming capacitor is distributed along the high-voltage winding)	= 0.23 amp
Current due to C_3 (assuming 16 kv across capacitor)	= 0.006 amp
T O T A L	0.281 amp

Total maximum current as percentage of rated transformer current equals 0.04 per cent.

POWER FACTOR OF CURRENTS DUE TO C_1, C_2 AND C_3

The power factor of current due to C_1 is the power factor of the insulation. It is assumed that the power factor will not be more than 10 per cent.

The power factor of the voltage across C_2 can vary from 0.87 to zero to -0.87.

The power factor of current due to C_2 can vary from 0.50 to unity to 0.50 (see Figure 2). It can be seen, therefore, that if C_2 capacitance is evenly distributed along the high-voltage winding, the power factor of the current will be unity.

The power factor of the voltage across C_3 can vary from -0.87 to -1.0 to zero to 1.0 to +0.87.

The power factor of current due to C_3 can vary from 0.5 to zero to minus unity to zero to 0.5. Under evenly distributed capacitance condition, the power factor will be minus unity. A maximum unbalance of 100 per cent is expected in this case.

(c) Maximum errors in power measurement expected (per phase values):

Errors due to C_1 (0.045 amp, 2.4 kv, 10 per cent power factor)	= 11 watts
Errors due to C_2 (0.23 amp, 2.4 kv, 1.0 power factor)	= 560 watts
Errors due to C_3 (0.006 amp, 2.4 kv, 1.0 power factor)	= 15 watts
T O T A L	586 watts

Total error as percentage of rated transformer capacity equals 0.04 per cent.

(d) The maximum error for VAR measurement will be slightly higher than for power above.

A P P E N D I X II

SUGGESTIONS FOR LIMITING BURDEN ON CURRENT TRANSFORMERS IN DISTRIBUTING STATIONS

To limit the burden to 0.9 ohm, the following metering equipment can be connected:

1. Leads of 0.2 ohm or less.
2. AD ammeters on 3-ampere range.
3. Sangamo auto-current transformers connected step down.
4. SC graphic meter.
5. Watthour meter.

If Item 2 is changed to be on the 6-ampere range, then either

(a) Item 3 may be connected step up,

(b) two sets of current transformers may be paralleled, or

(c) current transformers may be connected buck-off.