THE HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO
RESEARCH DIVISION REPORT

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METERING ACCURACY OF RELAYING CURRENT TRANSFORMERS

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Conventional 230-kV relaying current transformers exhibit a metering accuracy that is suitable for most internal accounting, operating, or statistical purposes. 230-kV current transformers with controlled remanence, or 500-kV current transformers may not exhibit suitable accuracy on the desired ratios. The consideration of separate metering cores, using high permeability core materials, is recommended for applications where high metering accuracies are required.

Ontario Hydro uses many relaying current transformers on its 230-kV high voltage system and the number of these current transformers is steadily increasing with the growth of the system. Since these transformers may be used for internal accounting purposes or for statistical metering, it is desirable for these current transformers to exhibit good metering accuracy as well as good relaying accuracy. Since these two can not always be obtained in the same unit, separate cores may be necessary to satisfy each requirement or a compromise on the requirements must be made.

The purpose of this report is to indicate the metering accuracies that can be obtained on 230- and 500-kV current transformers. The use of different types of core materials as well as different types of core construction will be discussed.

Before proceeding to discuss the accuracies (metering and relaying) of current transformers it should be pointed out that one does not obtain any information on the metering accuracy of a given current transformer from the knowledge of its relaying accuracy, and vice versa. This is primarily due to the different current ranges covered by standard accuracy specifications. Standard metering accuracies cover the range of 10 to 100 per cent of rated current (0.5 to 5 amperes); while standard relaying accuracies cover the range of 100 to 2000 per cent of rated current (5 to 100 amperes).

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Because of the difference in current ranges there is a different accent on requirements of the core. For metering purposes the core should have high permeability at relatively low flux densities, while for relaying purposes the core should have high permeability at high flux density to cope with fault currents. In addition, low remanent flux density in relaying current transformers may adversely affect a relaying current transformer's metering performance.

METERING CURRENT TRANSFORMERS

I. High Permeability Core Materials

High permeability nickel-steel cores have been used traditionally for cores of metering current transformers exhibiting good accuracy. Because of their low flux densities at saturation, these core materials are seldom if ever used for relaying current transformers.

The advantages of using separate metering current transformers, having high permeability cores, are superior metering accuracy and small size. This is especially true for transformers having ratios of 1200-to-5 or less on 230 kV and 1800-to-5 or less on 500 kV.

Because of the metering current transformer's small size, manufacturers find little difficulty in providing space for them in current transformer pockets on bushings or in free-standing assemblies. It is a standard practice with many European utilities to have a separate metering transformer, using a nickel-steel core, in each high-voltage current transformer assembly.

II. Grain-Oriented Silicon Steel Cores

Grain-oriented silicon steel cores are used in high-accuracy high-ratio metering current transformers. The size of the core becomes large when the diameter of the core has to be increased to accommodate insulation for high voltages such as 500 kV. The size of the core becomes excessively large at low ratios for these voltages.

Table I, appended, gives the approximate area of core required for obtaining the stated accuracy class. The table was computed for the 0.3 per cent accuracy class using the high permeability core materials and for 0.3, 0.6, and 1.2 per cent accuracy classes using grain-oriented silicon steel cores. This table should be used only as a coarse guide because the actual area of core material used by any one manufacturer in his transformer will be determined primarily by the mean diameter of the core, the diameter in turn depends on the effectiveness and type of high-voltage insulation used.

RELAYING CURRENT TRANSFORMERS

Almost all relaying current transformers use grain-oriented silicon steel for their core material because of its high permeability at high flux density. This material, however, may have a remanent flux density of up to 80 per cent of saturation flux density resulting in the possibility of poor performance under certain overcurrent conditions/1/. As a means of reducing remanence, air gaps can be used in the core of the transformer, or the core could use the biased design. Both of these measures affect the metering accuracy of the relaying current transformer.

The standard relaying accuracy used in Ontario Hydro for 230-kV relaying current transformers is 2.5L800 on the 1200-to-5-ampere ratio. A typical exciting current curve for this accuracy and ratio is shown in Figure 1. The differences in the linear portions of the exciting current curves between the four types of core configurations of the transformer can be readily seen in this Figure.

The basis for the curves in Figure 1 are theoretical calculations and results of measurements performed on small current transformers, with and without remanence control. Based on Figure 1, composite error curves for the four core configurations were calculated for a burden of 1.8 ohms (B-1.8) at rated and 10 per cent rated current. These composite error curves are shown plotted in Figure 2. They reveal that it should be possible to obtain the CSA 1.2 B-1.8 metering accuracy class, for ratios of 1000-to-5 amperes and higher, from the 230-kV relaying current transformers standard in the Commission, regardless of the type of core construction employed.

Since it could be judged that 500-kV transformers will draw approximately twice the exciting current of the 230-kV units due to their increased diameter, 1.2 B-1.8 metering accuracy class should be possible to obtain on all 500-kV, current transformers on ratios of 1500-to-5 amperes and higher. Higher accuracies are possible on higher ratios or if no measures are taken to control remanence in the cores of the transformers.

COMPOSITE CORE CURRENT TRANSFORMERS

There always exists the alternative of making the current transformer meet the metering and relaying requirements. The easiest way of doing this is to choose a suitable combination of core materials to make up the core. Thus by choosing a core containing about one square inch of nickel steel and fourteen square inches of grain oriented silicon steel, a metering accuracy of 0.3 B-1.8 as well as a relaying accuracy of 2.5L800, both on the 1200-to-5 ampere ratio, can be obtained on a 500-kV transformer. The silicon steel portion of the core could be provided with gaps to reduce remanence without affecting the performance of the nickel steel for metering duties.

The choice between a composite core current transformer and separate relaying and metering current transformers depends on many factors. The size of the unit is not one of the factors since the volume of the composite transformer is approximately the same as for the separate metering and relaying transformer combined. In the case of separate transformers, there may be some disadvantage in having too many transformers in an assembly, each having different characteristics. On the other hand, the metering characteristics of a composite transformer could be easily spoiled by relatively high relaying burdens.

DISCUSSION

Data presented in this report indicate that 230-kV relaying current transformers, having a 2.5L800 accuracy on the 1200-to-5 ampere ratio and no control of remanence, should be capable of 1.2 B-1.8 metering accuracy on ratios of 600-to-5 amperes and higher, or 0.3 B-1.8 on ratios of 1200-to-5 amperes and higher. The data also indicate that the ratios for the above metering accuracies would have to be increased to 1000-to-5 amperes and 1600-to-5 amperes, respectively, if small air gaps are introduced to control remanence.

The metering accuracies for 500-kV relaying current transformers, are expected to be 1.2 B-1.8 for ratios of 800-to-5 or higher, or 0.3 B-1.8 for ratios of 1800-to-5 or higher for transformers with no control of remanence. With remanence controlled with air gaps, the ratios would have to be increased to 1500-to-5 amperes and to 2400-to-5 amperes, respectively, if the above metering accuracies are to be maintained.

Some of the ratios cited above may be too large for some applications. In that event it is thought to be advantageous to include a metering current transformer or perhaps a composite-core current transformer of suitable accuracy in the assembly. Table I indicates that a core of only one square inch in cross section of mumetal would give an accuracy of 0.3 B-1.8 on ratios of 1200-to-5 or higher on 230-kV, or ratios of 1800-to-5 or higher on 500-kV. This core, being less than 10 per cent of a relaying current transformer core, would add little to the size of the transformer, but would provide good metering accuracy when required.

CONCLUSIONS AND RECOMMENDATIONS

Closed core 230-kV relaying current transformers usually provide a metering accuracy that is suitable for operating, statistical and internal accounting purposes. The metering accuracy of 500-kV relaying current transformers, or 230-kV transformers with controlled remanence may not be acceptable on the required ratios. It is recommended that for those situations, separate metering transformers using high permeability nickel-steel cores, be considered.

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References

/1/ Remanent Flux in Current Transformers. Research Division Report 70-60.

TABLE I

CORE AREA REQUIREMENTS FOR METERING ACCURACY

Core Material	SM	M	S	S	S
	Area of Core (Square Inches)				
Accuracy	0.3 B-1.8	0.3 B-1.8	0.3 B-1.8	0.6 B-1.8	1.2 B-1.8
Ratio			230 kV		
400-5	7.0	20	-	34	11
600-5	2.5	9	40	13	5
800-5	1.0	3	16	5	2
1200-5	0.5	1	5	2	0.7
1800-5	0.8	0.5	2	0.7	0.3
2400-5	0.15	0.3	1	0.4	0.15
3200-5	0.10	0.2	0.5	0.2	0.1
			500 kV		
400-5	13	-	-	-	34
600-5	7	25	-	40	13
800-5	3.5	9	50	16	5
1200-5	1.0	3.5	16	5	2
1800-5	0.4	1.0	6	2	0.7
2400-5	0.25	0.5	2.5	1	0.4
3200-5	0.15	0.25	1.5	0.5	0.2

Notes: SM - very high permeability material (supermumetal, supermalloy).

M - high permeability material (mumetal, mopermalloy).

S - grain oriented silicon steel.

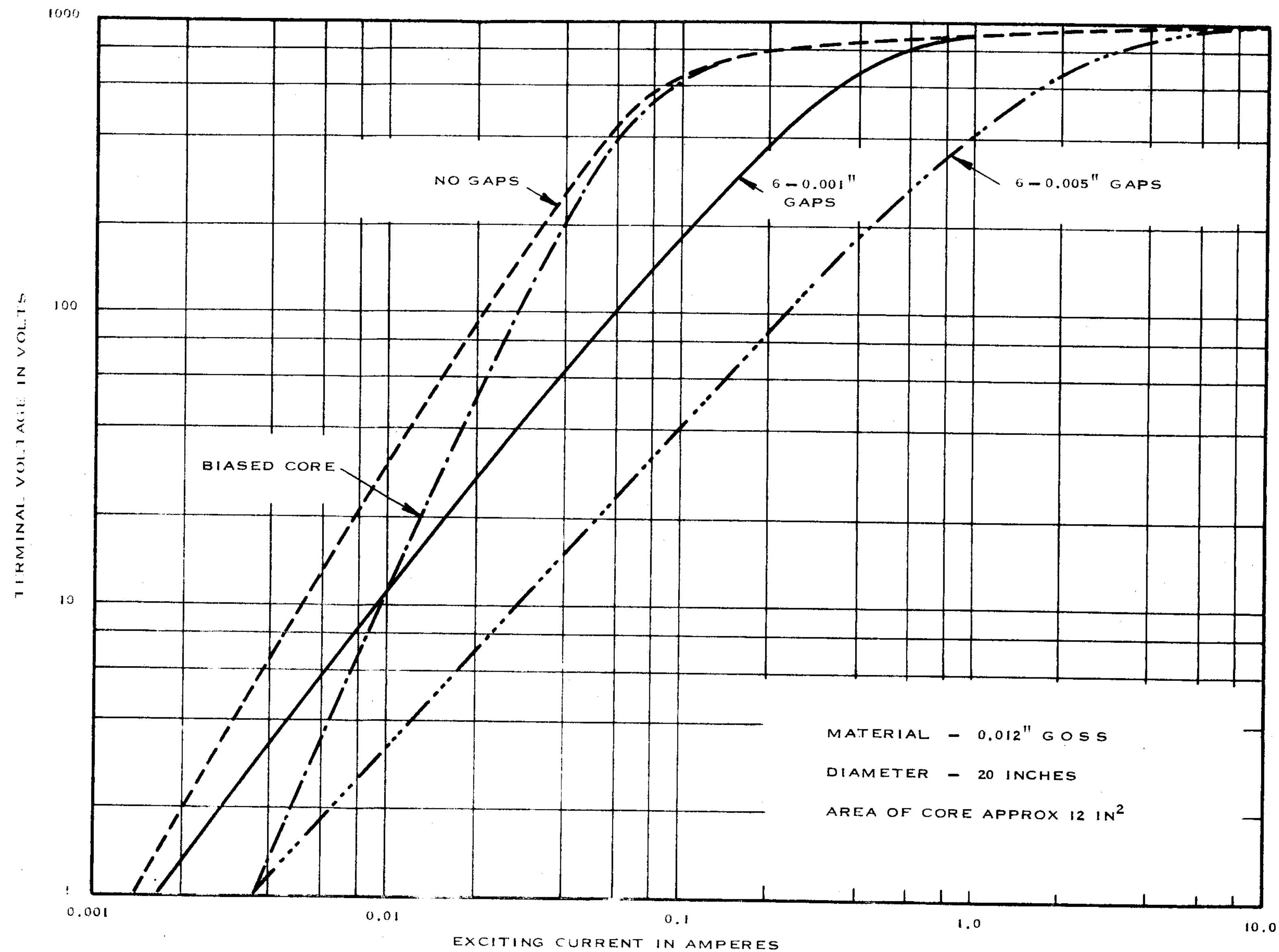

FIGURE I

TYPICAL EXCITING CURVES FOR 230—KV RELAYING CURRENT TRANSFORMERS

RATIO 1200 TO 5 AMP. RELAYING ACCURACY 2.5L800

123751—RD

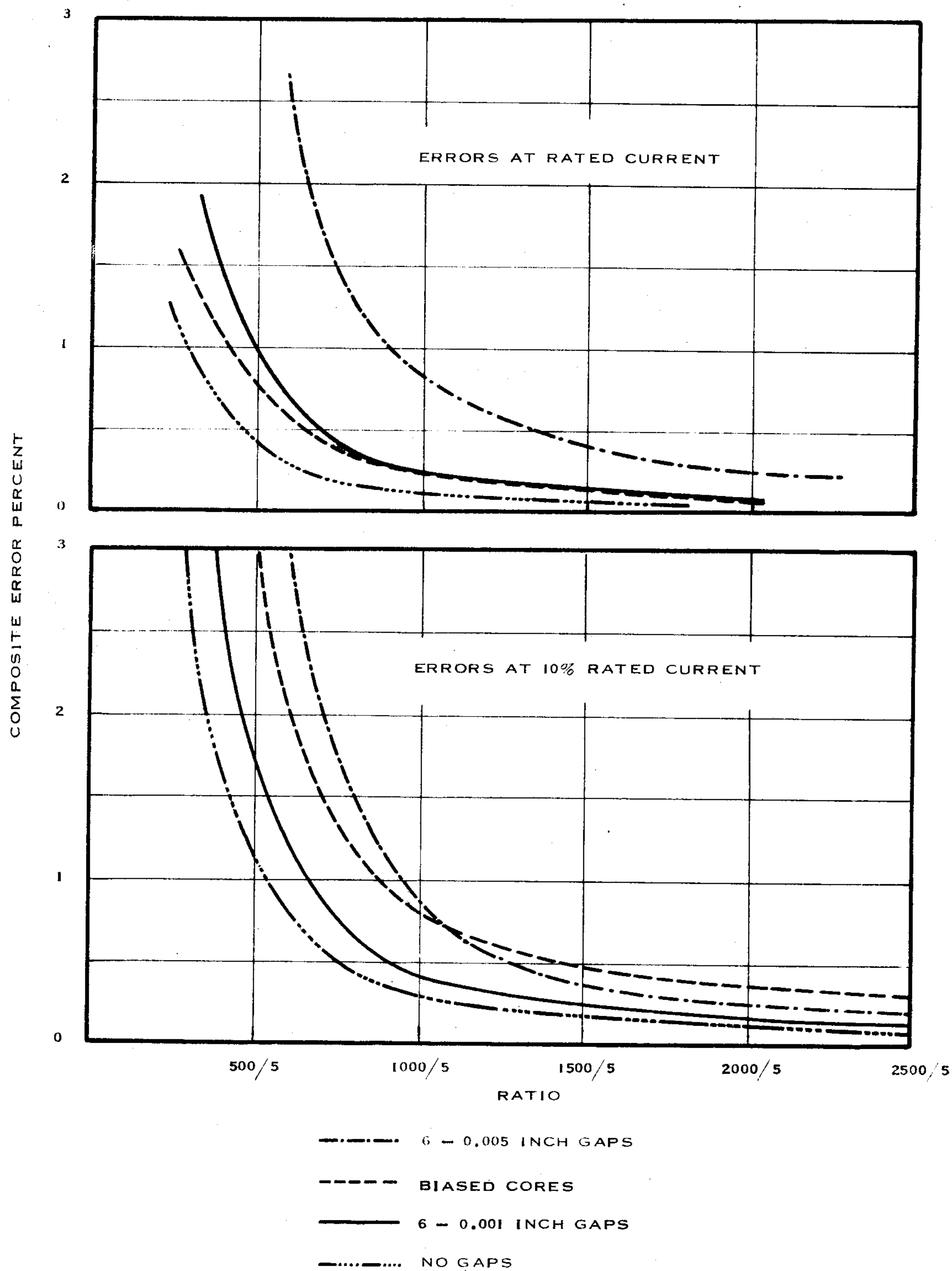

FIGURE 2

TYPICAL COMPOSITE ERROR CURVES FOR 230-KV RELAYING CURRENT TRANSFORMERS RELAYING ACCURACY 2. 5L800 AT 1200 TO 5 AMP

BURDEN B-1.8

123636-RD