July 23, 1929. M. S. WILSON 1,722,167

CURRENT TRANSFORMER

Filed July 10, 1928

Fig. 1.

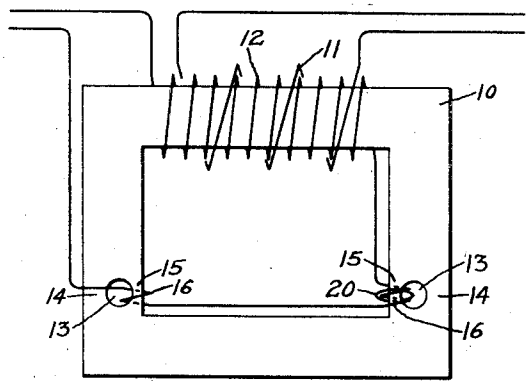


Fig. 2.

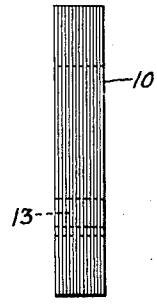


Fig. 3.

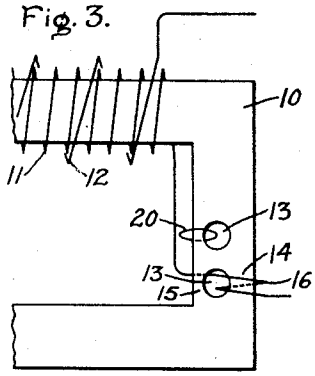


Fig. 5.

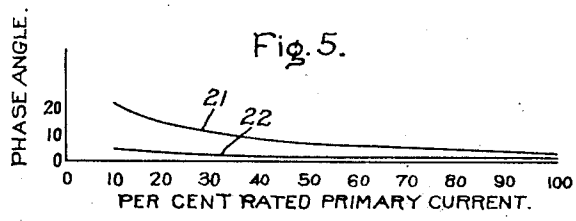


Fig. 6.

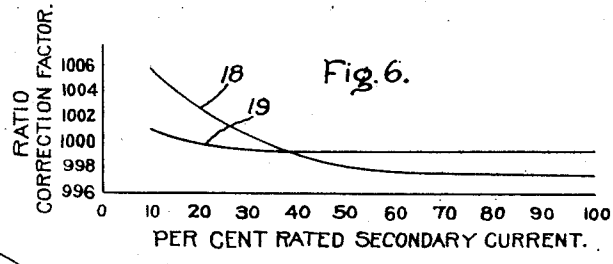
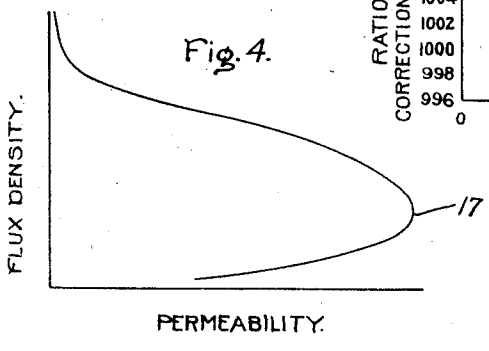


Fig. 4.



Inventor:
Myron S. Wilson,
by Charles F. Mullen
His Attorney.

Patented July 23, 1929. 1,722,167

UNITED STATES PATENT OFFICE.

MYRON S. WILSON, OF LYNN, MASSACHUSETTS, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

CURRENT TRANSFORMER.

Application filed July 10, 1928. Serial No. 291,670.

My invention relates to current transformers and its general object is to provide an improved transformer of this type having accurate ratio and phase angle characteristics. The desired results are attained by means of conductive turns properly enclosing a portion of the magnetic core flux and so influencing and controlling the flux as to reduce or eliminate ratio and phase angle errors.

The invention will be better understood from the following description taken in connection with the accompanying drawing in which Fig. 1 is a diagrammatic view of current transformer constructed in accordance with the invention; Fig. 2 is an end view of the magnetic core shown in Fig. 1; Fig. 3 is a view indicating a modified form of the invention; Fig. 4 is a curve showing the relation between the flux density and permeability of magnetic material such as may be used in a transformer core; Fig. 5 shows curves indicating the improvement in the phase angle made by the invention at different values of the primary current, and Fig. 6 shows curves indicating the improvement in current ratio made by the invention at different values of primary current.

Like reference characters indicate similar parts in Figs. 1, 2 and 3 of the drawing.

In the arrangement shown in Fig. 1, the transformer includes a rectangular laminated magnetic core 10 having a primary winding 11 and a secondary winding 12. The core 10 has two openings 13 at right angles to the laminations so that two short core sections 14 and 15 forming two parallel flux paths are formed in the core past each opening. Each opening 13 is preferably located near a corner of the rectangular core 10 and is also somewhat nearer the inner or outer edge of the core so that one of the parallel core sections 14 and 15 is smaller than the other in cross section, the inner core section 15 being preferably the smaller one. As shown in Fig. 1, each of the smaller or inner core sections 15 is surrounded by a small winding 16 of one or more turns. These small windings 16 are connected in series with each other and with the main secondary winding 12, the connections being such that the secondary current flowing in these windings 16 will induce magnetic flux in the core sections 15 in the same direction as that of the main primary flux. If it were not for the influence of the windings 16, the core flux would divide between the two parallel paths past each opening 13 in proportion to the cross sections of the two core sections 14 and 15. As the secondary current increases, an increasingly greater proportion of the total flux in the core will flow through the larger core section 14, due to the fact that as the flux density in section 15 increases, the reluctance of this section increases.

In the usual current transformer the primary current must supply not only the secondary current, but it must also supply the necessary exciting current to maintain the operating flux in the core. The value of the secondary current is therefore somewhat less than that determined alone by the value of the primary current and the turn ratio. It is therefore customary to obtain the desired current ratio by using a slightly reduced number of secondary turns so that the turn ratio is slightly smaller than the desired current ratio. Thus a transformer designed and rated as having a primary to secondary current ratio of four to one might have seventy-five primary turns but only two hundred ninety-nine instead of three hundred secondary turns. This is not objectionable but there is still the undesirable condition that the current ratio is not constant at different loads largely because the permeability of the magnetic core is different for different flux densities as indicated by the curve in Fig. 4, which shows the general shape of the permeability curve for magnetic material such as is commonly used in transformer cores. It will be seen that as the flux density increases from a low to a high value, the permeability at first increases till it reaches a maximum value indicated by the point 17 in the curve and then decreases beyond this point. Normally current transformers operate below the point of maximum permeability on the permeability curve.

The effect of the varying permeability and losses on the current ratio at different flux densities and loads is indicated in the curve 18 of Fig. 6 which is a representative curve for the usual type of current transformer. Any given secondary current must be multiplied by the current ratio to give the corresponding primary current, this current ratio factor differing somewhat from the actual turn ratio as already explained. This result is not accurate for all loads because the true current ratio is not the same for all loads.

The result must therefore be multiplied by a ratio correction factor as indicated by the curve 18.

The auxiliary series windings 16 shown in Fig. 1 and the openings 13 are arranged so that variations in true current ratio due to variations in permeability at different flux densities in the core are prevented or largely reduced. This effect is indicated by the curve 19 of Fig. 6. It will be seen that the ratio correction factor is much more nearly constant for the curve 19 than for the curve 18.

With no current flowing in the auxiliary windings 16, the primary core flux will divide between the two parallel core sections 14 and 15 in such proportion that the flux density will be the same in both sections. Current in the windings 16, however, unbalances this flux density. The windings 16 are connected so that the current in them induces magnetic flux in the narrower core sections 15 in the same direction as that of the main primary flux. The flux density is therefore higher in the section 15 than in the section 14 of the core.

The size and location of the openings 13 and the number of turns in the auxiliary windings 16 are so proportioned and arranged that the flux density in the core sections 14 is below that corresponding to maximum permeability and the flux density in the core sections 15 is above that corresponding to maximum permeability. This means that the core section 14 is operating on the increasing part of the permeability curve while the core section 15 is operating on the decreasing part of the permeability curve. It has been found that the result is a substantially constant effective permeability for the entire magnetic core and a substantially constant true current ratio as indicated by the curve 19 in Fig. 6. It may not be always practicable to maintain the constant current ratio as the transformer load is reduced to very low values and the curve 19 of Fig. 6 shows a small variation in the current ratio when the secondary current is very small. There is, however, a decided improvement even at very low values of current as shown by comparison of the curves 18 and 19.

It has been found that in order to produce the desired current ratio correction, the arrangement of the openings 13 and windings 16 is quite critical and difficult to predetermine. With even a slight variation from the proper arrangement, there may be no improvement whatever.

While the arrangement so far described has produced a decided improvement in current ratio accuracy, it has been found in tests which have been made that this was at the expense of some loss in phase angle accuracy and phase angle accuracy is often highly desirable. This phase angle inaccuracy may be corrected, however, by placing a short circuited winding 20, which may be a single short circuited turn, around one of the sections 15 of the core as shown in Fig. 1.

The curve 21 of Fig. 5 shows how the phase angle may vary for different values of primary current in a well designed current transformer. The curve 22 shows how the phase angle accuracy may be improved by means of the winding 20 shown in Fig. 1. The correction is particularly effective for low values of current as shown by the curve.

What is at present considered to be the best form of the invention is shown in Fig. 1. The arrangement of the openings 13 and windings 16 is in some respects quite critical as already stated, but various modifications may be made which will still give good results. For instance, two openings 13 with two windings 16 have been shown and described but good results have been secured with a single opening 13 and a single winding 16.

In the arrangement shown in Fig. 3, the core 10 has an opening 13 with the winding 16 surrounding the outer or wider section 14 of the core. The winding 16 in this case is connected so that the secondary current flowing in it tends to induce flux in a direction opposite to that of the main primary flux. This has the same effect as in the arrangement shown in Fig. 1 in that the flux in the core is forced or crowded over into the core section 15 so that the flux density in the section 15 is greater than in the section 14. The proportion and arrangement of parts are again such that the core section 14 operates on the increasing part of the permeability curve while the core section 15 operates on the decreasing part of the permeability curve.

While it is preferred that the short circuited winding 20 pass through the same opening 13 as shown in Fig. 1, this is largely to secure simplicity in construction. The winding 20 may, if desired, pass through a separate opening 13 as shown in Fig. 3.

The invention has been explained by describing and illustrating different modifications thereof and it will be apparent that further changes may be made without departing from the scope of the invention as defined in the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. A current transformer including a magnetic core having two sections arranged to conduct the magnetic core flux in parallel paths, a secondary winding, and an auxiliary winding surrounding one of said core sections to unbalance the flux density in the two sections, said core sections being so arranged and proportioned that one operates on the increasing part of the permeability curve while the other operates on the decreasing part of the permeability curve.

2. A current transformer including a mag-

netic core having two sections arranged to conduct the magnetic core flux in parallel paths, a secondary winding, and an auxiliary winding connected in series with said secondary winding, said auxiliary winding surrounding one of said core sections to unbalance the flux density in the two sections, said core sections being so arranged and proportioned that one operates on the increasing part of the permeability curve while the other operates on the decreasing part of the permeability curve.

3. A current transformer including a magnetic core having two sections arranged to conduct the magnetic core flux in parallel paths, a secondary winding, and an auxiliary winding surrounding one of said core sections and operating to induce flux in the same direction as that of the main core flux, said core sections being so arranged and proportioned that one operates on the increasing part of the permeability curve while the other operates on the decreasing part of the permeability curve.

4. A current transformer including a magnetic core having two sections arranged to conduct the magnetic core flux in parallel paths, a secondary winding, an auxiliary winding surrounding one of said core sections to unbalance the flux density in the two sections, said core sections being so arranged and proportioned that one operates on the decreasing part of the permeability curve and a short circuited winding associated with one of said sections.

5. A current transformer including a magnetic core having two sections arranged to conduct the magnetic core flux in parallel paths, a secondary winding, and a short circuited winding surrounding one of said sections.

6. A current transformer including a laminated magnetic core, a portion of said core being provided with an opening extending transversely to the laminations to divide said core portion into two sections in which the flux flows in parallel, a secondary winding, and an auxiliary winding associated with one of said sections and extending through said opening, said winding operating to unbalance the flux density in the two sections, said core sections being so arranged and proportioned that one operates on the increasing part of the permeability curve while the other operates on the decreasing part of the permeability curve.

7. A current transformer including a laminated magnetic core, a portion of said core being provided with an opening extending transversely to the laminations and to one side of the center thereof to divide the core into two sections of unequal cross section and in which the core flux flows in parallel paths, a secondary winding, and an auxiliary winding associated with one of said sections and extending through said opening, said winding functioning to increase the flux density in the smaller section and to decrease the flux density in the larger section.

8. A current transformer including a magnetic core having two sections arranged to conduct the magnetic core flux in parallel paths, a secondary winding, and an auxiliary winding surrounding one of said core sections to unbalance the flux density in the two sections, said unbalance of flux density producing a change in permeability in at least one of said core sections to maintain substantially constant current ratio in the primary and secondary windings.

In witness whereof, I have hereunto set my hand this fifth day of July, 1928.

MYRON S. WILSON.