Oct. 18, 1932. A. CALLSEN 1,882,773

CURRENT TRANSFORMER

Filed Dec. 12, 1930

Fig. 1.

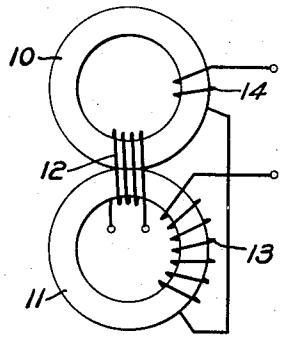


Fig. 2.

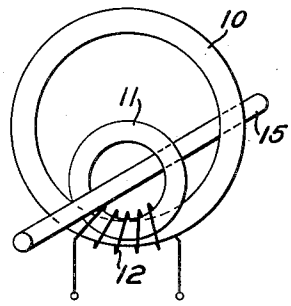


Fig. 3.

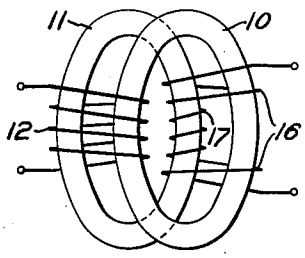


Fig. 4.

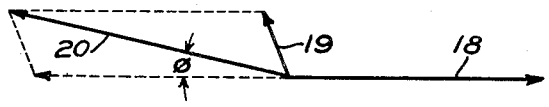


Fig. 5.

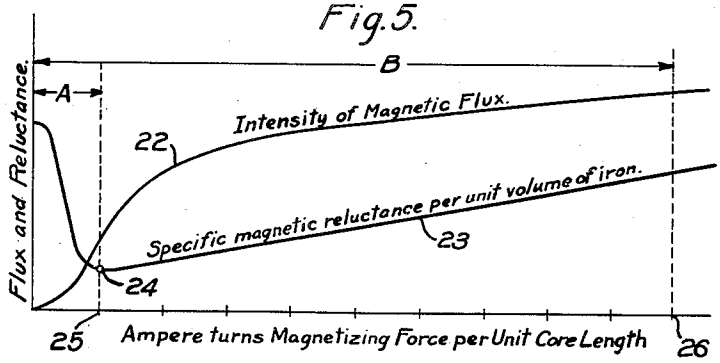
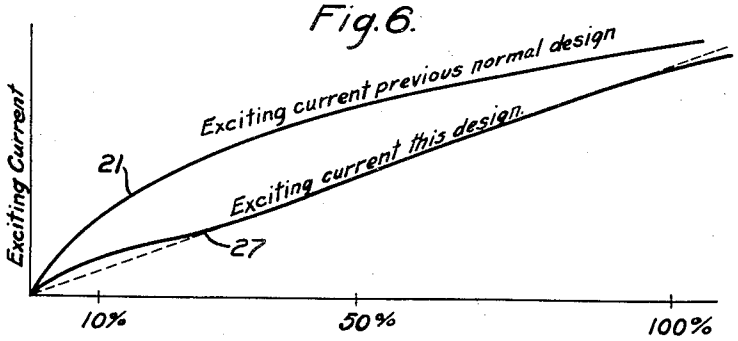


Fig. 6.



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UNITED STATES PATENT OFFICE

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CURRENT TRANSFORMER

Application filed December 12, 1930, Serial No. 501,853, and in Germany December 19, 1929.

This invention relates to current transformers of a type in which the phase angle and transformation errors may be made substantially uniform throughout the entire load range.

In current transformers of previously known designs, the exciting current does not vary directly with the load, because of the magnetic characteristics of the single iron core which is commonly utilized and, due to this non-uniform relation, the transformer errors, which are introduced by the exciting current, depend, in relative magnitude, upon the value of load at which the transformer is being operated. Adequate compensation for these errors at one particular value of load, therefore, cannot be entirely effective throughout the entire load range, and, in many applications in which uniform accuracy is required, the use of current transformers having such variable-error characteristics is highly unsatisfactory.

Through my invention, I am able to construct a current transformer having a substantially straight-line variation of exciting current with respect to load current. Such a relation results in practically uniform errors for different loads, and thus ensures that a proper compensation for errors at one predetermined point in the transformer load curve will also effect a similar compensation for these errors at all the other loads.

Generally stated, it is the object of my invention to provide a current transformer in which both the phase-angle and the transformation errors are substantially independent of the load.

Another object of my invention is to provide a current transformer in which the exciting current has a substantially straight-line variation with respect to the load.

Other objects of the invention will become apparent through a description of specific embodiments thereof, when taken in conjunction with the following drawing, in which

Figures 1, 2 and 3 represent, diagrammatically, three different embodiments of current transformers constructed in accordance with my invention.

Fig. 4 is a vector diagram, showing the relative magnitudes and phase positions of the primary, secondary and exciting currents in a current transformer, at some given load value.

Fig. 5 is a curve representing the magnetic characteristics of such iron cores as are utilized in the transformers of my invention, and

Fig. 6 is the exciting current curve for a current transformer constructed in accordance with my invention, and the curve for a comparable transformer of previously known designs.

To achieve the results desired, I provide, in a current transformer, two separate iron cores coupled with the secondary winding. According to my invention, the number of ampere turns of the primary conductor per unit length of iron core is different for the two cores, so that the magnetic intensities are of correspondingly different magnitudes.

Referring to the drawing, particularly Figs. 1, 2 and 3 thereof, numerals 10 and 11 indicate, in each figure, the two iron cores which are inductively related to the secondary winding 12. In the transformer of Fig. 1, the iron core 11 has the larger portion 13 of the primary winding located thereon, while the iron core 10 has the smaller portion 14 of the same winding located thereon.

In the embodiment shown in Fig. 2, the primary winding is in the form of a single through conductor 15, and the magnetic length of the annular core 10 is much greater than that of the annular core 11. The primary conductor 15 extends through the opening in each core, as shown.

The embodiment shown in Fig. 3 has one portion of the primary winding 16 arranged, as shown, to magnetize both cores 10 and 11, while the remainder 17 of the primary winding magnetizes only the core 11.

It is, therefore, evident that, in all three designs, the respective two cores are operated at different degrees of magnetic saturation, with a beneficial result to be explained.

The vector diagram of Fig. 4 shows the current relations which obtain in a current transformer which, for illustrative purposes, is assumed to have a ratio of 1:1. It will

be recognized that the selection of the 1:1 ratio is the equivalent of letting the vectors represent ampere turns instead of current and gives equal magnitudes to the vectors for both the primary and the secondary, thus permitting the relations to be represented more clearly in a single diagram.

In Fig. 4, vector 18 represents, at some given instant of time, the secondary current at a particular value of load, while vector 19 represents the corresponding exciting current, and vector 20 the primary current required for this given load condition.

It is seen that the secondary current differs substantially 180° from the phase position of the primary current, except for the effect of the exciting current which, in the diagram, has been exaggerated, in magnitude, to more clearly indicate its effect.

The diagram illustrates, as is well known in the art, that, in a current transformer, the current in the secondary coil, divided by the ratio of transformation, takes a value equal to the vector difference between the total primary current and the exciting-current component.

The exciting current varies with the load in current transformers, and, in those of previously known designs, in some manner such as is indicated by curve 21 of Fig. 6, in which the distance, measured along the horizontal axis, represents load current, and the distance along the vertical axis represents exciting current. By reference to curve 21 which deviates considerably from a straight line, it will be evident that, in the case of previously known current transformers, exciting-current vector 19 will change in length at a different rate than will primary and secondary current vectors 20 and 18, with the result that the angle error, denoted by theta, does not remain constant, and the transformation error does not remain uniform throughout the load range.

My invention, the structural arrangement of which has already been described, substantially overcomes this objectionable feature of variable exciting-current error in current transformers through the provision of the two separate iron cores which become saturated at different values of load current.

Fig. 5 illustrates, at curve 22, the dependence of the intensity of magnetic flux in the iron core upon the ampere-turns magnetizing force per unit core length, and curve 23 illustrates the specific magnetic reluctance of the iron, obtained from curve 22 according to known laws applying to this condition.

From these curves it can be seen that the reluctance offered by a magnetic circuit made up of iron is a function of the flux intensity, the iron offering a comparatively high reluctance at extremely low flux densities, a minimum reluctance at some intermediate density, and higher values again as the flux density is further increased.

In the current transformers of my invention, the magnetizing ampere turns per unit length of iron are so proportioned between the two cores that, for the cores designated by numeral 10, in Figs. 1, 2 and 3, the specific magnetic reluctance, at normal full load, is within the range designated by A in Fig. 5, which is below the minimum value 24 shown by curve 23, while, in the iron cores 11, this value lies within the range B, principally above the point of minimum value 24.

It will be seen that, in the curves of Fig. 5, the distance A is about one-tenth of the distance B. Hence, if, at full load, the ampere turns magnetizing cores 10 and 11 are of the values indicated by 25 and 26, respectively, the highly saturated core 11 will reach its point of minimum reluctance at approximately one-tenth of full load.

By thus proportioning the magnetic circuits 10 and 11, I am able to construct a current transformer in which the exciting current varies with the load in a manner indicated by curve 27 of Fig. 6. It will be evident that this curve, representing as it does the total exciting current of the transformer, comprises the sum of the individual exciting currents of the two iron cores 10 and 11 which, due to the relative degrees of magnetic saturation of these cores, as represented in Fig. 5, combine to produce the substantially straight-line variation, shown by curve 27 of Fig. 6.

It will be evident that a current transformer having such a straight-line variation of exciting current throughout the entire load range, will maintain substantially constant angle and transformation errors, irrespective of the load. The transformation error is represented by the difference in length of the primary and secondary current vectors 20 and 18, respectively, of Fig. 4, while the angle error is similarly represented by the angle theta, indicating the deviation of the primary and the secondary currents from the 180° phase position.

It is, therefore, evident that, through my invention, I have provided a method for making the transformation and the angle errors of a current transformer of substantially constant proportions for all loads, and, by a proper compensation of these errors for any given load, by known means, their effects will similarly disappear for all the other loads.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. A current transformer comprising, in combination, a primary winding, a secondary winding, and two separate iron cores similarly coupled with the secondary winding, said cores having similar magnetic lengths of iron, one core being enclosed by all of the primary winding turns and the other by only a portion of the total primary turns to thereby produce such relative degrees of magnetic saturation within the cores that, at normal load, the magnetic reluctance is in the range below the point of minimum value for one and in the range above the point of minimum value for the other.

2. A current transformer comprising, in combination, a primary winding, a secondary winding, and two separate iron cores having similar magnetic lengths, both of said cores being similarly coupled with one of said windings and one core being linked by a larger number of turns of the other of said windings than is the other core, the resulting difference in relative degrees of magnetic saturation within the two cores being such that at normal load the magnetic reluctance of one core will decrease with increasing magnetizing force and the reluctance of the other will increase with increasing magnetizing force.

In testimony whereof, I have hereunto subscribed my name this 24th day of November, 1930.

ALBERT CALLSEN.