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E. STEINERT

1,932,051

TRANSFORMER

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Fig. 1.

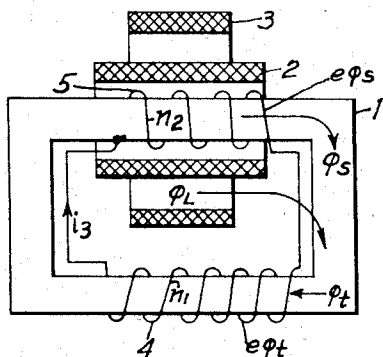


Fig. 2.

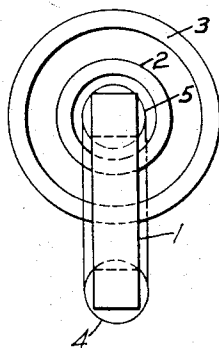


Fig. 3.

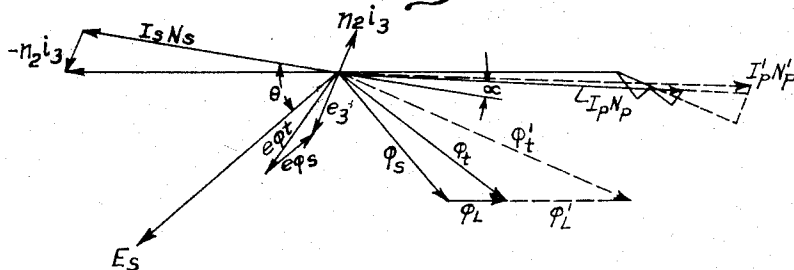
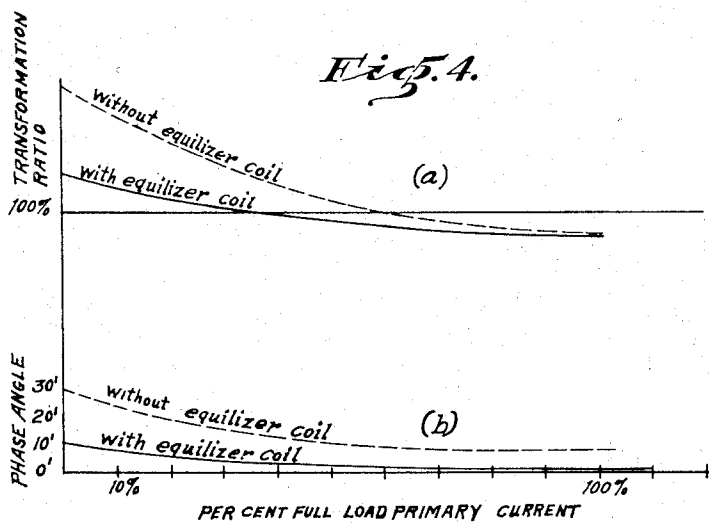


Fig. 4.



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TRANSFORMER

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9 Claims. (Cl. 175-358)

My invention relates to transformers and more particularly to means for improving the current ratio and the phase-angle performance of current transformers.

5 In current transformers, particularly those of the higher voltage ratings, the arrangement of the primary and secondary windings is such as to give a high magnetic leakage flux between them because of the relatively short effective length of the "high-low" space or flux leakage path between the windings. A portion of the leakage flux that passes between the primary and secondary windings traverses the outer leg of the iron core, that is, the portion of the core that is remote from that portion about which the primary and secondary windings are positioned. The leakage flux which traverses this portion of the iron core adds, vectorially, with the secondary or useful flux, thereby increasing the flux density in the outer leg of the core and increasing the exciting current required.

The presence of both the leakage and the secondary flux in a large part of the iron core requires that this portion of the magnetic circuit operate at a higher point on the saturation curve than the remaining portion of the core. This requires more primary ampere turns to excite the iron and consequently leaves less to be reproduced in the secondary than would be the case if the whole core carried the secondary flux only.

I propose to eliminate most of the leakage flux from the iron core by providing a third winding known as the "equalizer winding", positioned about the outer leg of the transformer and connected with either the secondary winding or a portion thereof, or with an auxiliary winding surrounding that portion of the magnetic core about which the secondary winding is positioned.

It is an object of my invention to provide a transformer having a substantially constant ratio of current transformation with varying primary circuit current.

It is another object of my invention to provide a transformer of the class described with simple means for adjusting the phase-angle relation between the primary and secondary current to a desired value.

A further object of my invention is to provide a transformer of the class described in which the dimensions of the iron circuit and the relating parts may be relatively small.

Other objects will be apparent from the following specification describing a preferred embodiment of my invention.

55 In the drawing, Figure 1 is a view, partly in longitudinal cross-section and partly in side elevation, of a transformer, the several parts of which are organized in accordance with my invention.

Fig. 2 is an end elevational view of the transformer shown in Fig. 1.

Fig. 3 is a vector diagram showing the phase-angle relation between a number of the quantities affecting the operation of the transformer; and

Fig. 4 illustrates curves showing approximately the difference in phase-angle relations and in the ratio of current transformation in a transformer of the character described when the equalizing coils of the invention are employed.

Referring to the drawing, and particularly Figs. 1 and 2 thereof, 1 indicates a core or loop of magnetic material shown as being rectangular in form. A secondary winding 2 and a primary winding 3 are shown positioned about the upper horizontal portion, or winding leg, of the core. An equalizer coil 4 is shown wound about the lower horizontal portion, or outer leg, of the transformer core and connected with a coil 5, which has a different number of turns than the core 4, and is wound about the winding leg within the opening of the primary winding 2. The connection between coil 4 and coil 5 is such that, if the two coils had the same number of turns and the secondary flux alone were in the core, the voltages induced in the two coils would buck each other, and no current would flow.

Instantaneous directions of currents and of magnetic flux are indicated in Fig. 1, and the approximate phase-relation between the several quantities are shown in the vector diagram of Fig. 3.

Referring to Figs. 1 and 3, that portion of the leakage flux which traverses the iron core is represented by ϕ_L , and the useful secondary flux is represented by ϕ_s . The dotted line ϕ'_t in Fig. 3 indicates the flux in the outer leg of the transformer when the equalizer winding is not employed. ϕ_t indicates the flux in this leg when the equalizer winding is employed. The vector ϕ'_L that connects the ends of the vectors ϕ_s and ϕ'_t represents the value of ϕ_L when the equalizer winding 4 is not employed.

ϕ_L is limited by the current which flows in the equalizer circuit, and is just large enough to induce the voltage needed to circulate said current.

The primary must supply, in addition to the ampere turns which appear in the secondary, other ampere turns to magnetize the core. When the equalizer is used, the magnetizing ampere turns are represented by the two small full-line triangles at the extreme right of Fig. 3. The first triangle consists of magnetizing ampere-turns parallel to ϕ_s and non-disc ampere-turns perpendicular to ϕ_s . These excite the part of the core which carries the flux ϕ_s . Besides this a similar small triangle represents the excitation of the part of the core which carries the flux ϕ_t . The latter triangle is replaced, if the equalizer is not used, by the large dotted triangle with sides parallel and perpendicular respectively to ϕ'_t . It will be noted that the total primary ampere turns used

to excite the core are much less when the equalizer is in use.

The voltage induced in the equalizer coil 4 by the flux ϕ_1 is represented on the vector diagram of Fig. 3 by the line e_{ϕ_1} . A value of e_{ϕ_1} is assumed sufficient to overcome the impedance of the equalizer windings. The voltage induced in the auxiliary winding 5 by the flux ϕ_1 is indicated on the diagram by the line e_{ϕ_1} . The current in the circuit of the equalizer winding 4 is assumed to be in phase with the resultant induced voltage e_3 .

It will be noted that a change in the number of turns of equalizer coil 4 or the auxiliary coil 5 affects the vector i_2 , thereby changing the phase-angle of the secondary ampere turns $I_2 N_2$. By a suitable selection of the number of turns in coils 4 and 5, the angle between the vector $I_2 N_2$ and the extension of vector $I_1 N_1$ can be made very small, or even reduced to zero. The resulting change in the length of the vector $I_2 N_2$ may be compensated for by changing the number of turns N_2 in the secondary winding, thus maintaining a proper secondary current I_2 .

It will also be noted that, as the exciting current is reduced because of the use of the equalizer winding, and vector $I_1' N_1'$ is shortened to vector $I_1 N_1$, the ratio between the primary and secondary ampere-turns approaches unity.

While the above description refers to an auxiliary winding 5 separate from the secondary winding of the transformer, it will be noted that the equalizer winding 4 may be connected to all or a portion of the secondary winding which will function as an auxiliary winding associated with the equalizer winding of the transformer.

It will be apparent to those skilled in the art that modifications may be made in the structure illustrated and described, without departing from the spirit of my invention, and I do not wish to be limited otherwise than by the scope of the appended claims.

I claim as my invention:

1. In a transformer, a core comprising a closed loop of magnetic material, a primary and a secondary winding wound about a portion of said core, and means for preventing stray magnetic flux which passes between said windings from entering the flux path of said magnetic circuit.

2. In a transformer, a core comprising a closed loop of magnetic material, a primary and a secondary winding wound about a portion of said core, and means for reducing the stray flux which enters said magnetic path comprising windings electrically connected together and inductively related to different portions of said magnetic core on opposite sides of the location cut by stray flux passing between the primary and secondary windings.

3. A transformer having a primary winding adapted to be connected in series relation with a line whose current is to be measured, a secondary winding inductively related to said primary winding, a core of magnetic material associated with said windings comprising a winding leg and an outer leg, and means for maintaining the ratio of current transformation at the terminals of the windings substantially constant for varying loads comprising equalizer windings on said winding leg and on said outer leg.

4. A transformer having a primary winding

adapted to be interposed in series relation with a line whose current is to be measured, a secondary winding inductively related to said primary winding, and a core of magnetic material associated with said windings comprising a winding leg and an outer leg, and means for neutralizing the effect of stray flux in said outer core leg comprising a winding on said outer leg connected with a winding on the winding leg.

5. A transformer having a primary winding adapted to be interposed in series relation with a line whose current is to be measured, a secondary winding inductively related to said primary winding, a core comprising a loop of magnetic material one portion of which passes through said windings, and means for maintaining the ratio of current transformation substantially constant for varying loads comprising an equalizer winding about a portion of said core remote from the primary and secondary windings and connected with winding turns about a portion of the core surrounded by said windings.

6. In a transformer, a core structure comprising a closed loop of magnetic material having a winding leg, a secondary winding wound about said winding leg, a primary winding wound about said secondary winding, and means for compensating for variations in the ratio of current transformation for varying loads comprising an equalizer winding about that portion of said core opposite said winding leg and connected with winding turns placed about said winding leg.

7. A transformer having a primary winding adapted to be connected in series relation with a circuit whose current is to be measured, a secondary winding inductively related to said primary winding, a core of magnetic material associated with said windings comprising a winding leg and an outer leg, and means for maintaining the phase angle relation between the current in the primary and secondary windings substantially constant for varying loads comprising equalizer windings on said winding leg and on said outer leg.

8. A transformer having a primary winding adapted to be interposed in series relation with a circuit whose current is to be measured, a secondary winding inductively related to said primary winding, a core comprising a loop of magnetic material one portion of which passes through said windings, and means for minimizing the phase angle displacement between the currents in said primary and secondary windings comprising an equalizer winding about a portion of said core remote from the primary and secondary windings and connected with winding turns about the portion of the core surrounded by said primary and secondary windings.

9. In a transformer, a core structure comprising a closed loop of magnetic material having a winding leg, the secondary winding wound about said winding leg, a primary winding wound about said secondary winding, and means for compensating for phase angle error between the currents in said primary and secondary windings for varying loads comprising an equalizer winding wound about that portion of the core opposite said winding leg and connected with winding turns positioned about said winding leg.

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