

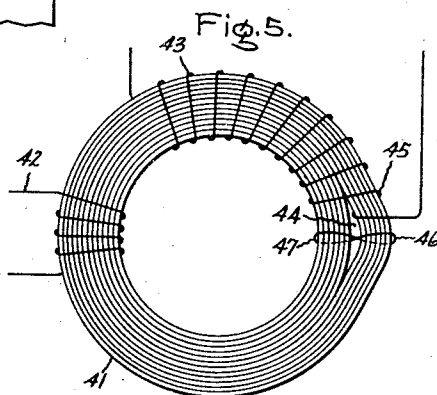
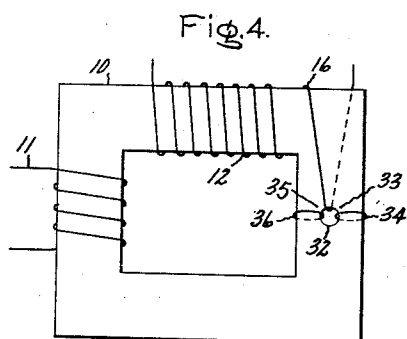
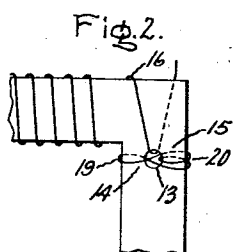
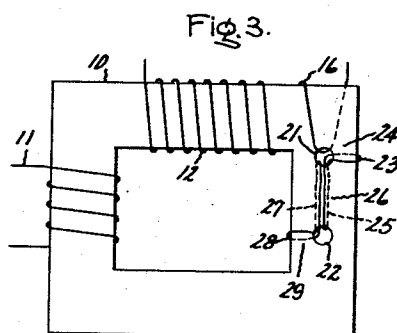
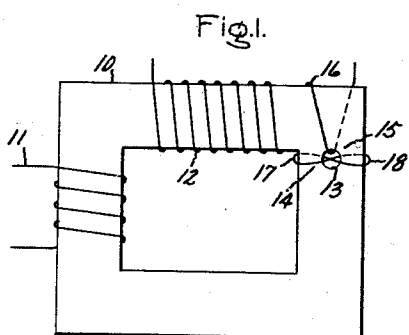
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F. R. D'ENTREMONT

2,284,406

TRANSFORMER

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Inventor:
Franklin R. D'Entremont,
by *Harry E. Dunham*
His Attorney.

UNITED STATES PATENT OFFICE

2,284,406

TRANSFORMER

Franklin R. D'Entremont, Lynn, Mass., assignor
to General Electric Company, a corporation of
New York

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13 Claims. (Cl. 175-358)

This invention relates to transformers and more particularly to compensating arrangements therefor whereby any desired ratio of transformation may be obtained.

In the ideal transformer, the ratio of transformation of primary to secondary voltage would be equal to the ratio of primary to secondary turns, and the ratio of primary to secondary current would be equal to the inverse ratio of the number of turns. However, due to the exciting current drawn by the transformer occasioned by the internal drop and losses, the true ratio of transformation does not equal the turn ratio. Ratio errors can be reduced for given conditions by using a turn ratio slightly different from the marked ratio, that is, in the case of a potential transformer the number of secondary winding turns may be slightly increased, or in the case of a current transformer the number of secondary turns may be slightly decreased. The transformer is then said to be compensated for that particular condition. The particular compensation for a given transformer depends largely upon the characteristics such as frequency, power factor, burden impedance, and primary voltage or current. It is not always possible to secure the exact compensation desired by this method, for example, in the case of current transformers having a relatively few turns in the secondary windings, one turn may amount to something like one per cent of the total number of turns, and frequently in order to secure the exact compensation desired a fraction of a single turn is required. Such fractional turn compensation may be obtained by providing a secondary winding having one turn linking only a fractional part of the core structure. It is extremely difficult to calculate with a high degree of accuracy the exact division to be made in the core for the accommodation of the effective fractional turn because of certain variable factors entering into the manufacture, assembly and use of a particular transformer. In addition, the effective part turn compensation of such arrangements will not be constant, but will change with different values of secondary current due to the changes in permeability of the magnetic circuit on either side of the turn that encloses only part of the magnetic circuit. Furthermore, a transformer provided with fractional turn compensation determined solely by the cross-sectional area of the core divisions has the disadvantage that once the transformer is assembled the ratio cannot be readjusted for further correction.

It is therefore an object of this invention to

provide a new and improved transformer in which any desired ratio of transformation may be obtained in a simple and effective manner. It is a further object of the invention to provide a partial turn compensated transformer in which the partial turn ratio may be adjusted without altering the core structure and the effect of the partial turn will remain constant over the normal current range.

For a consideration of what I believe to be novel and my invention, attention is directed to the following description and the claims appended thereto taken in connection with the accompanying drawing.

In the drawing Fig. 1 is a diagrammatic view of a current transformer constructed in accordance with the invention; and Figs. 2, 3, 4, and 5 are diagrammatic views illustrating additional modifications of the invention.

In the arrangement shown in Fig. 1, the transformer includes a rectangular laminated core 10 having a primary winding 11 and a secondary winding 12. The core 10 is provided with an opening 13 at right angles to the laminations so that two short core sections 14 and 15 forming two parallel paths are formed in the core past the opening. Thus, a unitary magnetic core is provided with a portion defining two parallel paths for the magnetic core flux, or the core has two sections arranged to conduct the magnetic core flux in parallel paths. The opening is preferably located near a corner of the rectangular core and near one end of the secondary winding 12. The end turn 16 of the secondary winding 12 is threaded through this opening and constitutes a fractional turn, since it links but a portion of the core structure 10. The winding 12 with the end turn 16, therefore, includes a portion surrounding the entire core and a second portion surrounding only one of the sections or parallel flux paths.

In the arrangement thus far described it will be obvious that if the secondary winding coil is open circuited and a source of current is connected across the primary winding 11, a primary flux will thread the core structure with the total flux dividing and passing the opening 13 therein in substantially direct proportion to the cross-section of the core portions 14 and 15. Since only the flux passing through the core portion 15 links with the secondary end turn 16, the turn 16 is in effect only a fractional turn as regards the remaining turns of the secondary winding. If the opening 13 were placed in the exact center of the core, then it is obvious that exactly

one half of the total primary flux would thread through the end turn 16 and it in effect would constitute an exact one-half turn. This relationship, however, does not apply with a current flowing through the secondary coil, as when the secondary burden is connected. With a secondary current flowing a localized magnetic flux will circulate in the core structure around the opening 13, since the laminations comprise closed loops around the secondary conductor passing therethrough. This local circulating flux will tend to unbalance the primary flux distribution passing through the core portions 14 and 15. Depending upon the direction of the secondary winding turns, the unbalance of primary flux in the core portions 14 and 15 will cause either a greater or a lesser effectiveness of the fractional turn 16.

In order to maintain the desired balance of the primary flux passing through the core portions on opposite sides of the transverse opening 13, with secondary current flowing, I provide an auxiliary winding around the core comprising loops 17 and 18 connected in a series opposing relationship so that the voltages induced in the two loops by the primary flux will be in opposition. Thus, the loops or coils extend around each of the core sections and are connected in series opposition as regards to their voltages produced by the core flux so as to maintain a predetermined ratio between the core flux in each of the parallel paths or core sections. Also, assuming a total flux below a predetermined value the two parallel flux paths are substantially non-saturating. The auxiliary winding as shown in Fig. 1 comprises a figure eight coil having a single turn around each of the core portions 14 and 15, though it will be understood that the number of turns around each portion may be varied in accordance with the degree of compensation desired. If the number of turns in these two coils of the auxiliary winding are equal, the magnetic flux will divide equally through the two core portions, since any difference in flux distribution will produce a higher voltage in one of the auxiliary winding coils than in the other. This in turn would produce a current flow in the auxiliary winding tending to reduce the greater flux and increase the smaller in the two core portions. Exact half turn compensation is thus provided regardless of the exact location of the opening 13, as regards the width of the core, so long as neither core portion on the opposite sides of the opening is allowed to become saturated. This is a distinct advantage in that the exact location of the opening 13 through the core structure for the partial secondary turn 16 need not be calculated with extreme care, since the flux linkages with the partial turn 16 are accurately controlled by the auxiliary winding 17-18 independently of the relative cross-sectional areas of the two core portions 14 and 15.

If either more or less compensation is desired than would be provided by the one-half turn, the ratio of the number of turns in the two coils of the auxiliary winding may be varied until the desired compensation is effected. Thus, for example, if it is found that the auxiliary winding having one turn in each coil, as shown in Fig. 1, does not provide enough compensation, that is, less than a one-half effective turn is required, the number of flux linkages with the partial secondary turn 16 can be diminished by increasing the number of turns in the coil of the auxiliary winding surrounding the core portion 15. As 75

indicated in Fig. 2, the coil 19 comprises one turn whereas the coil 20 comprises two turns whereby one-third of the primary flux will be caused to pass through the core portion 15 and two-thirds through the core portion 14. The partial turn 16 is thus made an effective one-third turn instead of an effective one-half turn as in the case of Fig. 1.

This manner of effecting partial turn compensation is particularly advantageous in that it may be varied after the transformer has been otherwise completely assembled. In usage the characteristics of the transformer may be altered whereby it may become necessary to readjust the compensation thereof. With this arrangement, the compensation may be readjusted without completely dismantling the transformer which would, in itself, further disturb the electrical characteristics thereof.

In actual practice it is desirable that the space factor of the transformer be maintained as high as possible and for this reason it may be undesirable that the turns of the auxiliary winding linking the inner core portion 14 be arranged immediately adjacent the winding leg for the main secondary winding 12. In the event that this portion of the auxiliary winding requires a plurality of turns, then the secondary winding would have to be spaced a corresponding distance from the leg in which the auxiliary winding is provided. In Fig. 3 is shown a modification of the invention in which the various portions of the auxiliary winding may be longitudinally displaced in order that the auxiliary winding around the inner core portion may be arranged beyond the physical limits of the secondary coil. Two centrally located openings 21 and 22 are provided transversely through the core structure 10 and in longitudinal alignment with each other. The opening 21 is adjacent the secondary winding 12 and opening 22 is preferably located beyond the outer limit of the secondary winding. Two auxiliary windings are provided in this instance which cooperate in such a manner as to produce a result similar to that of the single winding as described in connection with the foregoing modification. The first auxiliary winding comprises a loop 23 surrounding the core portion 24 to the right of the opening 21, and an opposing series connected loop 25 surrounding the core portion 26 between the openings 21 and 22. The second auxiliary winding comprises one loop 27 surrounding the core portion 26 between the openings 21 and 22 adjacent the loop 25 of the first winding and a second loop 28 connected in a series opposing relationship arranged around the core portion 29 to the left of the lower opening 22. The effect of the first winding 23-25 is to cause the same amount of primary flux to flow through the core portion 24 and the core portion 26, and similarly, the effect of the second auxiliary winding 27-28 is to cause the same amount of primary flux to flow through the core portion 29 as flows through the portion 26. With the first and second windings having single turns in each coil, as shown in the drawing, they cooperate to force one-third of the total primary flux through the core portion 24 to the right of the opening 21 and two-thirds of the total flux through the core to the left of the opening 21. The flux passing through the core portion to the left of the opening 21 is divided equally so that one-half of it passes through the core portion 26 and one-half through the core portion 29. Thus one-third of

the total primary flux passes to the left of the lower opening 22 while two-thirds of the total flux passes to the right of the lower opening 22. By the arrangement indicated then, one third of the total primary flux will link with the partial turn 16 of the secondary winding. It is obvious that by varying the number of turns of the coil 23 of the first winding and coil 28 of the second winding, any desired flux linkage with the partial turn 16 may be obtained. It is obvious of course that the number of turns of each auxiliary winding coil surrounding the intermediate core portion 26 between the two openings 21 and 22 should be the same. As in the preceding modification, care should be taken in selecting the size of the core and in locating the openings 21 and 22 so that no part of the core will become saturated.

Referring now to Fig. 4, an additional modification of the invention is disclosed in which the auxiliary compensating winding for the transformer comprises individual short circuited turns. As in the first modification a single opening 32 is provided transversely through the laminations of the core structure 10 through which opening is threaded the end turn 16 of the transformer secondary winding 12. The core portion 33 to the right of the opening 32 is surrounded by a short circuited coil 34 while the core portion 35 to the left of the opening 32 is surrounded by a short circuited coil 36. By selecting the proper resistance for the coils 34 and 36, the effective reluctance of the core sections 33 and 35 may be varied to secure any desired distribution of the primary flux through this leg of the core and hence, through the partial secondary turn 16. For example, assume first that the coil 36 possesses zero resistance while coil 34 possesses infinite resistance. Under this condition any primary flux attempting to pass through the core portion 35 will induce a current in the coil 36 which in turn will produce a secondary flux in opposition to the primary flux so as to substantially neutralize the primary flux passing therethrough. The coil 34 having infinite resistance will have negligible current induced therein and consequently, a negligible secondary flux will be created thereby. It is obvious, therefore, that the effective reluctance of the core portion 33 will be relatively low whereas the effective reluctance of the core portion 35 will be relatively high so that substantially the entire primary flux will pass through the portion 33 and consequently, link with the secondary turn 16. Under this condition, the secondary turn 16 will constitute an effective full turn of the secondary winding. Conversely, assume that the coil 34 has zero resistance and coil 36 infinite resistance. Then substantially all of the primary flux will flow through the core portion 35 to the left of the opening 32 and hence, none of the primary flux will link with the secondary winding turn 16. With no primary flux linking the secondary turn 16, it will have zero effectiveness insofar as effecting any compensation in the transformation ratio of the transformer. It is obvious, therefore, that by selectively proportioning the resistances of the two coils 34 and 36, any desired amount of primary flux may be directed through the secondary winding turn 16 to effect any desired compensation in the transformation ratio. As in the preceding modifications, the location of the opening 32 as regards the width of the core need only be roughly calculated, keeping in

mind that the core sections on the opposite sides thereof should not be allowed to saturate during the operation of the transformer.

The resistances of the short circuited coils are preferably of a magnitude somewhat greater than the total resistance of the secondary circuit divided by the number of secondary turns. The values would normally range from 0.001 ohm to 0.1 ohm. There are two conditions which control these resistances; the first is to keep the values high enough so that the exciting current of the main core is not appreciably affected by the losses in the short circuited coils. The second factor is to have the resistances low enough so that substantially all of the ampere turns supplied by the secondary turn through the opening will be used in the short circuited coil in order that the magnetomotive force from this source will have very little effect on the main primary flux.

In the modifications of Figs. 1 to 4 inclusive, transformers are disclosed having magnetic structures built up of conventional punched laminations. It is obvious, however, that the compensating arrangements shown are equally applicable for use with transformers having magnetic structures of the wound ribbon type. In the modification illustrated in Fig. 5, the transformer comprises a wound ribbon magnetic core 41 provided with a primary winding 42 and a secondary winding 43. The core structure is so wound as to provide an opening 44 between adjacent layers in the midportion of the core structure. For effecting partial turn compensation for the transformer, the end turn 45 is threaded through the opening 44 substantially as indicated. For selectively controlling the amount of flux linking with the end turn 45 of the secondary winding, any one of the compensating arrangements described above may be applied. As indicated in the drawing, a figure eight coil such as shown in Fig. 1 is provided comprising loops 46 and 47 connected together in a series opposing relationship. In a manner substantially as described above in connection with the modification shown in Fig. 1 the figure eight coil will control the primary flux linkages with the end turn 45 of the secondary winding irrespective of the actual amount of the magnetic material which it surrounds. Again it should be kept in mind, however, that the core structure should be so divided that neither portion will operate under a condition of saturation. By selectively varying the number of turns of the coils 46 and 47, any amount of compensation may be obtained to vary the transformation ratio as desired.

Having described the principle of operation of my invention together with the apparatus which I now consider to represent the best embodiment thereof, I desire to have it understood that the apparatus shown is merely illustrative and that the invention may be carried out by other means.

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

1. An electric transformer including a unitary magnetic core, a portion of said magnetic core defining two parallel paths for the magnetic core flux, a winding on said core having one portion surrounding said core and a second portion surrounding only one of said parallel paths, an auxiliary winding arranged around said core portion having one coil surrounding each of said two parallel paths, said coils being connected in series opposition as regards their voltages produced

by the core flux, and the number of turns of each of said auxiliary winding coils being such as to produce a predetermined distribution of magnetic flux between said two parallel paths.

2. A transformer including a laminated magnetic core, a portion of said core being provided with an opening therethrough extending transversely to the laminations to divide said core portion into two sections, a secondary winding having a portion surrounding the entire core and one portion surrounding only one of said sections, and an auxiliary winding including coils surrounding each of said sections and extending through said opening, said auxiliary winding serving to maintain a predetermined balance in the flux density in said two sections.

3. A transformer including a magnetic core having two sections arranged to conduct the magnetic core flux in parallel paths, a secondary winding surrounding said core and having one turn linking only one of said sections, and an auxiliary winding having coils extending around each of said core sections and connected together in a series opposing relationship so as to maintain a predetermined proportion of the total core flux in said core section linked by said one secondary turn.

4. A transformer including a magnetic core having two non-saturating sections arranged to conduct the magnetic core flux in parallel paths, a secondary winding having a portion linked by the total core flux and a second portion linked only by the core flux in one of said paths, and an auxiliary winding having portions provided on each of said core sections, said auxiliary winding portions being so arranged as to effect a distribution of the core flux between said parallel paths in a predetermined ratio irrespective of the relative cross-sectional areas of said paths.

5. A transformer including a magnetic core having two sections arranged to conduct the magnetic core flux in parallel paths, a secondary winding having a portion linked by the total flux and a portion linked by the flux in only one of said paths, and an auxiliary winding surrounding each of said parallel paths so as to maintain a predetermined ratio of distribution of the magnetic flux in said parallel paths throughout the normal current range of said transformer.

6. A transformer including a magnetic core having two sections arranged to conduct the magnetic core flux in parallel paths, a secondary winding having a portion linked by the total core flux and a second portion linked only by the flux in one of said paths, and a short circuited winding arrangement surrounding each of said core sections so as to maintain a predetermined ratio between the core flux in each of said parallel paths.

7. A transformer including a magnetic core having an opening extending therethrough providing two non-saturating parallel paths for the magnetic core flux, an auxiliary winding having a coil surrounding each of the magnetic core sections on opposite sides of said opening, said coils being connected together in a series opposing relationship.

8. A transformer including a unitary magnetic core, an opening in said core providing two non-saturating parallel paths in a portion of said core for the magnetic core flux, and auxiliary windings extending through said opening and around said core sections for maintaining substantially constant the flux distribution through said paths throughout the normal current range of said transformer.

9. A transformer comprising a core having an opening formed therein, a winding on said core, said winding having a plurality of turns completely surrounding said core, at least one turn of said winding passing through said opening in said core and means extending through said opening and around the core portions on the opposite sides thereof for maintaining substantially constant the ratio of the flux linkages with said turn passing through said opening relative to the total core flux.

10. A transformer comprising a core having an opening formed therein, a primary and a secondary winding on said core, said secondary winding having a portion thereof completely surrounding said core and another portion passing through said opening in said core, and means for maintaining a predetermined ratio between the primary core flux linking with said winding portion passing through said opening and the total primary core flux.

11. A transformer including a magnetic core, a portion of said core being provided with a pair of spaced apart openings extending transversely through said core, a first auxiliary winding having one coil surrounding the core section defined by the first of said openings and one side of said core and a second coil connected in a series opposing relationship to said first coil arranged around the core section defined by said two openings, a second auxiliary winding having a first coil arranged around the core section defined by said second opening and the opposite side of said core and a second coil connected in a series opposing relationship with said first coil of said second winding and surrounding said core section defined by said two openings.

12. A transformer including a magnetic core, a portion of said core being provided with an opening extending through said core to divide said core into two parallel flux paths, a secondary winding having a portion surrounding the entire core and one portion surrounding only one of said paths, and separate short circuited coils provided around said two parallel flux paths, the resistance of said coils being such as to effect a predetermined ratio of the flux distribution through said parallel flux paths.

13. A current transformer including a magnetic core having two sections arranged to conduct the core flux in parallel paths and a short circuited winding surrounding each of said sections, the resistance of said windings being such as to effect a predetermined ratio of the flux distribution through said parallel flux paths.

FRANKLIN R. D'ENTREMONT.