May 6, 1952 K. D. BEARDSLEY 2,595,753

EQUALIZER WINDING FOR FIVE-LEGGED THREE-PHASE CORES

Filed Dec. 31, 1949

Fig. 1.

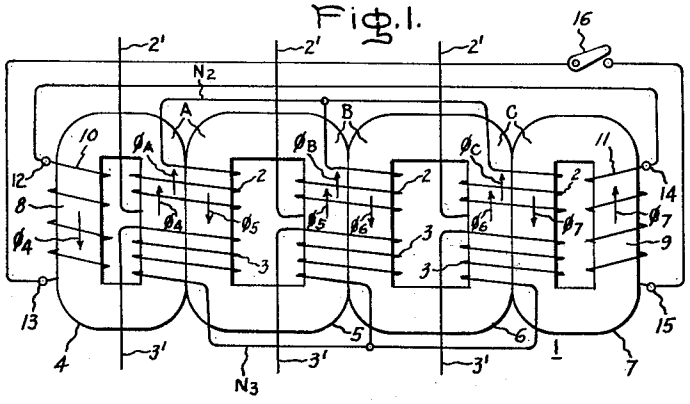

Fig. 3.

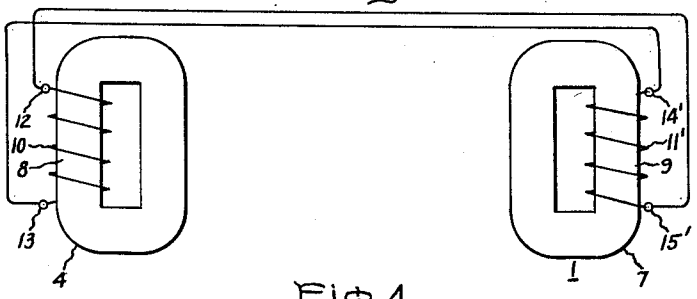

Fig. 4.

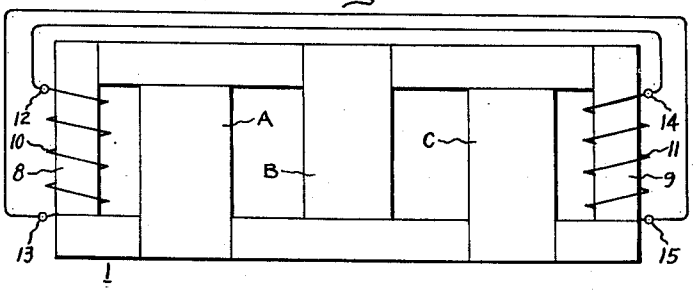

Fig. 2a.

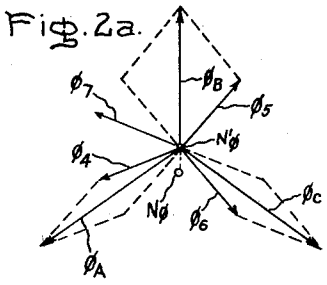

Fig. 2b.

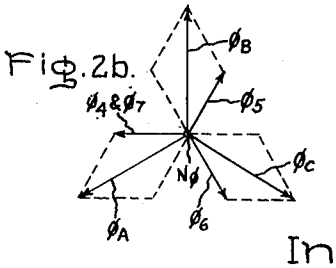

Fig. 2c.

$\phi_A = \phi_4 - \phi_5$

$\phi_B = \phi_5 - \phi_6$

$\phi_C = \phi_6 - \phi_7$

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EQUALIZER WINDING FOR FIVE-LEGGED THREE-PHASE CORES

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2 Claims. (Cl. 323—50)

1

This invention relates to induction apparatus and more particularly to three-phase transformers of the five-legged core type in which Y—Y connections are employed. The use of five-legged cores permits the construction of transformers of reduced height as compared with transformers employing other types of cores. Such transformers, therefore, have found extensive use in mining applications and the like in which head-room is limited and apparatus of minimum height is desired. It has been found, however, that when Y—Y connections of primary and secondary windings are employed with transformers having five-legged cores substantial displacement of the neutral point generally occurs, with resultant unbalance of the transformer voltages.

It is accordingly a principal object of the present invention to provide an improvement in induction apparatus of the five-legged core type, whereby neutral displacement is substantially prevented when Y—Y connections are employed therein. In accordance with my invention I provide equalizer windings on the outside legs of five-legged cores to reduce to a minimum neutral-shift due to the difference in phase of the fluxes which exist in the outside legs.

My invention will be better understood from a consideration of the following description taken in connection with the figures of the accompanying drawing, and its scope will be pointed out in the appended claims. In the drawing Fig. 1 is a schematic cross section of a transformer of the five-legged core type having a wound strip-steel core and including equalizer windings in accordance with my invention; Figs. 2*a* and 2*b* are vector diagrams illustrating, respectively, neutral-shift in the fluxes in a five-legged core without the use of equalizer windings and the corresponding fluxes without neutral-shift; Fig. 2*c* gives the algebraic relationships of the fluxes shown in Figs. 2*a* and 2*b*; Fig. 3 is similar to Fig. 1, except with modified equalizer windings and connections; and Fig. 4 is similar to Fig. 1 except that the core shown therein is of conventional laminated construction.

Referring now to Fig. 1 there is shown a three-phase transformer having a five-legged core 1, primary windings 2 and secondary windings 3. Core 1 is of the wound strip-steel type comprising a plurality of separate coils 4, 5, 6 and 7. Coils 5 and 6 may be termed center coils while coils 4 and 7 are end coils. Corresponding side portions of coils 4 and 5, coils 5 and 6, and coils 6 and 7, respectively, are placed in contact to form the main center legs A, B and C of the transformer.

2

The remaining side portions of coils 4 and 7 form the auxiliary outside legs 8 and 9 of the transformer.

Primary windings 2 and secondary windings 3 are wound on main legs A, B and C, and are arranged for Y—Y connections. In other words corresponding ends of windings 2 are commonly connected to form a neutral point N_2, while corresponding ends of windings 3 are commonly connected to form a neutral point N_3. The opposite or free ends of windings 2 form primary connections 2' to the transformer, while the corresponding ends of windings 3 form secondary terminals 3' of the transformer. It will be understood that the terms "primary" and "secondary" are employed primarily for purposes of distinguishing between the two sets of windings and either windings 2 or windings 3 may be input windings of the transformer while the other windings are the output windings thereof.

A pair of auxiliary or equalizer windings 10 and 11 are provided on outside legs 8 and 9 and are oppositely wound thereon. Winding 10 terminates in terminals 12 and 13, while winding 11 terminates in corresponding terminals 14 and 15. Terminals 12 and 14 are interconnected and terminals 13 and 15 are similarly interconnected. A switch 16 is shown in the line interconnecting terminals 13 and 15 for the purpose of illustrating the effect of placing equalizer windings 10 and 11 in operation, as will be described hereinafter.

In operation three-phase voltages are impressed on either windings 2 or 3 and a plurality of fluxes are established in the various legs of core 1. The fluxes in individual coils 4—7 are designated ϕ_4—ϕ_7, respectively, and are represented in Fig. 1 by arrows having similar designations. While individual fluxes ϕ_4—ϕ_7 exist in coils 4—7, the net fluxes ϕ_A, ϕ_B and ϕ_C existing in main legs A, B and C, which are representative of the voltages in windings 2 and 3, are the vector differences of the component fluxes existing in the individual coils forming legs A, B and C. More particularly, ϕ_A is the vector difference of ϕ_4 and ϕ_5. Similarly, ϕ_B is the vector difference of ϕ_5 and ϕ_6, and ϕ_C is the vector difference of ϕ_6 and ϕ_7. The subtraction of the various fluxes is shown algebraically in Fig. 2*c*.

Referring now to Fig. 2*a*, there is shown a vector diagram illustrating the relationship of the various fluxes in core 1 without the effect of equalizer windings 10 and 11, or with switch 16 assumed to be open. It will be seen that fluxes ϕ_4 and ϕ_7 are equal but not in phase. Accordingly fluxes ϕ_A and ϕ_C are equal in magnitude and sym-

metrical with respect to the vertical axis, but ϕ_B is smaller due to the shift of the neutral from Nϕ to N'ϕ. It can be shown that such neutral-shift is due to a difference in phase between fluxes ϕ_4 and ϕ_7. By forcing fluxes ϕ_4 and ϕ_7 to be in phase, therefore, the neutral-shift may be substantially eliminated or reduced to a minimum. In accordance with my invention I accomplish this result by the use of equalizer windings 10 and 11 which are provided with equal numbers of turns and are oppositely wound on outside legs 8 and 9. If it is assumed that equalizer windings 10 and 11 are connected in series relation by closing switch 16, the vector relationship shown in Fig. 2b is obtained wherein fluxes ϕ_4 and ϕ_7 are equal and in phase. It will be seen that the component fluxes ϕ_4 and ϕ_7 are in phase and that ϕ_B is substantially equal in magnitude to ϕ_A and ϕ_C. Accordingly there is substantially no neutral shift.

In the arrangement of Fig. 1 windings 10 and 11 are shown oppositely wound on legs 8 and 9 with corresponding terminals connected together. It will be obvious, however, that these equalizer windings may be wound in the same direction and cross-connected. Such an arrangement is shown in Fig. 3 wherein equalizer winding 10 is shown wound on leg 8 in the same direction as in Fig 1. Equalizer winding 11', however, is wound on leg 9 in the same direction as winding 10 and not in the opposite direction with respect thereto as winding 11 is wound in Fig. 1. While, in the arrangement of Fig. 1, core 1 is shown as being of the wound strip-steel type, it will be obvious that my invention applies equally well in connection with other types of five-legged cores as, for example, a core of the conventional laminated type as shown in Fig. 4.

It will be noted that the equalizer windings provided by my invention are wound on outside or auxiliary legs which otherwise are devoid of windings and are, therefore, easily provided therewith. Moreover the use of such windings does not appreciably increase core losses or create other undesirable effects. From the foregoing it will be seen that my invention thus provides a simple and inexpensive structure in three-phase induction apparatus employing five-legged cores and having Y—Y connections, to eliminate or reduce neutral-shift to a minimum and thus provide inherent neutral stability therein.

While I have shown and described preferred embodiments of my invention, it will be understood that my invention may well take other

forms and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

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

1. In three-phase induction apparatus, a magnetic core of the five-legged type having three main center legs and a pair of auxiliary outside legs, main windings wound on said main legs and including primary and secondary windings connected in Y—Y relationship, said primary winding being connected to a three-phase alternating current source, and a pair of equalizer windings wound on said auxiliary legs and connected in series opposed relation with each other to reduce to a minimum neutral-shift in the fluxes in said main legs and in the voltages in said main windings.

2. In three-phase induction apparatus, a magnetic core of the five-legged type having three center legs and a pair of outside legs, main windings wound on said center legs and including primary and secondary windings connected in Y—Y relationship, said primary winding being connected to a three-phase alternating current source, and a pair of equalizer windings, one of said equalizer windings being wound on one of said outside legs and the other of said equalizer windings being wound on the other of said outside legs, said equalizer windings being oppositely wound with respect to each other and connected in series relation with each other to reduce to a minimum neutral-shift in the fluxes in said center legs and in the voltages in said main windings.

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