

Sept. 2, 1930.

H. S. PETCH

1,774,944

ELECTRIC CURRENT TRANSFORMING MEANS

Filed Jan. 4, 1926

2 Sheets-Sheet 1

Fig. 1.

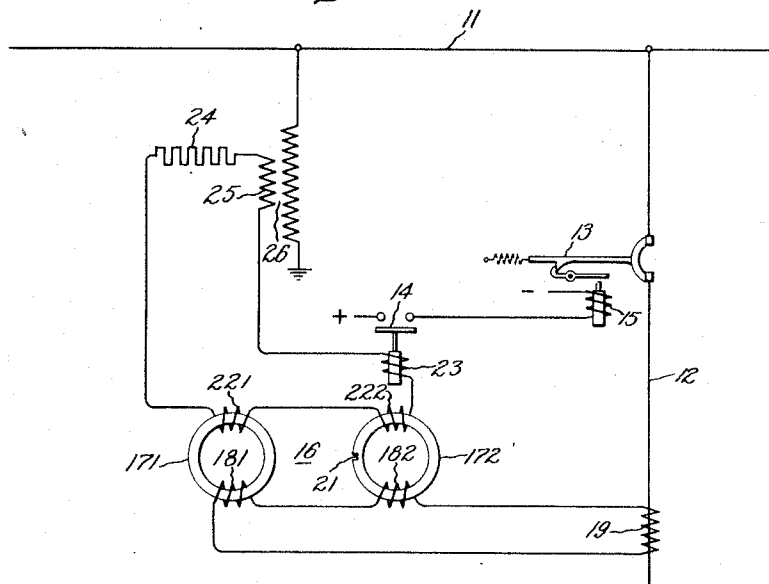
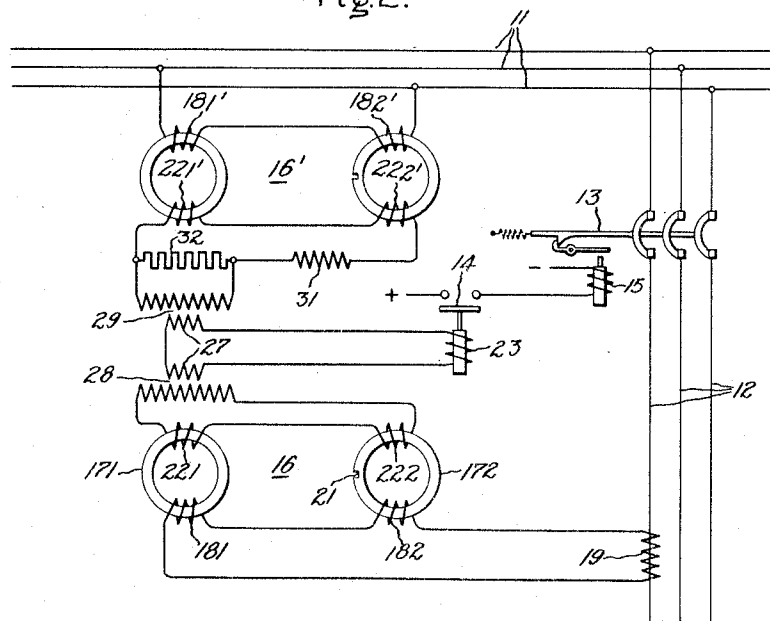


Fig. 2.



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Fig. 3.

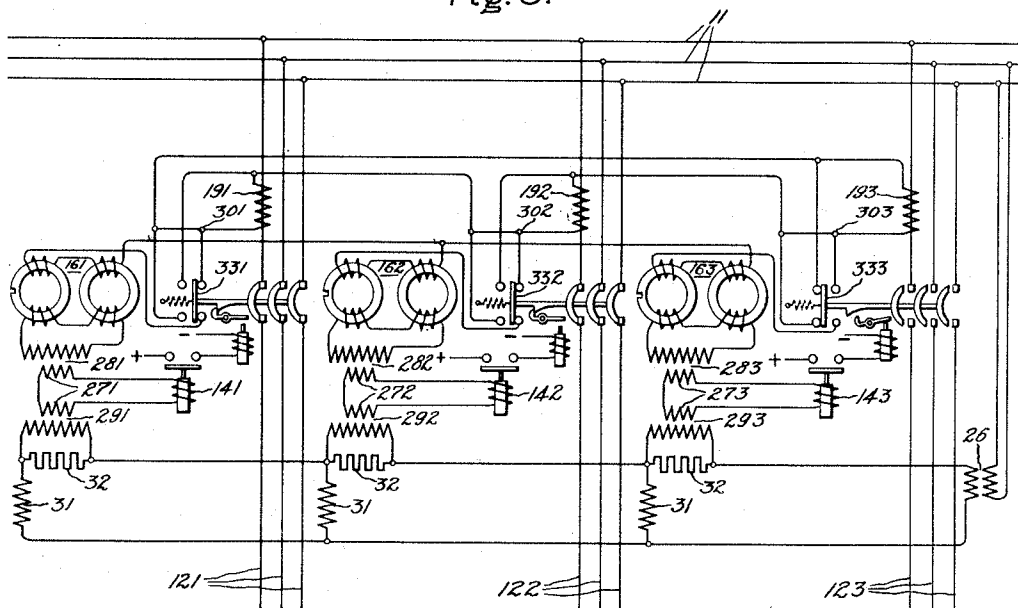


Fig. 4.

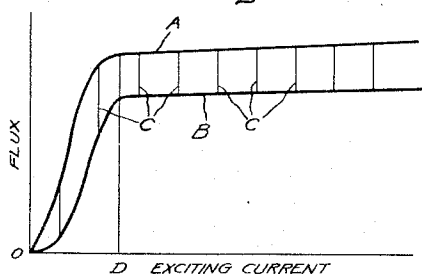


Fig. 5.

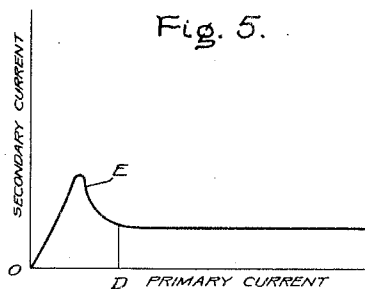
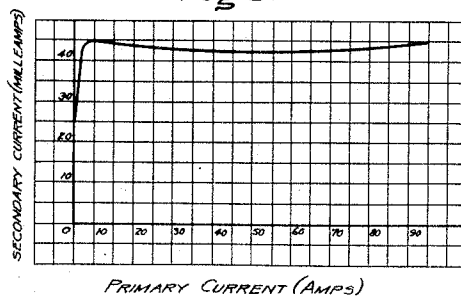


Fig. 6.



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His Attorney.

UNITED STATES PATENT OFFICE

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ELECTRIC-CURRENT-TRANSFORMING MEANS

Application filed January 4, 1926, Serial No. 79,172, and in Great Britain January 21, 1925.

My invention relates to electric current transforming means and has for an object to provide a device having a characteristic such that the secondary current is substantially constant in value while the value of the primary current varies over a wide range.

According to my invention, two core parts are provided having primary and secondary windings arranged on each in such a way that the potentials induced in the secondary windings will be in opposition, and the turns of the windings and the reluctances of the core parts are so proportioned that the desired characteristic is obtained.

My invention further comprises the combination of transforming means as set forth with protective apparatus for alternating current circuits.

My invention will be better understood from the following description taken in connection with the accompanying drawings and its scope will be pointed out in the appended claims.

In the accompanying drawings, Figs. 1, 2 and 3 illustrate diagrammatically protective arrangements embodying my invention, and Figs. 4, 5 and 6 are curves illustrating characteristics of transforming devices embodying my invention.

According to one method of carrying out my invention, the primary and secondary windings of two transformers are connected in series respectively (i. e. primary to primary and secondary to secondary), and arranged as specified above, and the primary and secondary windings consist of approximately equal turns, respectively, but one of the core parts is of slightly greater reluctance than the other. Preferably ring cores are used and, if they are similar, a slot cut partly across the core to form a portion of restricted cross-section or the equivalent may be provided in one of them in order to increase the reluctance of the magnetic circuit therein. With such an arrangement the magnetization curve for the iron core of less reluctance may be similar to the diagrammatic curve marked A in Fig. 4; that is, a curve which rises steeply from the origin and then bends over when the core is saturated

and becomes approximately a straight line of small gradient. The abscissae of this curve are magneto-motive force, or, for a given number of turns, exciting current, and the ordinates represent the flux density, or, for a given cross-sectional area of core, the flux. If the other core, i. e. the core of greater reluctance, is similar in dimensions and reluctivity to the first core, except in respect of the slot therein, the magnetization curve for it might be similar to the diagrammatic curve B of Fig. 4. As the potentials induced in the secondary windings of the two transformers are, respectively, proportional to the fluxes in the cores, and, as these potentials are arranged to oppose one another, the resultant potential will be proportional to the difference between the ordinates of the curves A and B, as represented by the lines marked C. For all values of exciting current greater than that represented by the abscissa OD, it will be noticed that the lines C are approximately equal in length. The curve of Fig. 5 shows the relation of the secondary current or the resultant induced potential to the exciting current.

In addition, if a larger range of primary current is required within which the secondary current shall be constant, by a suitable proportioning of the turns of the primary and secondary windings, the curves A and/or B can be so modified that, for values of exciting current less than that represented by the abscissa OD the difference ordinates, as represented by the line C, can be made substantially equal up to points on the curves relatively near the origin, i. e. the hump E of the curve of Fig. 5 can be flattened out. An actual curve obtained from tests is shown in Fig. 6.

As an example of a case to which the present invention may be applied, one may refer to protective arrangements for alternating current circuits, for example of the power directional type wherein the operation of a protective relay is dependent upon the phase relationship between two currents (i. e. dependent upon the phases of the current and the potential of the protected circuit), but is independent of the magnitudes of said currents. Such a protective arrangement is de-

scribed, for instance, in Letters Patent of the United States, No. 1,549,478 to A. S. Fitzgerald August 11, 1925, assigned to the same assignee as this invention.

6 The device according to my invention may be arranged so that its primary winding is energized responsively to the current in the protected circuit, its secondary winding being arranged to effect operation of a protective relay in conjunction with a winding
10 energized in accordance with the potential of the protected circuit in response to a predetermined vectorial difference between the currents in the windings. In like manner a
15 second device according to the invention may be arranged so that its secondary winding is connected directly to the winding energized in accordance with the potential, referred to above, the primary winding of the
20 device being then energized responsively to the potential of the protected circuit.

Protective arrangements for alternating current circuits using transforming means of the kind referred to above are illustrated diagrammatically, by way of example, in
25 Figs. 1, 2 and 3 of the accompanying drawings. Figs. 1 and 2 are diagrams of connections wherein a single feeder is adapted to be disconnected in the event of a fault causing a reversal of power, and Fig. 3 shows an
30 application of the same principle to the protection of two or more feeders connected in parallel.

With reference first to Fig. 1, the bus-bar 11 is shown connected to the feeder 12 through a
35 circuit breaker 13. The protective gear includes a protective relay 14 which, when energized, excites the tripping coil 15 from any suitable source and thus causes the circuit breaker 13 to open the circuit of the feeder.
40 The electric transforming means according to my invention is designated in general by the reference numeral 16, and is here shown as comprising two similar ring cores 171 and
45 172 having primary windings 181 and 182 respectively, connected in series with the secondary winding of a current transformer 19, the primary winding of which is energized responsively to the current in the feeder 12.
50 A slot 21 is provided in one of the cores to increase the reluctance thereof. The secondary windings 221 and 222 are shown as being wound in opposite directions respectively. The secondary windings are connected in
55 series with the coil 23 of the relay 14, the resistance 24 and the secondary winding 25 of a potential transformer 26, the primary winding of which is adapted to be energized in accordance with the potential of the bus
60 bar 11. The windings 221, 222 and 25 are arranged to supply opposed potentials to the coil 23.

The operation of this arrangement is as follows:—In normal conditions the resultant
65 potential which is induced in the secondary

windings 221 and 222 and is applied to the coil 23 is opposed to and substantially equal to that induced in the secondary winding 25 of the potential transformer 26 and applied to the same coil. Resistance 24 is a relatively large ohmic resistance which acts both
70 to reduce the current taken by the potential transformer to a suitable amount and to ensure that this current is substantially in phase with the potential. In normal circumstances
75 therefore, when the power factor of the feeder is unity or relatively high, there is no resultant potential applied to the relay coil 23. In the event, however, of a fault, occurring on the feeder, which causes the current therein to reverse, the potential applied to the coil 23 from the transforming means
80 16 will be reversed and the resultant potential on the coil 23 will be the arithmetical sum of the two potentials applied thereto. In these circumstances relay 14 will operate, thereby disconnecting the feeder 12. In the event of a through fault being carried by the feeder, when it may be very considerably
85 overloaded, the secondary current of the transforming means 16 will not be appreciably greater than it was in normal conditions and consequently no operation of the relay 14 will be effected, unless the vectorial difference between the voltage and current of the feeder reaches a predetermined value. If it be considered desirable, the relay 14 may be designed to function in case of low or no voltage. This corresponds in effect to a vectorial difference between the current and voltage of the feeder 12 which is one-half the maximum vectorial difference.
90

The arrangement illustrated in Fig. 2 differs from that in Fig. 1 mainly on account of the addition of the transforming means
105 16' which is similar to that marked 16 of Fig. 1, but which is provided in the circuit carrying a current which depends on the potential. This second transforming means 16' will ensure that the resultant potential applied to the relay 14 depends upon the vectorial difference between the current and potential of the feeder 12 irrespective of the change of the value of this potential. In Fig. 2, however, instead of the coil 23 being
110 energized directly from the secondary windings 221, 222 and 25, as in Fig. 1, the coil 23 is connected in series with the secondary windings 27 of current transformers 28, 29 which are supplied, respectively, from the current in one of the phase conductors of the protected circuit and a potential thereof. The primary windings 181' and 182' of the transforming means 16' are shown as being
120 connected to the two other phase conductors of the circuit through the bus bar 11, and therefore the potential across the windings 181' and 182' is in quadrature to the current in that conductor of the feeder 12 with which the current transformer 19 is associated. In
125

order to obtain the correct vectorial relation between the currents in the transformers 28 and 29, that is to have the substantially equal currents furnished thereby to the relay 23 normally in phase opposition, a large inductance 31 is connected in series with the secondary windings 221' and 222' of the transforming means 16'. This inductance 31 acts to bring the phase of the current therein substantially back to that of the current in that conductor of the feeder 12 with which the current transformer 19 is associated. The ohmic resistance 32, which is shown in parallel with the primary winding of the transformer 29, is adapted to compensate for the phase displacement which would otherwise arise due to the copper and iron losses in the transformer.

Fig. 3 shows an arrangement for the protection of three feeders 121, 122 and 123 connected in parallel. When all the three feeders are in operation, effective protection will be obtained by balanced current protective apparatus alone. When, however, only two of them are in operation, to obtain effective protection, balanced power protection must be used. In Fig. 3, therefore, the feeder marked 123 is assumed to be out of commission and an auxiliary switch 333 is shown in a position in which it short-circuits the protective arrangements for this feeder. The current transformers 191, 192 and 193 are connected in series normally to provide a circulating current circuit. If the feeders are designed normally to carry equal currents, these current transformers will be similar. If the feeders are designed so as to carry an unevenly-distributed load, the current transformers will be constructed so that in normal circumstances their secondary windings carry equal currents. Across equipotential points 301, 302 and 303 of this circulating current circuit are connected the primary windings of the transforming means 161, 162 and 163. From a potential transformer 26 are supplied the primary windings of the transformers 291, 292 and 293, these circuits including an inductive resistance such as 31 and an ohmic resistance such as 32 for the reasons specified above.

The operation of this arrangement is as follows:—In normal conditions (with the feeder 123 out of commission) current circulates in the secondaries of current transformers 191 and 192, but not in the primary windings of any of the transforming means 161, 162 and 163. The relays 141, 142 and 143 are, therefore, energized only through the potential transformer 26 and the transformers 291, 292 and 293, and these relays are constructed so as not to operate in these circumstances. In the event of a fault occurring on one of the feeders 121 or 122, say for example feeder 121, if the bus-bar is not connected with any load other than through

said feeders the fault will be fed directly through the faulty feeder 121 and also through the sound feeder 122. It might happen in these circumstances that the current carried by these two feeders were equal in value, but that carried by the faulty feeder would be opposed vectorially to that carried by the sound feeder. In these circumstances the difference current circulates through the primary windings of the transforming means 161 and 162, said difference current being proportional to the arithmetical sum of the currents carried by the feeders. Operation will be effected thereby in the protective relay 141, but not in 142 as the vectorial difference between the currents in the secondary windings 272 of the transformers 282 and 292 will not be substantially altered. If at the time the fault occurs in the feeder 121 the bus-bar should be heavily loaded apart from feeders 121 and 122, it might happen that the currents carried by the two feeders were both in the same direction, that in the sound-feeder being considerably the greater; the current in the faulty feeder being made up of a negative component and a positive component; or alternatively the current in the faulty feeder might be approximately zero, if the negative and positive components were substantially equal. In either case, a current proportional to the difference current will energize the primary windings of the transforming means 161, and, combined with the potential supplied through the potential transformer 26, will effect the operation of the protective relay 141, but not of the protective relay 142.

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

1. In combination with a circuit whose current is subject to variation, transforming means arranged to be energized from said circuit for supplying an approximately constant secondary current over a wide range in primary current comprising two core parts, a primary winding on each of said core parts arranged to be energized from said circuit, a secondary winding on each of said core parts, said secondary windings being connected and arranged so that the potentials induced therein are in opposition and the turns in said primary and secondary windings and the reluctances of said core parts being so proportioned that the secondary current is approximately constant over a wide range in primary current.

2. In combination with a circuit whose current is subject to variation, transforming means arranged to be energized from said circuit for supplying an approximately constant secondary current over a wide range in primary current comprising two core parts, one being of greater reluctance than the other and each having primary and secondary windings of the same number of

turns, said primary windings being arranged to be energized from said circuit and said secondary windings being connected and arranged so that the potentials induced are in opposition.

3. In combination with a circuit whose current is subject to variation, transforming means arranged to be energized from said circuit for supplying an approximately constant secondary current over a wide range in primary current comprising two core parts, each having primary and secondary windings of the same number of turns, said primary windings being arranged to be energized from said circuit and said secondary windings being connected and arranged so that the potentials induced therein are in opposition and one of said core parts being arranged to become substantially saturated by a smaller flux than the flux necessary substantially to saturate the other core part.

4. In combination with a circuit whose current is subject to variation, transforming means arranged to be energized from said circuit for supplying an approximately constant secondary current over a wide range in primary current comprising two substantially similar ring cores, one of which has a portion of restricted cross-section, a primary winding on each of said cores, said primary windings comprising the same number of turns and being connected to be energized from said circuit, and a secondary winding on each of said cores, said secondary windings comprising the same number of turns and being connected and arranged so that the potentials induced therein are in opposition.

5. In combination with a circuit wherein the current is subject to variation, transforming means arranged to be energized from said circuit for supplying an approximately constant secondary current over a wide range in primary current comprising two transformers having their primary windings arranged to be energized from said circuit and their primary and secondary windings connected respectively in series and arranged so that the potentials induced in the secondary windings are in opposition, said primary and secondary windings comprising substantially equal turns respectively and the cores of said transformers having different reluctances.

6. In a protective arrangement for an electric circuit wherein protective apparatus comprising a relay is arranged to control the circuit on the occurrence of abnormal circuit conditions, transforming means arranged to be energized from the circuit for supplying an approximately constant current for controlling said relay comprising two transformers having their primary windings arranged to be energized from said circuit and their primary and secondary windings connected respectively in series and arranged so that the potentials induced in the secondary wind-

ings are in opposition, the turns in said primary and secondary windings and the reluctances of the cores of said transformers being so proportioned that the secondary current is approximately constant over a wide range in primary current.

7. In a protective arrangement for an electric circuit wherein protective apparatus comprising a relay is arranged to control the circuit in accordance with the vectorial relationship between the current and the potential of the circuit, transforming means arranged to be energized from the circuit for supplying the relay with a current dependent only on said relationship comprising two substantially similar cores, one of which has a portion of restricted cross-section, a primary winding on each of said cores, said primary windings comprising the same number of turns and being connected to be energized in accordance with the current in the circuit, and a secondary winding on each of said cores, said secondary windings comprising substantially the same number of turns and being connected and arranged so that the potentials induced therein are in opposition.

In witness whereof, I have hereunto set my hand this nineteenth day of December, 1925.

HERBERT STANLEY PETCH.