Sept. 5, 1933.

A. O. AUSTIN

1,925,167

CURRENT TRANSFORMER

Filed March 7, 1930

3 Sheets-Sheet 1

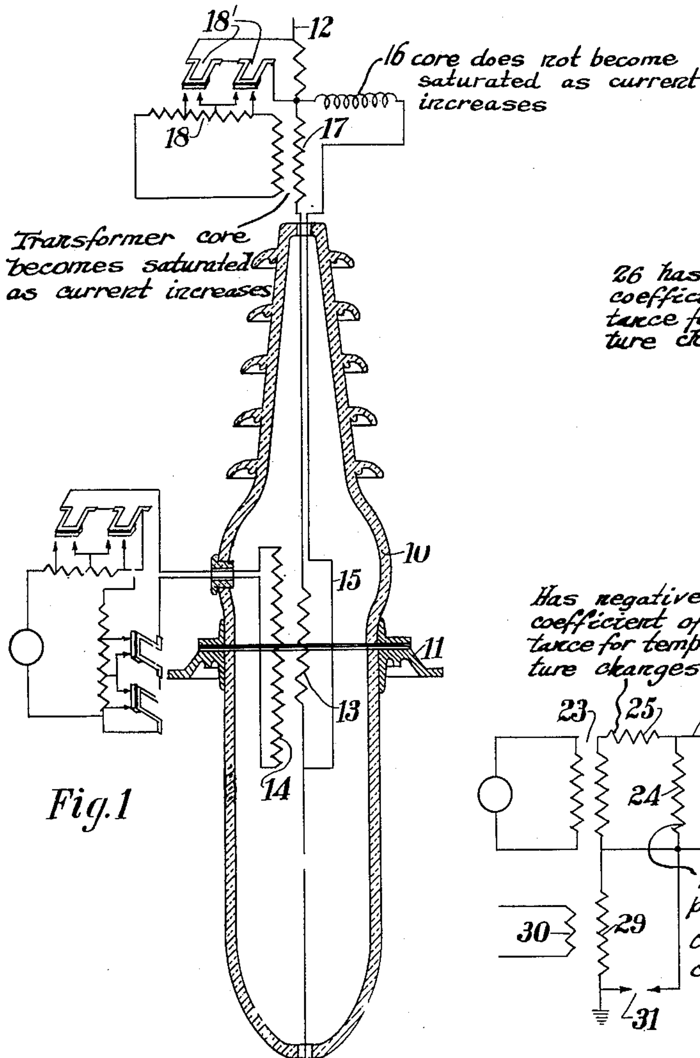

Fig. 1

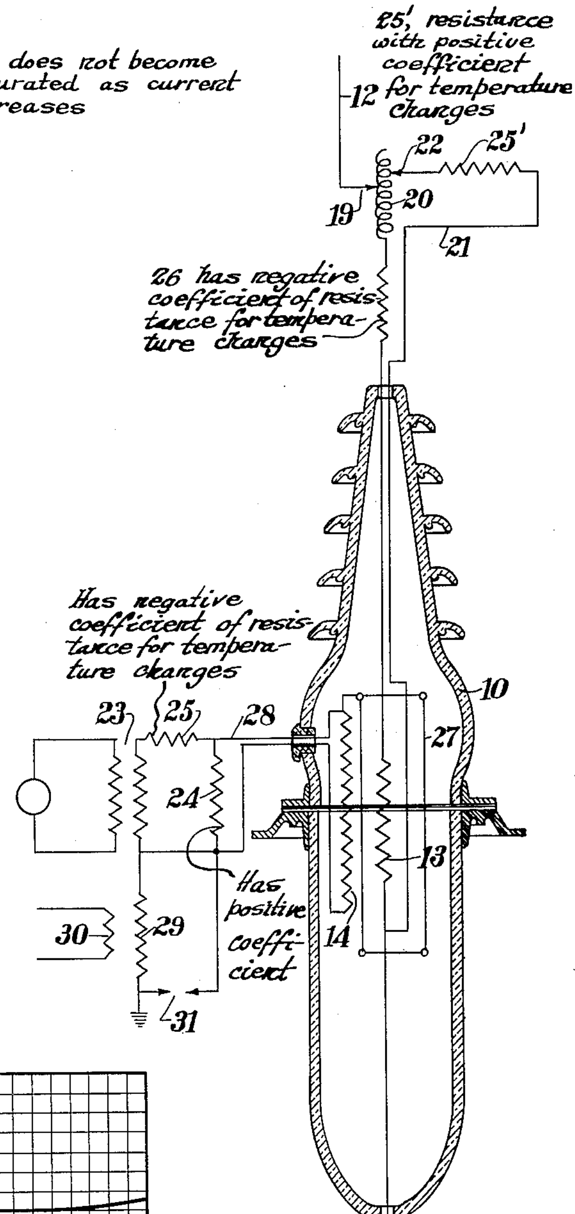

Fig. 2

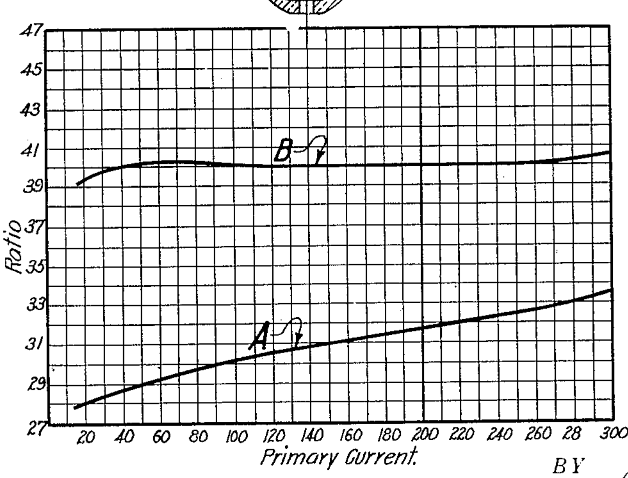

Fig. 3

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CURRENT TRANSFORMER

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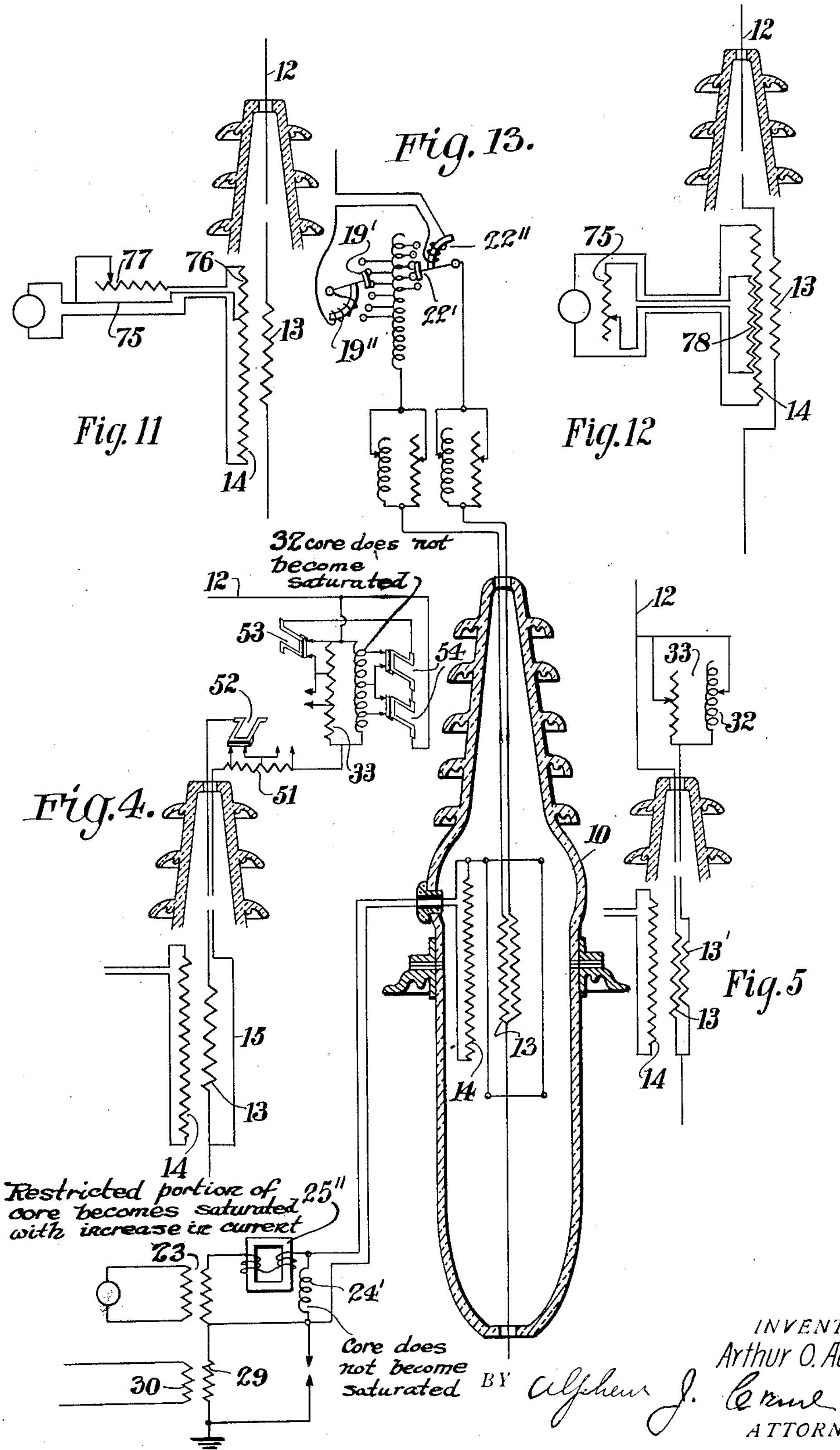

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CURRENT TRANSFORMER

Filed March 7, 1930 3 Sheets-Sheet 3

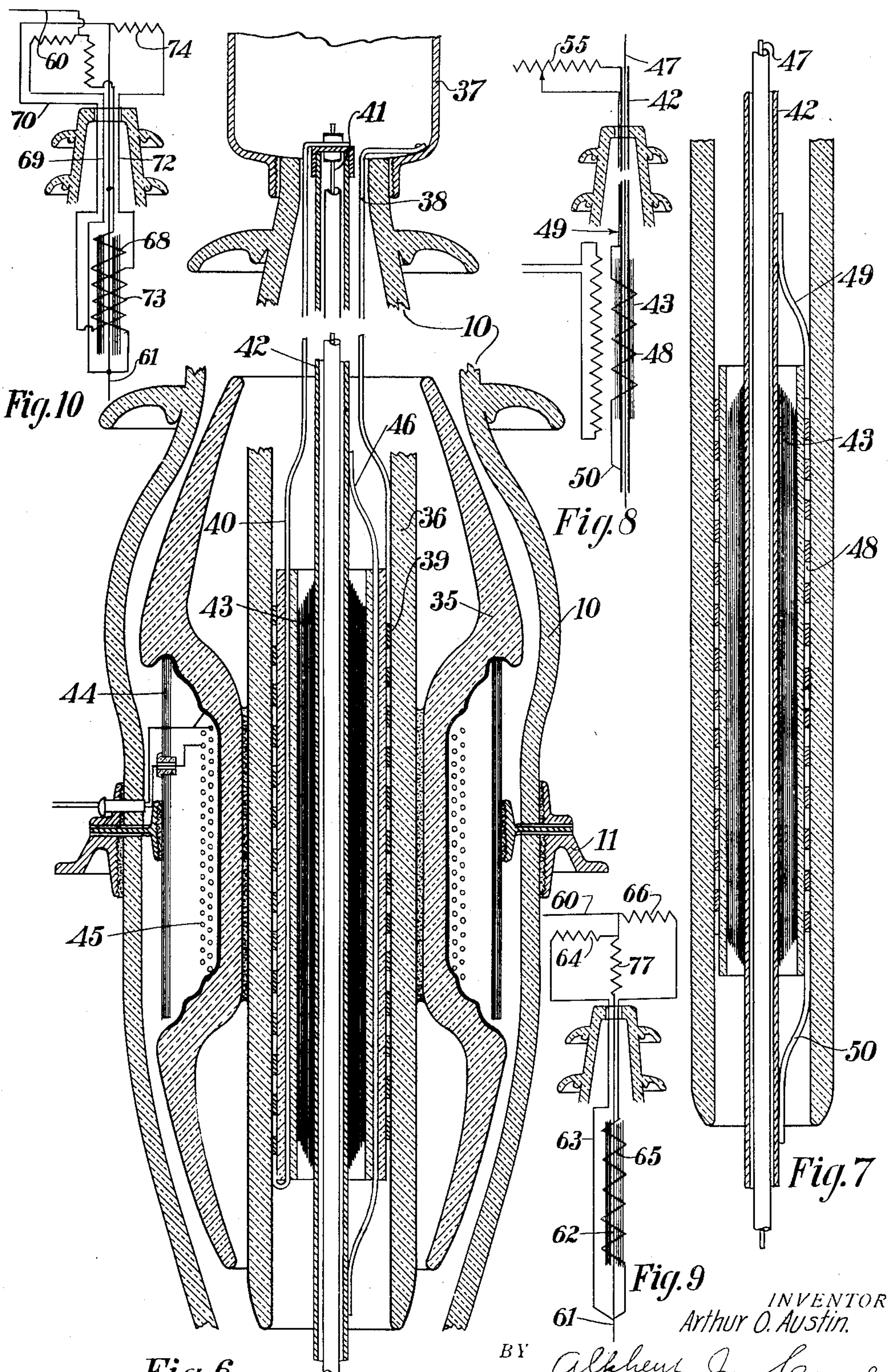

Fig. 10

Fig. 6

Fig. 8

Fig. 9

Fig. 7

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1,925,167

UNITED STATES PATENT OFFICE

1,925,167

CURRENT TRANSFORMER

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Application March 7, 1930. Serial No. 433,921

24 Claims. (Cl. 171—119)

This invention relates to current transformers for diverting relatively small amounts of energy from high potential conductors and especially to current transformers mounted in high potential bushings.

One object of the invention is to provide means for regulating the ratio of transformation in the current transformer.

Another object of the invention is to provide economical means for maintaining a substantially constant transformation ratio for a given range of current passing through the bushing.

Other objects and advantages will appear from the following description.

The invention is exemplified in the combination and arrangement of parts shown in the accompanying drawings and described in the following specification, and it is more particularly pointed out in the appended claims.

In the drawings:

Fig. 1 is a diagrammatic sectional view of a bushing insulator having one embodiment of the present invention applied thereto.

Fig. 2 is a view similar to Fig. 1 showing a slightly different form of the invention.

Fig. 3 is a curve illustrating the operation of the invention.

Fig. 4 is a view similar to Figs. 1 and 2 showing a slightly different arrangement of the shunt circuit for the current transformer primary.

Fig. 5 is a view similar to Fig. 4 but showing another modification.

Fig. 6 is a fragmentary vertical sectional view of a bushing insulator having a modified form of the invention applied thereto.

Fig. 7 is a fragmentary vertical sectional view of the core and primary winding of another form of the invention.

Fig. 8 is a diagrammatic vertical sectional view showing another modification.

Figs. 9, 10, 11, 12 and 13 are diagrammatic views of other modifications.

In high voltage lines, it is frequently desirable to obtain an indication of the current flowing in the high voltage conductors. This is generally accomplished by the use of current transformers as is well known in the art. Current transformers for high voltages, however, are expensive, due to the insulation required between the primary and secondary circuits of the transformers. Where the current in the high tension winding is small, the characteristics of the so-called single turn current transformers are likely to be rather poor. In the type of current transformers which utilize the insulation of high potential bushings, as shown in my prior Patent No. 1,723,000, this difficulty is largely eliminated. Current transformers may be used for several different purposes. In some cases, it may be desired to provide equipment in which the ratio of the current transformer can be readily changed. In other cases, a very close correction for ratio or power factor may be desired so that the current transformer may be utilized for metering. In other cases, it may be desired to equip a bushing with both a current transformer and a capacitance coupling. In current transformers as heretofore built, the ratio between the current in the primary and secondary windings usually varies as the current in the primary changes. In the present invention, means is provided for correcting this objection. In order to obtain a correction of ratio, a compensating system is provided which may be applied either to the primary or the secondary circuit of the transformer or to both.

One form of correction circuit is illustrated in Fig. 1 in which the numeral 10 designates a bushing insulator supported on a flange 11. The conductor 12 passes through the bushing and is insulated thereby from the flange 11. Within the bushing 10 is the primary winding 13 and the secondary winding 14 of a current transformer similar to that more fully described in my prior patent mentioned above. The conductor 15 shunting the primary winding 13 is connected to the incoming lead 12 through an impedance 16. In series with the primary winding 13 is an impedance 17. Where the cross section of the iron in the current transformer is rather small or worked at a high flux density, the saturation of the core tends to change the ratio between the current in the windings 13 and 14 as the current in the winding 13 changes. For many purposes, it is desirable to maintain a constant ratio between the current in the conductor 12 and the current in the secondary 14 throughout a particular range of current value in the conductor 12. This is accomplished in the present invention by controlling the current in the primary winding 13 by changing the proportion of the total current in the conductor 12 which is caused to flow through the winding 13. Where it is desired to boost the current in the secondary 14 to maintain a constant ratio as the current in the conductor 12 increases, this may be done by increasing the proportion of the main current flowing in the primary 13. The proportion of the current in the primary 13 is controlled by changing the relative values of the impedances 16 and 17 as the current increases in the conductor 12.

One way of accomplishing this result is by the use of an air core reactance for the impedance 16 or a metal core reactance, the core of which does not become saturated as the current increases. If at the same time 17 is provided with an iron core, which does become saturated as the current increases, it will be apparent that the ratio between the impedances 16 and 17 will be increased with the increase in current, and the relative portion of the current flowing through the primary 13 will be correspondingly increased. The impedance 17 may consist of a current transformer having a resistance 18 in its secondary circuit. The current transformer 17 can have a magnetic circuit which becomes saturated as the current increases so that a relatively larger portion of the current will flow through the winding 13 as the current in the conductor 12 increases, thus compensating for the leakage of magnetic flux in the current transformer 13–14 and maintaining a substantially constant ratio between the current in the conductor 12 and the current in the secondary 14. The impedance 17 may be in the form of a current transformer as described or may simply be a reactance coil having a core which becomes saturated as the current increases. When a current transformer is used for this purpose, its reactance may be readily adjusted by changing the resistance 18 in the secondary circuit. If desired, a relay may be placed in the circuit which will automatically adjust the resistance 18 to lower the impedance of the transformer as the current increases. Thermal relays 18′ are shown in Fig. 1 arranged to cut out successive portions of the resistance 18 as the current increases and thus reduce the reactance 17. Thermal relays may be used for varying the impedance in the branches of the secondary circuit as well as the primary and for changing the various adjustable impedances shown in the other figures of the drawings.

The marked improvement obtained by a correction of the kind described above is illustrated by the curve shown in Fig. 3 in which the variation in ratio between the current in the primary and the current in the secondary of the main current transformer without compensation is shown by the curve A, while the curve B shows the substantially constant ratio obtained when the compensating circuits described above are employed.

The impedance members 16 and 17, instead of consisting of reactance coils, may be formed of resistance members as shown at 25′ and 26, Fig. 2. Reactances, however, have the advantage that the I^2R losses are less than where resistances are used. Where resistances are employed, the resistance 25′ should have a positive coefficient of resistance for temperature changes, and the resistance 26 should have a negative coefficient. With this arrangement, the resistance of the shunt 15 will increase and more current will flow through the winding 13 as the current in the conductor 12 increases. If it is desired to change the ratio for different currents in the conductor 12, this may readily be accomplished by properly selecting resistances 25′ and 26. If it is desired to increase the ratio between the current in the conductor 12 and the current in the secondary 14, as the current in the conductor 12 increases, this may be done by reversing the characteristics of the impedances 25′ and 26 from that described above. If, on the other hand, it is desired to decrease the ratio with an increase in current, the current transformer would have to be over-compensated. By controlling the characteristics of the transformer, there will be installations where it is possible to use more sensitive relays or instruments during the normal operation of the transformer, and, at the same time, it will be possible to safe-guard the relays or instruments against over-load due to abnormal conditions.

In the form of the invention shown in Fig. 2, the incoming lead 12 is adjustably connected at 19 to the winding 20 of an auto transformer. One side of the winding 20 of the transformer is connected to the winding 13 of the main current transformer. The other lead 21 is adjustably connected at 22 to the winding of the auto transformer and forms a shunt about the winding 13. Any type of series transformer may be used for supplying current to the shunt 21 and the connections may be inside or outside of the bushing, as desired. With the arrangement shown, it is very easy to change the number of ampere turns of the primary winding 13 and the ratio of the current in the conductor 12 to the current in the secondary 14 by providing a suitable tap switch at the top of the bushing as shown at 19′ and 22′ in Fig. 13. This switch may be arranged so that the ratio can be changed while the bushing is in operation. The switch may be designed to shift either the point 19′ or the point 22′, or both. By making both the points 19′ and 22′ adjustable, but by different steps, it is possible to use one for fine adjustment and the other for coarse adjustment. Relays 19″ and 22″ for changing the adjustments automatically may be employed if desired.

Compensation for variations in ratio may be provided in the secondary as well as in the primary circuit. The secondary circuit as shown in Fig. 2 may be provided with an insulating transformer 23 and a shunt impedance 24 and a series impedance 25. Normally the current in the secondary circuit 14 will be approximately proportional to that in the primary circuit 13. The current in the secondary, however, will depend upon the useful magnetic flux but, as the current in the primary increases, the leakage of magnetic flux will increase and the ratio of the current in the primary to the current in the secondary will increase, and in many cases the transformation ratio will not remain constant through the desired range of the current in the primary unless a large and expensive current transformer is employed. This change in ratio may be compensated for by the impedances 24 and 25, similar to those shown at 25′ and 26. Where the relative portion of the current from the secondary winding 13 which flows through the shunt 24 decreases with an increase in current in the main circuit, a larger portion of the current will flow through the primary of the transformer 23, thus compensating for the change in ratio of the main current transformer 13–14. This condition is obtained where 24 is a resistance having a positive coefficient, and 25 is a resistance having a negative coefficient. It is evident that either resistance 24 and 25 in some cases could be used independently of the other. In general, however, a wider range of current may be covered by utilizing the two together. In place of resistances, reactances may be used for the members 24 and 25 as shown at 24′ and 25″, Fig. 13. Where reactance coils are used, it is usually preferable to employ iron cores. For 25″ a reactance will be used which will become saturated as the current increases so that it will tend to permit more current to flow through the meters or relays operated by the secondary of the main transformer. The reactance 24' may have a core which is not saturated, or an air core, as desired. By utilizing an iron core for reactance 25'' which has a restricted portion or a magnetic circuit composed of paths having different reluctance, it is possible to control the rate of saturation or impedance.

Where an external or series transformer is used, as shown at the top of Fig. 2, to energize or control the current in the primary of the bushing transformer, a correction may be readily effected by inserting impedance directly in the two circuits which carry the current into the bushing transformer. The impedance 25 is placed in the lead 21 and the impedance 26 is placed in series with the winding 13. These impedances will automatically change the ratio of current in the respective circuits as previously explained. By use of the impedances in connection with the adjustable transformer taps for the transformer winding 20, a high degree of correction and compensation for variations in the current transformer may be obtained. In some cases, it may be desirable to equip the bushing not only with a current transformer but also with a capacitance tap as shown in Fig. 2. For this purpose, the bushing is provided with a capacitance member 27 insulated from the primary winding 13 and from ground. The capacitance tap may be brought out entirely independently of the secondary winding 14, and where this is done, the connection for the secondary winding may be the same as that shown in Fig. 1. Generally, however, it is desirable to place the secondary 14 of the current transformer and the plate 27 forming the capacitance member close together, and where this is done, it is usually preferable to connect them electrically so as to have the same potential. An arrangement of this kind is shown in Fig. 2 in which one lead from the secondary winding 14 is connected to the lead 28 from the capacitance member 27. This lead passes through the primary of the insulating transformer 23 and extends through the primary 29 of a current transformer to ground. The secondary of the insulating transformer 23 is connected to the ammeter or other load of the main current transformer. The transformer 23 should have low electrostatic capacity between its windings, either directly or through the core. A step-down transformer for the capacitance tap has a low voltage winding 30 which may be connected with any instrument to be operated by the capacitance tap. The winding 29 may be connected to the primary winding of the transformer 23 either at its center or at any other convenient point. A limiting gap 31 is provided across the primary winding 29. It is evident that the ratio may be readily changed in the insulating transformer 23. Any change in the characteristics caused by the insulating transformer may be compensated for by the compensating means described above.

In Fig. 4 the shunt about the primary winding 13 of the current transformer is provided with an inductive reactance 32 which may have an air core or an iron core which does not become saturated for the range of current passing therethrough. Since the core for the transformer winding 13 has a limited magnetic circuit, the magnetic circuit will approach saturation so that the ratio of the current flowing in the winding 13 and in the shunt about the winding will change as the current in the incoming lead 12 increases, a larger proportion of the current flowing through the winding 13 for the higher current values. This will compensate for the variation in transformation ratio and in some cases, a sufficient compensation may be secured in this way without the use of additional impedance in series with the winding 13. In some instances it may be found advantageous to place a resistance shunt 33 in parallel and a resistance 51 in series with the reactance 32. This resistance shunt will serve to provide a non-inductive path through the bushing for the transmission of carrier currents and for radio work. If the resistance 33 has a positive coefficient, it will supplement the action of the reactance 32 in changing the proportion of the current flowing through the winding 13 as a current in the main conductor 12 increases. The shunt about the winding 13 may also be utilized for correction of variation in phase angle between the current in the conductor 12 and the current in the secondary winding 14. Without some corrective means, the current in the secondary winding 14 will be slightly out of phase with the current in the conductor 12. By providing supplemental primary turns 13 for the transformer in the shunt circuit, as shown in Fig. 5, and by varying the relation of the inductive and non-inductive windings 32 and 33, this phase displacement may be corrected and the current in the secondary brought into step with the current in the primary. The reactance 32 and the resistance 33 may be made adjustable for this purpose.

Several different arrangements may be used to correct ratio and phase angle so that a close approximation will be obtained over a wide range of current in the primary or for different demands on the secondary. Where no compensating circuit is applied to the primary, the phase angle of the current in the secondary is usually slightly out of step with the current in the primary. The main current in the primary lead 12 is made up of two components, one of them through the winding 13 which magnetizes the core, and the other through the shunt circuit 15. Since the current in the lead 12 is determined by the source and the load, and is practically independent of changes in the current transformer but is divided between the winding 13 and the shunt 15, any change in the ratio of the currents in 13 and 15 will affect the ratio of the current in the primary 12 to the current induced in the secondary. Furthermore, if the phase angle in the winding 13 is changed with respect to the current in the main winding 12, the phase angle of the current in the secondary will be affected accordingly. The phase angle of the current 13 with respect to the main current 12 may be changed by changing the phase angle of the current in the shunt path 15 with respect to the current in the winding 13. As an example, a transformer which has a lagging phase angle may have this phase angle reduced to zero or even converted to a leading phase angle by allowing sufficient current to pass through a suitable reactance in series with the shunt 15. By using both a reactance and a resistance for controlling the current in the shunt, it is possible not only to correct phase angle but ratio as well. Where a close control is desired over a considerable range of current in the primary, the reactance and resistance of the circuit may be controlled by the use of thermal or other relays 52, 53 and 54, Fig. 4.

In some cases it may be more advantageous to control ratio and phase angle by regulating the impedance in series or in multiple with the load or burden on the secondary circuit as shown in Fig. 1. While single relays may be usually used to correct both phase angle and ratio, relays may be used separately for the correction of phase angle and ratio if desired; these relays being applied to either the primary circuit or the secondary circuit as desired. In some cases, it may be desirable to provide relays which will insert a resistance or reactance after a certain current is reached, and other relays which will reduce the resistance or reactance again after the current exceeds a given higher value. In some transformers equipped with primary shunt control, the ratio may be too high for the small currents and for the very high currents but too low for the intermediate currents. It is evident that by proper relays, the variations in ratio under these conditions may be corrected. The same general scheme may be applied for correcting the phase angle as well as ratio. Since the relays in general will affect only a portion of the circuit, their failure to operate in any instance will not affect the functioning of the transformer in general but only the correction.

The correction may be applied to a supplemental winding as at 13′ in Fig. 5. The current in this supplemental winding may be controlled by relays as previously described. It is preferable to control the current in a supplemental winding or in a shunt circuit rather than by changing the number of turns in the primary winding as in the latter case heavy currents must be handled.

The correcting means above described may be used in conjunction with the means for changing the number of turns in the primary winding as disclosed in my prior application, Serial Number 406,281. The correcting means may be applied to other types of current transformers besides those illustrated, such as those having a closed magnetic circuit. The ability to correct both phase angle and ratio over a wide range of current makes the invention particularly applicable in circuits where it is desired to meter currents and in which there may be very small currents for a portion of the time, or even a reversal in the direction of energy flow or in which the power factor is low.

In some cases it may be advisable to use the combination of current transformer and capacitance tap for obtaining both current and potential for metering. Where the voltage is well balanced, the potential for metering may be taken from a phase so that minimum phase angle correction will be required for the potential circuit. If potential is supplied by the capacitance tap transformer, it will be necessary to correct phase angle for the potential in this circuit. In some combinations, there may be a material advantage in correcting one part of the ratio or phase angle curve by a reactance or impedance in the primary side, and in others in the secondary circuit. Likewise, relays may be used for correcting one portion of the ratio or phase angle curve in the secondary and another portion by operation in the primary. By designing a properly constructed impedance which may be placed either in the primary circuit to control the shunt or in series with the load on the secondary side, it is possible to correct the ratio over a considerable range. This is particularly true where the magnetic material in the reactance or impedance is such that the saturation will produce a voltage component which will tend to maintain a proper ratio. It is evident that where magnetic material is used in the reactance having a very short path, a high flux may be made to develop with fewer ampere turns than where the magnetic path is longer. By making up a core of magnetic material, where the length of the magnetic path is small for the quantity of magnetic material and the number of ampere turns, it will be seen that the voltage component of the reactance may be controlled over a considerable range of current. It is evident that the same results may be obtained by using several different magnetic circuits in series or by using a proper section of iron core such that the flux and saturation progress at the proper rate. The same results may be accomplished by using magnetic materials of different permeability.

Instead of placing the primary winding of the current transformer in a gap in the main conductor, as indicated in Figs. 1 and 2, it is sometimes desirable to run leads up to the top of the bushing from the primary winding, one of which is connected to the incoming conductor and the other of which connects to a conductor which extends through the bushing without interruption. This arrangement is shown in Fig. 6 in which the bushing 10 is provided with auxiliary sleeves or baffles 35 and 36. The incoming transmission line is connected to the reservoir 37 at the top of the bushing 10 and a lead 38 leads down from the incoming line to the primary 39 of the current transformer. A lead 40 extends up from the opposite end of the primary winding and is connected to an insulated conductor 41 which extends down through the central tube 42 but is insulated from the tube at its lower end. By this arrangement, it will be seen that the current goes down through the lead 38 and back through the lead 40 and then again down through the lead 41. A magnetic core 43 is provided within the primary winding 39 and a magnetic shell 44 provides a portion of the return circuit for the magnetic flux in the core 43. The secondary winding of the current transformer is shown at 45. In an arrangement of this kind, it is found that the current flowing through the conductor 41 sets up a circumferential flux in the core 43 which tends to saturate the iron of the core without producing any effect upon the secondary winding 45. The saturation of the core by this circumferential flux interferes with the useful flux set up by the coil 39. To overcome this effect, a jumper 46 is electrically connected with the tube 42, both above and below the core 43, and extends outside of the core so that the tube 42 and the jumper 46 forms a short-circuit turn interlinked with the core 43.

It will be seen that the circumferential magnetic flux in the core 43 will be interlinked with this short-circuit turn so that a current would tend to flow in this short-circuit turn opposing the circumferential flux in the core, and thus keeping this flux down so that it will not saturate the core and interfere with the useful flux extending lengthwise of the core.

In the modification shown in Fig. 7, the current from the main circuit passes directly through the conductor 47 extending through the central tube 42 but insulated from the tube. A primary winding 48 is wound about the core 43 and is provided with a lead 49 at its upper end, electrically connected to the tube 42 above the core, and with a lead 50 at its lower end electrically connected to the tube below the core. With this arrangement, the coil 43 with its leads 49 and 50 forms a closed turn interlinked with the core 43 but including the turns 48 of the primary winding. The circumferential flux set up in the core 43 by the current in the conductor 48 will tend to produce a current in the interlinked turn comprising the parts 48, 49 and 50, but in this case this current will be directed circumferentially about the core 43 so that it will in turn induce lines of force in longitudinal direction in the core 43, and these lines of force will induce a voltage in the secondary winding 45 producing the secondary current. This provides a very simple arrangement for energizing the current transformer. A variable impedance 55 may be introduced in series with the winding 48 to control the amount of current therein as shown in Fig. 8. This impedance may be automatically controlled by relays in the manner previously explained if desired.

Figure 9 shows one form of primary in which the current in the main lead 60 is divided between several circuits. The current of the several circuits being combined again in the lead 61 as it leaves the primary of the current transformer. In general, the current flowing in lead 62 passes through the center of the magnetic core. This sets up a tangential flux in the core which may be controlled to a large extent by the design of the magnetic path in the core, being retarded or accelerated as desired. If a conductor 63 passes outside of the core and is connected to the lead 62 at both ends, the voltage set up by the tangential flux in the core will cause current to flow in this lead. If the resistance 64 in the circuit 63 is low, the current flowing in this conductor will be approximately equal to that in 62 and will tend to neutralize the flux set up by current passing through 62. It is evident that the current in 60 and 61 may be practically double that in either lead 62 or 63 which may be an advantage where heavy currents must be carried. If an impedance 64 is placed in series with the winding 63, the relative current in 62 and 63 may be controlled to a very large extent.

Some of the various methods described above may be used to change the relative amounts of current flowing in the different branch circuits for different values in 60 and 61, to control the ratio and phase angle over a wide range of current. The potential set up in the circuit formed by leads 62 and 63, which includes the magnetic circuit energized by the current in 62, may be used to magnetize the magnetic core with lines of force extending in a longitudinal direction of the core by using the potential to force a current around the winding 65. The current in the winding 65 may be controlled by the number of turns and by a series impedance 66.

Current in the winding 65 may be utilized to increase the current carrying capacity of the transformer circuit. Where a high current must be passed through the current transformer, the winding 65 may be made for a comparatively small current capacity by supplying the proper number of turns. This winding may, of course, be made up with taps or with coils, which may be arranged in series or multiple as desired. By controlling the characteristics of the impedances 64 and 66, a large correction may be effected for ratio and phase angle. If desired, a further impedance 67 may be interposed in the conductor 62. In addition to controlling the effective current in the primary which affects the current in the secondary, by the design of the several impedances, it is possible to effect further corrections by the use of relays as previously described.

In Fig. 10 an arrangement somewhat similar to that in Fig. 9 is shown. In this arrangement, however, the main current flows through a winding 68 which magnetizes the core and in a circuit 69 which extends outside of the core. After passing through the winding 68 and lead 70, the current then passes down through the core of the magnetic circuit through lead 71. The current in this lead tends to set up a tangential flux in the core. By closing the circuit with a winding 72 so as to include the tangential flux in the circuit formed by 71 and 72, it is possible to use the potential generated to force current through the magnetized winding 73. The current in the winding 73 may be regulated by an impedance 74 and used as a main magnetizing circuit or a corrective circuit as desired. An arrangement of this kind may have a particular advantage where it is desired to change the magnetizing force generated particularly by winding 68. As the leads from the winding 68 are returned by conductor 70, it is possible to make up this winding with taps or with several coils which may be arranged to provide the desired energizing force.

In the modification shown in Fig. 11, the winding 14 is tapped out at 75 and the portion 76 of the winding is connected with a variable impedance 77 which may be controlled by hand or by automatic means, in a manner previously described. By regulating the impedance 77, various amounts of the flux in the transformer will be expended in inducing current flowing through the upper portion 76 of the coil, thus varying the amount available for inducing current in the main secondary circuit. By proper values of the impedance 77, the ratio and phase angle of the transformer may be regulated.

Fig. 12 is similar to Fig. 11 except that the regulating impedance 77 is supplied by a supplemental secondary winding 78 instead of a winding 76 in series with the main winding 14.

I claim:

1. The combination with an alternating current circuit of a current transformer energized by said circuit and having a primary and a secondary winding, the effect of said current transformer on the total current in said circuit being negligible and a corrective circuit for said transformer comprising an impedance in shunt with the primary winding of said transformer.

2. The combination with an alternating current circuit of a current transformer energized by said circuit but constituting a practically negligible part of the total normal load on said circuit and having primary and secondary windings, said primary winding having a main and a shunt circuit, the ratio of the impedance in said main and shunt circuit being variable to compensate for variations in the transformation ratio of said transformer for different current values.

3. The combination with an alternating curcent circuit of a current transformer energized by said circuit but constituting a practically negligible part of the total normal load on said circuit and having primary and secondary windings, of a corrective circuit for said transformer comprising an impedance in parallel with the primary winding of said transformer, the ratio of the impedance in the series circuit of said primary winding to the impedance in shunt with said primary winding being variable and decreasing as

the combined current in the two circuits increases to increase the proportion of the total current flowing through said primary winding.

4. The combination with an alternating current circuit of a current transformer energized by said circuit but constituting a practically negligible part of the total normal load on said circuit and having a primary and a secondary winding, of a divided circuit for said primary winding, the branches of which circuit have impedances therein which relatively vary automatically with the current flowing in said transformer to change the ratio of said impedances so as to vary the proportion of the total current flowing in the different branches of said circuit.

5. The combination with an alternating current circuit of a current transformer energized by said circuit but constituting a practically negligible part of the total normal load on said circuit and having primary and secondary windings, of a divided circuit for one of said windings, one branch of said divided circuit having an impedance which increases with the amount of current flowing therein while the impedance of the other branch of said circuit does not increase proportionately.

6. The combination with an alternating current circuit of a current transformer energized by said circuit but constituting a practically negligible part of the total normal load on said circuit and having primary and secondary windings, of a divided circuit for one of said windings, a resistance in one branch of said circuit having a positive coefficient of resistance for temperature changes, and a resistance in the other branch of said circuit having a negative coefficient of resistance for temperature changes.

7. The combination with a current transformer having primary and secondary windings, of a divided circuit for one of said windings, one branch of said divided circuit having a reactance element therein provided with a core which becomes saturated for the higher values of current in said branch while the other branch of said circuit is not so provided.

8. The combination with a bushing insulator, of an alternating current circuit extending through said insulator, a current transformer disposed in said insulator and energized by said circuit but having a practically negligible effect on the total current in said circuit, said transformer having primary and secondary windings, and means for diverting varying proportions of the current flowing in one of said windings as the amount of current in said transformer changes to compensate for variations in the transformation ratio of said transformer.

9. The combination with a bushing insulator having a current transformer therein, of a capacitance tap for said transformer, a correction impedance in the secondary circuit of said transformer, electrical connection between said secondary circuit and said capacitance tap and an insulating transformer for said secondary circuit.

10. The combination with a bushing insulator, of a current transformer disposed within said insulator, a high potential conductor connected with the primary of said current transformer and extending through said bushing insulator, a shunt circuit for diverting a portion of the current in said high potential conductor about the primary of said current transformer, and means for increasing the portion of the current of said high potential conductor which passes through the primary of said current transformer as the current in said high potential conductor increases while the total current passing through said conductor is practically unaffected by said means.

11. The combination with a bushing insulator, of an alternating current circuit passing through said insulator, a current transformer disposed within said insulator and energized by said circuit but forming only a practically negligible portion of the total normal load on said circuit, an electrical translating device connected with the secondary of said transformer, a shunt for diverting a portion of the secondary current of said transformer away from said translating device, and means for decreasing the amount of current so diverted as the current in said secondary increases.

12. The combination with a bushing insulator, of a current transformer disposed within said insulator, a high potential conductor extending through said insulator, the primary of said current transformer being disposed in series with said high potential conductor, a shunt for diverting a portion of the current of said high potential conductor about the primary of said current transformer, and a reactance in series in said shunt having a core which does not become saturated for the values of current flowing therein.

13. The combination with a bushing insulator, a high potential conductor extending through said insulator, the primary of said current transformer being disposed in series in said high potential conductor, a shunt circuit for diverting a portion of the current of said high potential conductor about said primary, a reactance disposed in said shunt circuit and a resistance in parallel with said reactance.

14. The combination with a current transformer, of a corrective circuit for said transformer comprising a variable impedance and a thermal relay for varying said impedance.

15. The combination with a current transformer having a divided circuit, of a variable impedance for adjusting the ratio of the currents in the branches of said circuit, and a thermal relay for adjusting said impedance.

16. A current transformer having primary and secondary windings, supplemental primary turns in shunt with said primary winding, and means for displacing the phase angle of the current in said shunt turns relative to the current in said primary winding.

17. A current transformer having a main primary winding, and a supplemental primary winding in shunt with said main primary winding, and reactance in series with said supplemental primary winding for displacing the phase angle of the current in said supplemental primary winding relative to the current in said main primary winding.

18. The combination with a current transformer, of means for correcting the phase angle of the current in the secondary of said transformer comprising supplemental primary turns in shunt with the primary winding of said transformer, and adjustable reactance in series with said supplemental primary turns.

19. The combination with a conductor for alternating currents, of a current transformer comprising a primary winding in series with said conductor, and means for correcting for variations in the phase angle in the secondary of said current transformer from the phase angle of the current in said main conductor, said means com-

prising a shunt in parallel with the primary winding of said transformer, said shunt being adapted to divert a portion of the current of said main conductor from said primary winding such that the current left in said primary winding will produce the phase angle desired in the secondary of the transformer.

20. The combination with a conductor for alternating currents, of a current transformer having a primary winding in series with said conductor, and means for correcting the transformation ratio of said transformer, said correcting means comprising a shunt for diverting a portion of the current of said main conductor from said primary winding such that the current left in said primary winding will produce the desired transformation ratio the effect of said correcting means on the total current in said conductor being practically negligible.

21. The combination with a conductor for alternating currents, of a current transformer having its primary winding in series with said conductor, and means for correcting for errors in phase angle and transformation ratio in the secondary of said transformer, said means comprising a shunt for diverting a portion of the current of said main conductor from said primary winding, said shunt having variable impedance therein for adjusting the diverted portion of the current so that the current remaining in the primary winding will produce the desired phase angle and transformation ratio in the secondary the corrective effect of said correcting means being dependent upon the division of the current in said conductor rather than upon a change in the total current therein.

22. The combination with an alternating current circuit of a current transformer energized by said circuit but constituting only a minor portion of the normal load on said circuit so that the effect of said transformer on the total current in said circuit is practically negligible, said transformer having primary and secondary windings, and a divided circuit from one of said windings, the resistance in one branch of said circuit having a higher positive coefficent of resistance for temperature changes than in the other branch of said circuit.

23. The combination with a transformer having primary and secondary circuits, of a correction reactance connected with one of said circuits and controlled by its magnetic field to vary as a function of the current flowing in the transformer circuit with which it is connected to compensate for variations in the performance of said transformer for different currents in said transformer cricuits.

24. The combination with a transformer having primary and secondary circuits, of a shunt for one of said circuits and a correction impedance element for controlling the division of energy between the parallel circuits of which said shunt is one branch and one of said transformer circuits the other, said impedance element having a magnetic core which varies the impedance of the element as the core approaches saturation, the characteristics of the core being so related to the transformer that the variations in the impedance due to saturation of the core will compensate for variations in the performance of the transformer caused by varying magnetic losses in said transformer as the current changes therein.

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