July 12, 1932. W. BÜTOW 1,866,751

INTEGRATING AND DIFFERENTIAL TRANSFORMER

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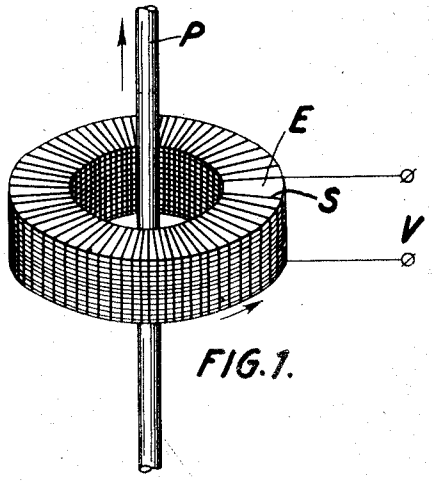


FIG. 1.

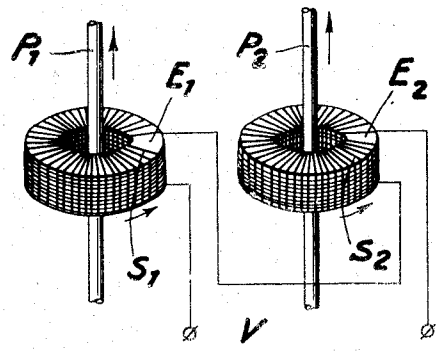


FIG. 2.

FIG. 3.

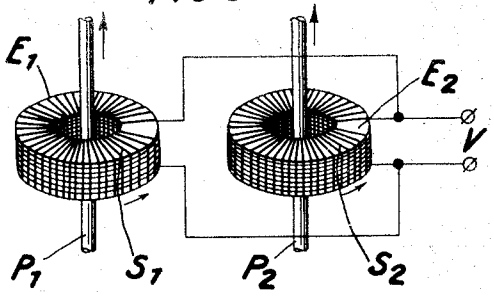


FIG. 4.

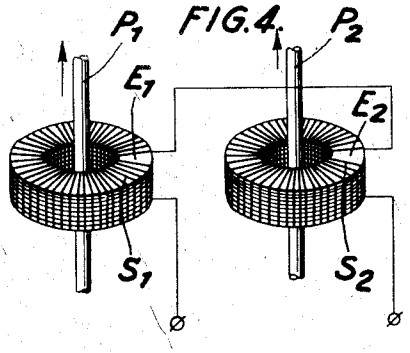


FIG. 5.

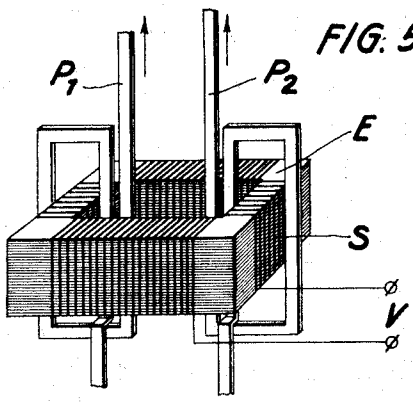
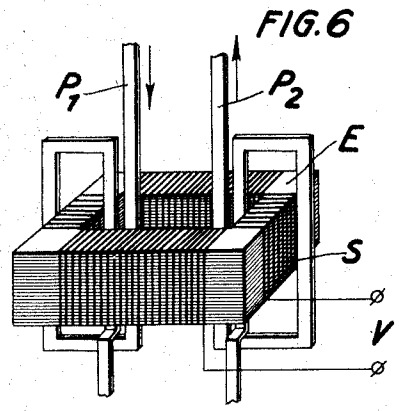


FIG. 6



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INTEGRATING AND DIFFERENTIAL TRANSFORMER

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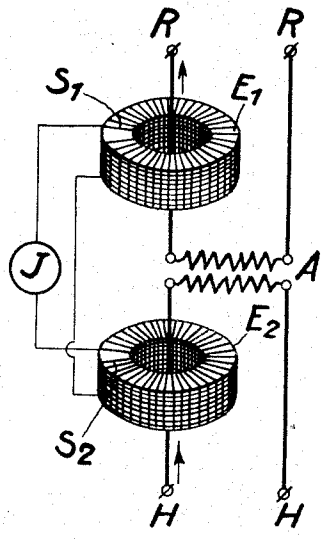


FIG. 7.

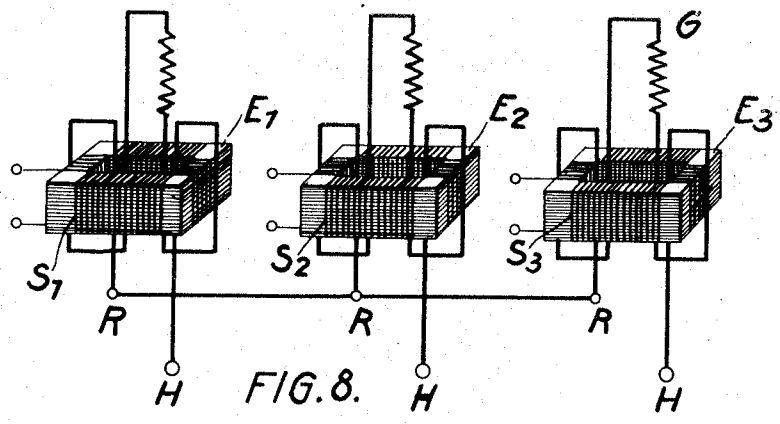


FIG. 8.

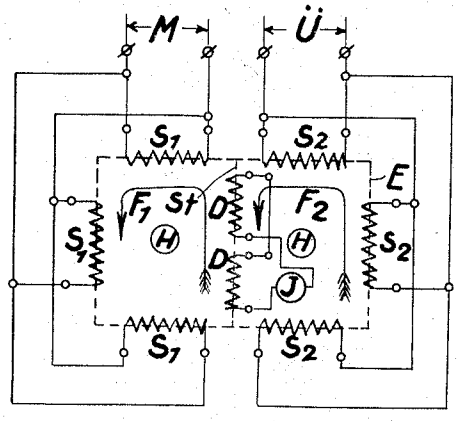


FIG. 15.

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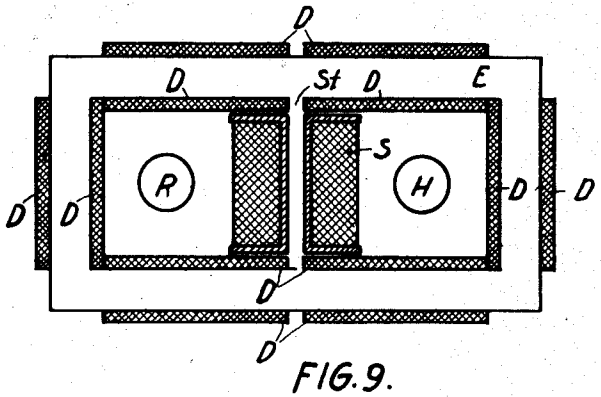


FIG. 9.

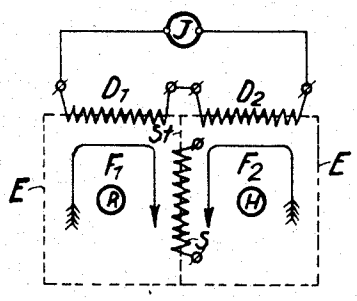


FIG. 11.

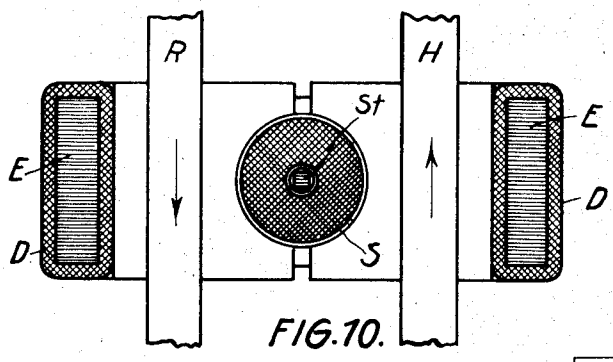


FIG. 10.

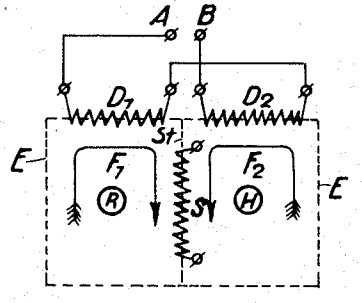


FIG. 12.

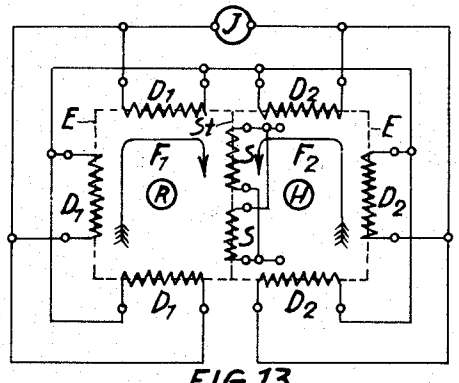


FIG. 13.

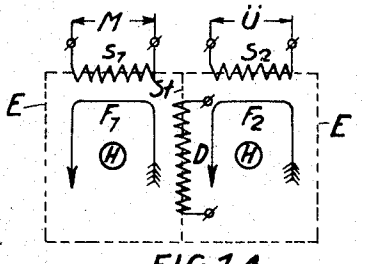


FIG. 14.

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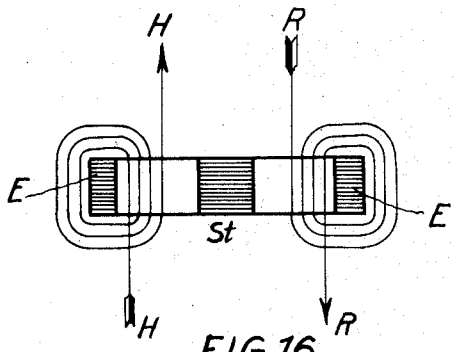


FIG. 16.

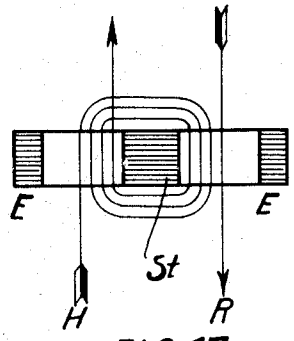


FIG. 17.

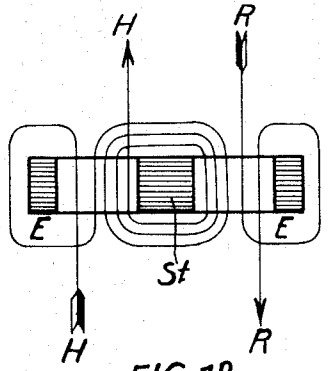


FIG. 18.

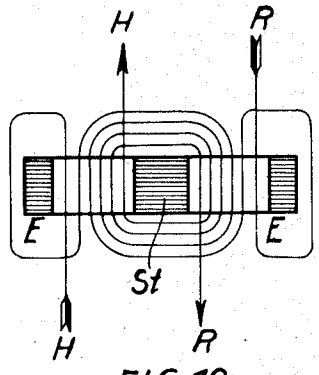


FIG. 19.

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UNITED STATES PATENT OFFICE

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INTEGRATING AND DIFFERENTIAL TRANSFORMER

Application filed December 9, 1929, Serial No. 412,894, and in Germany June 11, 1928.

It is frequently necessary to measure the sum and difference of the currents passing through two or more electric conductors. This problem has frequently to be solved for instance when electric machines or apparatus have to be protected and the present invention provides an integrating and differential transformer which as hereinafter described enables the sum as well as the difference of such currents to be measured with one and the same transformer.

In all the figures the iron core is marked E. P signifies the primary winding, S the secondary winding. Figure 1 refers to a current transformer of usual construction. Figure 2 shows how to connect two normal current transformers in order to measure the sum of the currents on the secondary side of the transformers. This can also be effected by using the connection represented in Figure 3, two normal current transformers being employed also. The connection shown in Figure 4 enables to measure the difference of the primary currents.

The sum or the difference of currents can also be established by using special current transformers having but one core yet two primary windings. Figure 5 shows a current transformer with the primary windings P_1 and P_2 being wound around the iron core E. The current in the secondary winding S of this current transformer and the voltage V at its terminals corresponds with the sum of the currents in the primary windings. By changing over the direction of current in one of the primary windings the connection shown in Figure 6 is obtained; with this connection the difference of the primary currents is measured.

Figures 7 and 8 are diagrams of the well-known so-called differential connection for protective purposes that is to say a connection by means of which the reliability of operation in line systems etc. is secured. In Figure 7 two normal current transformers are used, the iron cores of which are respectively maked E_1 and E_2, while the secondary windings S_1 and S_2 are differentially connected together with a relay J thus acting when the currents in the primary windings H respectively R which at the same time form the windings of a transformer A situated for instance at the beginning of the line to be protected differ from another. Figure 8 relates to the same connection built up with special current transformers of the type shown in Figure 6. It is suggested to protect the windings of a three phase generator G. The beginning H and the end R of each winding are wound on the iron cores E_1 respectively E_2 respectively E_3 of special current transformers the secondary windings of which are marked respectively S_1, S_2 and S_3. The windings of the generator G are connected in star by establishing an artificial zero point.

Figures 9 and 10 relate to a special current transformer of a type which can be used advantageously in the connection represented in Figure 8. The iron core E has a bridge S*t* on which a winding S is arranged the current of which corresponds with the sum of the currents flowing through the primary conductors H and R. Another winding D around the iron core E is subdivided into partial-windings for instance six of those windings substantially equal and connected so as to measure the difference of the primary currents flowing through H and R. Such a special current transformer may be named an integrating and differential current transformer that is to say a current transformer forming the sum as well as the difference of primary currents.

Figures 11 and 12 indicate how to connect the subdivided secondary winding D for measuring either the difference (Fig. 11) or the sum (Fig. 12) of the primary currents flowing through H and R. As the additional winding S on the bridge S*t* already measures the sum of the primary currents the connection shown in Figure 11 will be employed usually.

Figure 13 refers to particulars of the connection indicated in Figure 11. The winding D consists of six partial windings in order to obtain equality of the fluxes F_1 and F_2 in the two parts of the iron core E. The additional winding S on the bridge S*t* is likewisely subdivided into two equal partial windings connected together in parallel.

For the purpose of protecting a three-phase generator three integrating and differential transformers are used, the primary conductors of which may proceed from the beginning and end of each winding of the generator. Overload relays are joined to the terminals of the windings S, while relays J are connected, as shown in Fig. 13.

Figure 14 illustrates that the same special current transformers can be used too if the currents to be compared with are flowing in the same direction through the windows or openings of the special transformer thus generating the fluxes F_1 and F_2 the directions of which are marked by arrows.

Fig. 15 shows the transformer in Fig. 14 with subdivided windings.

The power output of the part serving for the differential measurement may be increased by winding the primary conductors several times round the iron core E, as shown in Figure 16.

Figure 17 indicates how the power output of the part serving for the integrating measurement may be increased. The primary conductor H has been wound several times around the bridge S*t*, the primary conductor R forming but a single bar.

Figures 18 and 19 show means for increasing the total power output of the aforesaid special current transformers. According to Figure 18 both primary conductors H and R are wound around the iron core E and the primary conductor H is furthermore wound several times around the bridge S*t*. According to Figure 19 both primary conductors H and R are wound several times around the bridge S*t* of the iron core E.

In Figure 1 of the accompanying drawings the iron core of a normal current transformer is marked E. In the secondary winding S appears the voltage V when the primary winding P is traversed by current.

By means of two such normal current transformers, the sum of the currents in the conductors P_1 and P_2 can be measured as indicated in Figures 2 and 3. The voltage V appearing at the terminals of the secondary windings corresponds to the sum of the currents passing through the primary conductors P_1 and P_2. The connection shown in Figure 3 is known as an unsymmetrical connection and is used more particularly when protection is required from earth leakage.

The difference between the two primary currents will be obtained by changing over the connection of the secondary windings S_1 and S_2. This connection is shown in Figure 4, concerning the employment of normally constructed current transformers. It is well known that either the sum or the difference of currents may be measured with current transformers by connecting in series their secondary windings. If connecting these windings so as to obtain counteracting of the induced electromotive forces the resulting voltage at the secondary terminals and the secondary current to correspond with the difference of the primary currents.

One iron core and one secondary winding may be utilized instead of two transformers by carrying the primary windings P_1 and P_2 through the window or opening of the iron core of a normal current transformer as shown in Figures 5 and 6, where the primary windings P_1 and P_2 are wound on the core or yoke E.

The action of the connection shown in Figure 5 corresponds to that of the connection shown in Figure 3. Similarly the connection shown in Figure 6 corresponds to that shown in Figure 4. In the connections shown in Figures 3 and 4 two iron cores are magnetized and the currents are electrically integrated while in the connections shown in Figures 5 and 6 the magnetic fluxes in the transformer core are correspondingly integrated, for only a single iron core is traversed by the integral flux. In both cases the final effect is quite the same.

The well known forms of current transformers hitherto manufactured or current transformer connections referred to above are utilized for measuring and protection purposes in single phase or polyphase installations. Thus the usual transformer illustrated in Figure 1, is utilized for measuring purposes and for the feeding of maximum relays. The connections shown in Figure 3 or Figure 5 are used for protection against earth leakage and those of Figures 4 and 6 in the case of differential protection. The well known connections for the latter are diagrammatically shown in Figures 7 and 8; J in Figure 7 signifies a differential current relay.

If in the case of the protection of a generator for example integrating and differential connections are required, an integrating and differential current transformer according to the present invention may be used. Figures 9 and 10 show the construction.

On the iron core E is arranged the winding D in which is measured the difference of the currents which flow through the primary conductors H and R, and the core E is provided in the centre with a bridge S*t*, the cross section of which depends on the purpose for which it is intended and on which is arranged the secondary winding S, by means of which is measured the sum of the currents flowing through the primary conductors H and R.

If measuring instruments are to be connected to the secondary winding or coil S, the bridge S*t* will be made of large cross section but if on the contrary only relays are to be connected to the said winding the bridge S*t*

may be of a comparatively small cross section.

The winding D is a differential winding and is constituted by several parallel windings, for instance six as shown, whereby all these parallel windings have the same number of spires and are distributed uniformly over the iron core E. Such a subdivided differential winding has been named a push winding and its operation is well known from the theory of transformers, especially from high tension transformer for testing purposes. This push winding eliminates the unfavourable action of any dissymmetry of the flux tending to generate a so-called disturbance current in the secondary winding. If for instance the flux at the place of one partial winding of the push winding tends to increase over the flux at the places of the other partial windings a current will flow from the first named partial winding to all the other partial windings, connected together in parallel, whereby the first named partial winding almost acts as a primary winding feeding a secondary winding consisting of the totality of the remaining partial windings, which therefore also take an increased tension and an increased current generating an additional magnetization thus causing that all parts of the iron core are floated by the same flux. The push winding therefore effects an uniform distribution of the magnetic flux; any local excess of the magnetic flux is almost "pushed" by the partial winding directly induced from this flux to the totality of the remaining partial windings. Generally the push winding consists of a plurality of equal coils and these may be arranged side by side or also partly overlap each other. When as shown in Figure 11, a current flows in the two conductors H and R in the opposite direction, two oppositely directed magnetic fluxes F_1 and F_2 of equal strength will be produced in the iron core E which will cancel each other in an iron core without a bridge. Therefore, if the currents passing through H and R are of equal strength no electromotive force will be able to appear in the differential windings D_1 and D_2.

In a current transformer as shown in Figures 9 and 10 the two fluxes F_1 and F_2 induced by the primary currents flowing in the conductors H and R close over the bridge S*t* in which accordingly appears the sum of these fluxes. An electromotive force which corresponds to the sum of the currents will therefore appear at the terminals of the winding S which is mounted on the bridge S*t*, whilst the electromotive forces will cancel each other in the secondarily connected differential windings D.

The instrument or relay J joined to the terminals of two secondary windings D_1 and D_2 connected in series as shown in Figure 11 will therefore only receive a current when the currents in the lead and return of the primary conductors H and R are of different strength.

According to Figure 12, the differential windings D_1 and D_2 can also be connected in such a manner that at the terminals A and B an electromotive force will act which corresponds to the sum of the currents in the primary conductors H and R.

The subdivision of the windings D_1 and D_2 into push windings connected in parallel is shown in Figure 13. The result of these windings is, as already mentioned, that the flux is uniformly distributed even when the conductors H and R are not arranged symmetrically. The push winding has the further advantage that strange fields which are generated by conductors situated in close proximity to the transformer cannot exercise any disturbing influence. The winding S arranged on the bridge S*t*, is also protected from the influence of strange dispersion fields owing to the fact that it is completely surrounded by the iron core E.

The integrating and differential transformer is especially qualified for the protection of generators. In the case of a three-phase generator the leads of the windings for the three phases are carried through three of the aforesaid integrating and differential transformers. Their ends are only connected for establishing a control or zero point behind the transformers. Three differential relays may be connected as shown in Figure 11. When the generator is to receive a wattmetric earth leakage protection, the current coils of the three required wattmetric earth leakage relays of usual construction and of any of the well known types may be connected in series with the coils of the aforesaid differential relays. The earth leakage relays receive their voltage from a voltage transformer connected between the neutral or zero point of the machine and earth.

Due to this application, which is given merely by way of example, only three current transformers are required for the generator protection whilst hitherto it was necessary to use at least six. The transformers may be mounted on the terminal board of the machine where they require therefore considerably less room than those hitherto known.

When the direction of current in one of the primary windings of a transformer as shown in Fig. 11 or 12 is reversed, a connection shown in Fig. 14 will be obtained, both primary conductors being marked H in this figure. The positions and functions of the windings D and S are exchanged as compared with Fig. 11. By means of the coil D which is now positioned on the bridge S*t*, the difference of the currents in the two conductors will then be measured, whilst elec-

tromotive forces M and Ü, respectively, are generated in the windings S_1 and S_2, in proportion to the currents in the windings.

Referring now to Fig. 15, the windings on the yoke or core E at opposite sides of the bridge *St* are subdivided into three units each, S_1. S_1, S_1 at the left, and S_2, S_2, S_2 at the right. The winding on the bridge *St* is subdivided into two units D, D. The windings on the yoke are connected in parallel and the windings on the bridge are in differential connection. The action of all units is substantially equal. The differential relay J is connected to the units D.

The primary windings may as already stated be carried through the window of the iron core or be wound round it several times as indicated in Figure 16.

As shown in Figure 17, one conductor may also be carried through the window of the iron core, whilst the other one may be wound several times round the bridge. This arrangement, which results in more ampere-turns becoming effective for the integrating transformer, is more particularly suitable in case of the primary currents being relatively small.

In the arrangement shown in Figure 18, both primary conductors are wound round the iron core E, and one of the two conductors is wound several times round the bridge *St*.

Finally Figure 19 shows that both conductors may be wound round the iron core E, and both carried several times round the bridge *St*. Due to the connection shown in Figures 18 and 19 not only the power output of the integrating transformer but also the power output of the differential transformer are considerably increased.

Having thus described my invention what I claim and desire to secure by Letters Patent is:

1. An integrating and differential current transformer comprising a plurality of primary windings, an iron core formed with two outer branches and a central branch and provided with the usual windows, primary conductors passing through said windows, the number of the said primary conductors being substantially equal for each window, a winding mounted on said central branch and generating a current corresponding to the sum of the currents passing through said primary conductors, and windings mounted on each of said outer branches and generating currents corresponding to the single currents passing through said primary conductors whereby said windings on each of the outer branches being differentially connected so that the resulting current on the secondary side corresponds to the difference of the currents passing through said primary conductors.

2. An integrating and differential current transformer comprising a plurality of primary windings, an iron core formed with two outer branches and a central branch and provided with the usual windows, primary conductors passing through said windows, in the same direction, a winding mounted on said central branch and generating a current corresponding to the difference of the single currents passing through said primary conductors, and windings mounted on each of said outer branches and generating currents corresponding to the sum of the currents passing through said primary conductors for the purpose specified.

3. An integrating and differential current transformer comprising a plurality of primary windings, an iron core formed with two outer branches and a central branch and provided with the usual windows, primary conductors passing through said windows, the number of the said primary conductors being substantially equal for each window, a winding mounted on said central branch and generating a current corresponding to the sum of the currents passing through said primary conductors, said winding on the central branch being subdivided into a plurality of partial windings of substantially equal action, and windings mounted on each of said outer branches and generating currents corresponding to the single currents passing through said primary conductors whereby said windings on each of the outer branches being differentially connected so that the resulting current on the secondary side corresponds to the difference of the currents passing through said primary conductors.

4. An integrating and differential current transformer comprising a plurality of primary windings, an iron core formed with two outer branches and a central branch and provided with the usual windows, primary conductors passing through said windows, in the same direction, a winding mounted on said central branch and generating a current corresponding to the difference of the single currents passing through said primary conductors, said winding on the central branch being subdivided into a plurality of partial windings of substantially equal action, and windings mounted on each of said outer branches and generating currents corresponding to the sum of the currents passing through said primary conductors for the purpose specified.

5. An integrating and differential current transformer comprising a plurality of primary windings, an iron core formed with two outer branches and a central branch and provided with the usual windows, primary conductors passing through said windows, the number of the said primary conductors being substantially equal for each window, a winding mounted on said central branch and generating a current corresponding to the

sum of the currents passing through said primary conductors, and windings mounted on each of said outer branches and generating currents corresponding to the single currents passing through said primary conductors whereby said windings on each of the outer branches being subdivided into a plurality of partial windings of substantially equal action, connected together in parallel, the said windings on each of the outer branches being differentially connected so that the resulting current on the secondary side corresponds to the difference of the currents passing through said primary conductors.

6. An integrating and differential current transformer comprising a plurality of primary windings, an iron core formed with two outer branches and a central branch and provided with the usual windows, primary conductors passing through said windows, in the same direction, a winding mounted on said central branch and generating a current corresponding to the difference of the single currents passing through said primary conductors, and windings mounted on each of said outer branches and generating currents corresponding to the sum of the currents passing through said primary conductors for the purpose specified, said windings on each of the outer branches being subdivided into a plurality of partial windings of substantially equal action, connected together in parallel.

7. An integrating and differential current transformer comprising a plurality of primary windings, an iron core formed with two outer branches and a central branch and provided with the usual windows, primary conductors passing through said windows, the number of the said primary conductors being substantially equal for each window, a winding mounted on said central branch and generating a current corresponding to the sum of the current passing through said primary conductors, said winding on the central branch being subdivided into a plurality of partial windings of substantially equal action, and windings mounted on each of said outer branches and generating currents corresponding to the single currents passing through said primary conductors whereby said windings on each of the outer branches being subdivided into a plurality of partial windings of substantially equal action, connected together in parallel, the said windings on each of the outer branches being differentially connected so that the resulting current on the secondary side corresponds to the difference of the currents passing through said primary conductors.

8. An integrating and differential current transformer comprising a plurality of primary windings, an iron core formed with two outer branches and a central branch and provided with the usual windows, primary conductors passing through said windows, in the same direction, a winding mounted on said central branch and generating a current corresponding to the difference of the single currents passing through said primary conductors, said winding on the central branch being subdivided into a plurality of partial windings of substantially equal action, and windings mounted on each of said outer branches and generating currents corresponding to the sum of the currents passing through said primary conductors for the purpose specified, said windings on each of the outer branches being subdivided into a plurality of partial windings of substantially equal action, connected together in parallel.

9. An integrating and differential current transformer comprising an iron core formed with two outer branches and a central branch and provided with two usual windows, two primary conductors one passing through the first and the other through the second of said windows, one of said primary conductors being wound several times around said central branch, a winding mounted on said central branch and generating a current corresponding to the sum of the single currents passing through said primary conductors, and windings mounted on each of said outer branches and generating currents corresponding to the single currents passing through said primary conductors whereby in the case of differential connection the resulting current on the secondary side corresponds to the difference of the currents passing through said primary conductors.

10. An integrating and differential current transformer comprising an iron core formed with two outer branches and a central branch and provided with two usual windows, two primary conductors, one passing through the first and the other through the second of said windows, both of said primary conductors being wound several times around said central branch, a winding mounted on said central branch and generating a current corresponding to the sum of the single currents passing through said primary conductors, and windings mounted on each of said outer branches and generating currents corresponding to the single currents passing through said primary conductors whereby in the case of differential connection the resulting current on the secondary side corresponds to the difference of the currents passing through said primary conductors.

11. An integrating and differential current transformer comprising an iron core formed with two outer branches and a central branch and provided with the usual windows, two primary conductors one passing through the first and the other through the second of said windows in the same direction one of said primary conductors being wound several times around said central branch, a

winding mounted on said central branch and generating a current corresponding to the difference of the single currents passing through said primary conductors and windings mounted on each of said outer branches and generating currents corresponding to the sum of the currents passing through said primary conductors for the purpose specified.

12. An integrating and differential current transformer comprising an iron core formed with two outer branches and a central branch and provided with the usual windows, two primary conductors one passing through the first and the other through the second of said windows in the same direction both of said primary conductors being wound several times around said central branch, a winding mounted on said central branch and generating a current corresponding to the difference of the single currents passing through said primary conductors and windings mounted on each of said outer branches and generating currents corresponding to the sum of the currents passing through said primary conductors for the purpose specified.

13. An integrating and differential current transformer comprising an iron core formed with two outer branches and a central branch and provided with the usual windows, primary conductors passing through said windows, said primary conductors being wound several times around said outer branches, a winding mounted on said central branch and generating a current corresponding to the sum of the currents passing through said primary conductors, and windings mounted on each of said outer branches and generating currents corresponding to the single currents passing through said primary conductors whereby in the case of differential connection the resulting current on the secondary side corresponds to the difference of the currents passing through said primary conductors.

14. An integrating and differential current transformer comprising an iron core formed with two outer branches and a central branch and provided with the usual windows, primary conductors passing through said windows in the same direction, said primary conductors being wound several times around said outer branches, a winding mounted on said central branch and generating a current corresponding to the difference of the single currents passing through said primary conductors and windings mounted on each of said outer branches and generating currents corresponding to the sum of the currents passing through said primary conductors for the purpose specified.

15. An integrating and differential current transformer comprising an iron yoke having two side bars and a central bridge intermediate said bars, primary windings in the windows of said yoke, and secondary windings on said yoke and said bridge.

In testimony whereof I have affixed my signature.

WALTER BÜTOW.