(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 216 500 B1**

(12) # EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: **03.06.92**

(51) Int. Cl.5: **H01F 27/38**, H01F 29/02, H01F 31/00

(21) Application number: **86306422.6**

(22) Date of filing: **19.08.86**

(54) **Electromagnetic induction apparatus.**

(30) Priority: **19.08.85 JP 180489/85**
18.03.86 JP 58111/86

(43) Date of publication of application:
01.04.87 Bulletin 87/14

(45) Publication of the grant of the patent:
03.06.92 Bulletin 92/23

(84) Designated Contracting States:
FR GB IT SE

(56) References cited:
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CH-A- 306 155
FR-A- 488 384
FR-A- 891 965
FR-A- 2 290 012
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Grundschaltungen Nachrichten Technik, pages 117-118

Handbuch Elektrotechnik - Elektronik, pages 368-369

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Description

BACKGROUND OF THE INVENTION

This invention relates to an electromagnetic induction apparatus which comprises a transformer and which is utilized for power transmission and distribution systems, etc., and more particularly to an electromagnetic induction apparatus which does not require the installation of a shunt reactor.

Fig. 20 is a circuit diagram showing the single-line connection state of a substation which employs and electromagnetic induction apparatus comprising a transformer as has heretofore been utilized in a power transmission or distribution system, while Fig. 21 is a perspective view showing a practical construction in the case where the circuit in Fig. 20 is three phases.

Referring to the figures, 1 designates a transformer having a primary winding 1a and a secondary winding 1b, and a tertiary winding 1c which is electromagnetically coupled to the primary winding 1a as well as the secondary winding 1b. A primary side switching device 2 is connected to the primary winding 1a, a primary side transmission or distribution line 3 has one end connected to the primary side switching device 2 and the other end connected to an external circuit (not shown), and a capacitance 4 is formed between the primary side transmission or distribution line 3 and ground. A secondary side switching device 5 is connected to the secondary winding 1b, a secondary side transmission or distribution line 6 has one end connected to the secondary side switching device 5 and the other end connected to an external circuit (not shown), and a capacitance 7 is formed between the secondary side transmission or distribution line 6 and ground. A tertiary side switching device 8 is connected to the tertiary winding 1c, and a shunt reactor 9 has one end connected to the tertiary side switching device 8 and the other end grounded or which is star- or delta-connected in three phases. The flows 10 and 11 of "leading" reactive powers are supplied from the shunt reactor 9 to the respective capacitances 4 and 7 when the switching devices 2, 5 and 8 are closed.

Next, the operation of the substation furnished with the prior-art electromagnetic induction apparatus will be explained.

Usually, the switching devices 2, 5, and 8 are closed, so that the "leading" reactive powers are supplied from the shunt reactor 9 through the transformer 1 to the capacitance 4 of the primary side transmission or distribution line 3 and the capacitance 7 of the secondary side transmission or distribution line 6 respectively as indicated by the arrows 10 and 11.

In a case where the transformer 1 and the shunt reactor 9 have become unnecessary for the power system or where an accident has occurred, the switching devices 2, 5 and 8 are opened, and the transformer 1 and the shunt reactor 9 are separated from the power system.

In addition, Fig. 22 is a circuit diagram showing the single-line connection state of another prior-art example, while Fig. 23 is a perspective view showing a practical construction in the case where the circuit in Fig. 22 is used in three phases. Symbols 2 - 7 denote the same constituents as those shown in Figs. 20 and 21.

A transformer 20 has a primary winding 20a and a secondary winding 20b, a switching device 12 on the primary side is connected to the primary side transmission or distribution line 3, and a shunt reactor 13 on the primary side has one end connected to the switching device 12 and the other end grounded or which is star- or delta-connected in three phases. A switching device 14 on the secondary side is connected to the secondary side transmission or distribution line 6, and a shunt reactor 15 on the secondary side has one end connected to the switching device 14 and the other end grounded or which is star-or delta-connected in three phases.

The flows 16 and 17 of "leading" reactive powers are respectively supplied from the shunt reactors 13, 15 through the switching devices 12, 14 to the capacitances 4, 7 when the switching devices 12, 14 are closed.

Next, the operation will be explained. Usually, the switching devices 2, 5, 12 and 14 are closed, so that the "leading" reactive powers are supplied from the shunt reactors 13 and 15 through the corresponding transmission or distribution lines 3 and 6 to the respective capacitances 4 and 7 as indicated by the arrows 16 and 17. Besides, in a case where the transformer 20 and the shunt reactors 13, 15 have become unnecessary for the operation of the power system or where an accident has occurred, the switching devices 2, 5, 12 and 14 are opened, and the transformer 20 and the shunt reactors 13, 15 are separated from the power system.

In general, in a case where the transmission or distribution lines 3 and 6 are overhead lines of long distances or where they are constructed of cables even when they are of short distances, they have great capacitances 4 and 7, which consume "leading" reactive powers. The supply of the reactive powers from a power station (not shown) in a remote place results in inflicting heavy power losses on the power transmission or distribution system and spoiling the stability of this system. Accordingly, the "leading" reactive powers which the transmission or distribution lines 3 and 6 require are supplied from the substation near these lines 3 and 6 by disposing the phase modifying means, namely, the shunt reactor 9 or shunt reactors 13, 15 as shown in Figs. 20 - 23.

Fig. 24 is an equivalent circuit diagram of the transformer 20 having the two windings as shown in Fig. 22, and Fig. 26 is a horizontal partial sectional view of the transformer 20. In these figures, 21 indicates the primary side terminal of the transformer 20, 22 the secondary side terminal of the transformer 20, 23 a magnetic space defined between the primary winding 20a and the secondary winding 20b, 24 a leakage flux generated in the space 23 by the primary winding 20a and the secondary winding 20b, X the leakage reactance of the transformer 20 induced by the leakage flux 24, r the winding resistance of the transformer 20, and $\bar{Z}m$ the excitation impedance of the transformer 20.

Usually, the following inequalities hold:

$$X >> r \quad (1)$$

$$|X| << |\bar{Z}m| \quad (2)$$

Therefore, the winding resistance r can be neglected as it is sufficiently small, and the excitation impedance $\bar{Z}m$ can be regarded as being infinitely large, so that the equivalent circuit in Fig. 24 is simplified as shown in Fig. 25. Accordingly, the shunt reactors (reactances connected in parallel with the power transmission or distribution system) do not exist equivalently. Thus, the equivalent circuit of the transformer 20 is expressed by only the leakage reactance X as shown in Fig. 25, so that the connection of the respective transmission or distribution lines 3 and 6 to the terminals 21 and 22 corresponds to connecting "a reactor whose reactance is X" in series with the power transmission or distribution system.

Likewise, the equivalent circuit of the transformer 1 with the three windings as shown in Fig. 20 is expressed as shown in Fig. 27, and it involves the following:

X_{12}: leakage reactance caused by a leakage flux flowing through a magnetic space defined between the primary winding 1a and the secondary winding 1b,

X_{13}: leakage reactance caused by a leakage flux flowing through a magnetic space defined between the primary winding 1a and the tertiary winding 1c,

X_{23}: leakage reactance caused by a leakage flux flowing through a magnetic space defined between the secondary winding 1b and the tertiary winding 1c,

where

$$X_{12} = X_1 + X_2$$
$$X_{13} = X_1 + X_3$$
$$X_{23} = X_2 + X_3$$

In Fig. 27, 25 indicates the primary side terminal of the transformer 1, 26 the secondary side terminal thereof, and 27 the tertiary side terminal thereof. The connection of the primary side transmission or distribution line 3, the secondary side transmission or distribution line 6 and the tertiary side transmission or distribution line to the primary side terminal 25, the secondary side terminal 26 and the tertiary side terminal 27 respectively corresponds to connecting "reactors whose reactances have magnitudes X_1, X_2 and X_3 respectively" in series with the power transmission or distribution system. Accordingly, as in Fig. 25, no reactance connected in parallel with the power transmission or distribution system exists with the transformer 1 only, and the shunt reactor 9 needs to be separately disposed.

As stated above, the prior-art electromagnetic induction apparatus in the substation is equipped with the shunt reactor 9 or shunt reactors 13, 15 as the phase modifying means for compensating the "leading" reactive powers which are consumed by the capacitances 4, 7 between the respective transmission or distribution lines 3, 6 and ground. Therefore, it has had several problems to be explained below:

(i) A large installation space for the shunt reactor(s) 9 or 13, 15 is required as shown in Fig. 21 or Fig. 23. Moreover, expenses necessary for subsidiary installations such as fundamental fire-prevention devices for the shunt reactor(s) 9 or 13, 15 become enormous.

(ii) In a case where the shunt reactor(s) 9 or 13, 15 operate(s) as the phase modifying means, current flows through the shunt reactor(s) 9 or 13, 15. Power loss to be incurred in the winding(s), electromagnetic shield(s) etc. of the shunt reactor(s) 9 or 13, 15 by the current cannot be neglected, either.

(iii) When the shunt reactor 9 is connected to the tertiary winding 1c as shown in Fig. 20, not only the shunt reactor 9 but also the tertiary winding 1c undergoes power loss. On the other hand, when the shunt reactors 13, 15 are directly connected to the transmission or distribution lines 3, 6 of high voltages as shown in Fig. 22, the shunt reactors 13, 15 must also have high-voltage specifications, so they become large in size and high in cost which entails increases in installation space as well as power loss.

French Patent Specification 45888 discloses an arrangement in which the primary and secondary windings of a pair of transformers are serially connected to one another. A compensator winding is wound around the core of each of the transformers.

When both transformers are used, the compensator coils are connected to one another.

GB Patent Specification 5190 discloses a transformer arrangement in which the secondary winding is divided so that the winding in effect is provided with supplementary coils connected in series with the secondary winding. The purpose of this is to prevent or lessen the risk of damage in the event of excessive loads being supplied to the transformer.

United States Patent Specification 2 221 619 discloses an electrical induction apparatus in which a primary winding is divided into two, respective parts being wound on separate cores. A secondary winding is wound on one of the cores. The secondary winding of the other core is connected by means of tap connections to the secondary winding of the first core.

SUMMARY OF THE INVENTION

This invention has been made in orderr to solve all the problems as mentioned above, and has for its object the provision of an electromagnet induction apparatus which is so constructed as to have the function of supplying "leading" reactive powers without the installation of a shunt reactor, thereby to reduce the space and to lower the power loss.

Another objection of this invention is to make the capacity of an equivalent shunt reactor which functions to supply "leading" reactive power variable.

According to the present invention, there is provided an electromagnetic induction apparatus for use in power transmission and distribution systems, the apparatus comprising a transformer having at least two windings connected to external circuits characterised in that a short-circuit winding is provided, and said at least two windings and the short-circuit winding are wound on a single core as well as being electromagnetically coupled to each other.

According to the present invention, there is further provided an electromagnetic induction apparatus for use in power transmission and distribution systems, the apparatus comprising a transformer having at least two windings connected to external circuits, characterised in that a reactor winding is provided and said at least two windings and the reactor winding are wound on a single core as well as being electromagnetically coupled to each other, one of said at least two windings being provided with a tap to form this winding into a tap winding, said reactor winding having one end thereof connected to one end of said tap winding and having the other end thereof connected to said tap.

In embodiments of this invention, two windings operate as an ordinary transformer, while a leakage flux appears in the magnetic space between the two windings and a short-circuit winding, and it equivalently functions as a shunt reactor, to supply "leading" reactive powers to transmission or distribution lines and capacitances.

In embodiments of the second aspect of performance of this invention, a tap voltage which is lower than the open-circuit voltage of a reactor winding is forcibly applied from a tap to the reactor winding, to generate a desired magnitude of leakage flux between the reactor winding and a tap winding.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a circuit diagram showing an embodiment of this invention,

Fig. 2 is a perspective view showing an embodiment in which a transformer in Fig. 1 is constructed of a shell type transformer,

Fig. 3 is a horizontal partial sectional view corresponding to Fig. 2,

Fig. 4 is a circuit diagram showing in a single-line connection state a case where the transformer in Fig.1 is used as the electromagnetic induction apparatus of a substation,

Fig. 5 is a perspective view showing a case where the circuit in Fig. 4 is used in three phases,

Fig. 6 is an equivalent circuit diagram corresponding to Fig. 1,

Fig. 7 is a perspective view showing an embodiment in which the transformer in Fig. 1 is constructed of a core type transformer,

Fig. 8 is a horizontal partial sectional view showing an embodiment in which the magnetic space of the transformer in Fig. 3 is formed of a gapped core,

Fig. 9 is a circuit diagram showing in a single-line connection state an example where in an embodiment in which a switching device is added to a short-circuit winding in Fig. 1 is used as the electromagnetic induction apparatus of a substation,

Fig. 10 is a perspective view showing a case where the circuit in Fig. 9 is used in three phases,

Figs. 11 and 12 are horizontal partial sectional views respectively showing the states in which the switching device of the transformer in Fig. 9 is opened and closed,

Fig. 13 is a circuit diagram showing another aspect of performance of this invention,

Fig. 14 is a perspective view showing an embodiment in which a transformer in Fig. 13 is constructed of a shell type transformer,

Figs. 15 and 16 are horizontal partial sectional, views respectively showing the states in which the tertiary winding of the transformer in Fig. 14 is opened and is connected to a tap,

Fig. 17 is a circuit diagram showing an embodiment in which a changer is added to the taps of the transformer in Fig. 13,

Fig. 18 is a horizontal partial sectional view showing an embodiment in which the magnetic space of a transformer in Fig. 15 is formed of a gapped core,

Fig. 19 is a horizontal partial sectional view showing and embodiment in which the transformer in Fig. 13 is constructed of a core type transformer,

Fig. 20 is a circuit diagram showing the single-line connection state of a substation in a prior art,

Fig. 21 is a perspective view showing a case where the circuit in Fig. 20 is used in three phases,

Fig. 22 is a circuit diagram showing another substation in a prior art under a single-line connection state,

Fig. 23 is a perspective view showing a case where the circuit in Fig. 22 is used in three phases,

Fig. 24 is an equivalent circuit diagram corresponding to Fig. 22,

Fig. 25 is an equivalent circuit diagram corresponding to Fig. 24,

Fig. 26 is a horizontal partial sectional view of a transformer in Fig. 22, and

Fig. 27 is an equivalent circuit diagram of a transformer in Fig. 20.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Now, an embodiment of this invention will be described with reference to the drawings. Fig. 1 is a circuit diagram in a single-line connection state showing the embodiment of this invention as a transformer which has, for example, three windings.

In Figs. 1-12, 1a-1c, 2-7, 10 and 11 indicate the same portions as in the prior art examples stated before, and 1A indicates a transformer corresponding to the transformer 1.

The core of the transformer 1A is denoted by 1d and S is a short-circuit line which short-circuits both the ends of the tertiary winding 1c and due to which the tertiary winding 1c becomes a short-circuit winding.

A leakage flux 18 is induced between the tertiary winding 1c and the primary winding 1a or secondary winding 1b by the short-circuit current of the tertiary winding 1c, and though not shown, such a leakage flux is also generated between the primary winding 1a and the secondary winding 1b. The leakage flux 18 passes through a magnetic space 19 which is illustrated only between the secondary winding 1b and the tertiary winding 1c here.

A switching device 29 is added to the short-circuit line S. In actuality, the switching device may well be connected between one end of the tertiary winding 1c and ground by leading the terminal of the tertiary winding 1c out of the transformer 1A as shown in Fig. 9, or between the lines of the tertiary winding connected in three phases. A power source V_0 such as a power station (not shown) or the like is connected to the primary winding 1a, and a magnetic flux 18A is generated in the core 1d by the power source V_0 when the switching device 29 has been opened. Thus, when the switching device 29 shown in Figs. 9 to 12 is opened as depicted in Fig. 11, the tertiary winding 1c falls into an unshorted state, and the shunt reactor function vanishes. When the switching device 29 is closed as depicted in Fig. 12, the tertiary winding 1c serves as the short-circuit winding and gives rise to the shunt reactor function, quite similarly to the state in which the short-circuit line S is provided as illustrated in Figs. 1 and 2. That is, the supply of the "leading" reactive powers 10, 11 can be on-off-controlled as is necessary by means of the switching device 29.

Now, the operation of the embodiment of this invention will be described. First, with the switching device 29 opened as shown in Fig. 11, the power source V_0 of the power station (not shown) is connected to the primary winding 1a to excite the transformer 1A. Then, the magnetic flux 18A is generated in the core 1d and interlinks with the primary winding 1a, secondary winding 1b and tertiary winding 1c in common. Under the electromagnetic induction action of the magnetic flux 18A, voltages proportional to the numbers of turns of the respective windings are generated across the primary winding 1a, secondary winding 1b and tertiary winding 1c. That is, in the state of Fig. 11, the output terminals of the secondary winding 1b are connected to the external circuit (not shown), thereby to operate as the output terminals of the ordinary transformer. Besides, since the tertiary winding 1c is in the open state, it is merely generating the voltage. Accordingly, no current flows through the tertiary winding 1c, and the tertiary winding 1c is not supplying electric power externally.

On the other hand, in the state in which both the ends of the tertiary winding 1c are short-circuited by the short-circuit line S or by the closure of the switching device 29 as shown in Figs. 1 and 2 or in Fig. 12, a short-circuit current flows through the loop of the tertiary winding 1c. Since the voltage across the tertiary winding 1c is forcibly rendered zero by the short-circuit current, the magnetic flux 18A in Fig. 11 flows through the magnetic space 19 between the tertiary winding 1c and the secondary winding 1b as well as the primary winding 1a. That is, the leakage flux 18 appears in the magnetic space 19 as shown in Fig. 3 or Fig. 12.

At this time, magnetic energy Q is generated in the magnetic space 19, and the value thereof is expressed by

$$Q \propto fB^2V$$

where f denotes the frequency of the power source V_0, B the flux density of the magnetic space 19 and V the volume of the magnetic space 19. Simultaneously, a short-circuit current $\dot{I}_3$ of a magnitude establishing a magnetic field of the flux density B in the magnetic space 19 flows through the tertiary winding 1c. In addition, currents $\dot{I}_1$ and $\dot{I}_2$ satisfying the following flow through the primary winding 1a and the secondary winding 2b in accordance with a transformer operation:

$$\dot{I}_1N_1 + \dot{I}_2N_2 = \dot{I}_3N_3$$

where N_1: number of turns of the primary winding 1a,

N_2: number of turns of the secondary winding 1b,

N_3: number of turns of the tertiary winding 1c,

and the shunt reactor function of supplying the magnetic energy Q externally is effected.

The leakage flux 18 functions equally to the shunt reactor(s) 9 or 13, 15 in the prior-art examples shown in Figs. 20 to 23 and supplies the "leading" reactive powers 10, 11 to the capacitances 4, 7 of the primary side and secondary side transmission or distribution lines 3, 6 as shown in Figs. 4, 5, 9 and 10.

Now, there will be explained the equivalence between the leakage flux 18 shown in Figs. 3 and 12 and the shunt reactor(s) 9 or 13, 15 in the prior art.

As elucidated in conjunction with Figs. 24 to 27, the leakage flux 24 appears also in the two-winding transformer 20 or three-winding transformer 1 of the prior-art construction. As illustrated in the equivalent circuit of Fig. 25 or 27, however, the leakage reactance functions as the series reactance which is connected in series with the circuit.

Meanwhile, the equivalent circuit of the transformer 1A with the tertiary winding 1c short-circuited is expressed as in Fig. 6. In the figure, 25-27 and X_1-X_3 are the same as in Fig. 27. By short-circuiting the tertiary winding 1c to ground, the reactance X_3 on the tertiary side functions as a parallel reactance which is connected in parallel with the circuit. That is, connecting the primary side transmission or distribution line 3 and the secondary side transmission or distribution line 6 to the primary side terminal 25 and the secondary side terminal 26 respectively corresponds to connecting "a shunt reactor whose reactance has the magnitude X_3" in parallel with the power transmission or distribution system. This signifies nothing but the fact that the magnetic space 19 shown in Figs. 3 and 12 functions physically as the magnetic space of the shunt reactor in the prior art.

Moreover, in the case of the two-winding transformer, when it is further provided with the tertiary winding 1c which is electromagnetically coupled to the primary winding 1a and the secondary winding 1b, it becomes identical to the construction of the three-winding transformer 1A and can also be operated similarly to the shunt reactor.

In this manner, the three-winding transformer 1A with both the ends of the tertiary winding 1c short-circuited functions also as the shunt reactor whose reactance has the magnitude X_3, without spoiling the original voltage transformation function of the transformer and can supply the "leading" reactive powers to the capacitances 4, 7 of the transmission or distribution lines 3, 6. Moreover, the voltage of the tertiary winding 1c can be selected at will irrespective of the voltages of the primary transmission or distribution line 3 and the secondary transmission or distribution line 6. Therefore, when the voltage across the tertiary winding 1c is rendered sufficiently low, the transformer 1A need not be especially enlarged.

Although the above embodiment has been explained as to the case when the transformer 1A is constructed as a shell type, the transformer may also be constructed with a core type one as shown in Fig. 7.

Also, while the air-core structure has been adopted as the magnetic space 19 through which the leakage flux 18 passes, a gapped-core structure may well be adopted by interposing a gapped core 28 as shown in Fig. 8.

Further, while the transformer 1A of the three windings has been explained as an example, it is needless to say that, even when the invention is applied to a transformer of four or more windings not shown, an electromagnetic induction apparatus having the same functional effect as stated above can be realized by short-circuiting the tertiary winding.

Next, another aspect of performance of this invention will be described. Fig. 13 is a circuit diagram showing the embodiment of another aspect of performance of this invention, Fig. 14 is a perspective view showing a practical construction corresponding to Fig. 13, and Figs. 15 and 16 are horizontal partial sectional views respectively showing the states in which a tertiary winding in Fig. 14 is opened and is connected to a tap. In the figures, 1a-1d, 18 and 19 denote portions similar to those described before, and 1B denotes a transformer corresponding to the transformer 1A.

The secondary winding 1b is provided with a plurality of taps 30, and owing to which the secondary winding 1b becomes a tap winding. In addition, the tertiary winding 1c has one end connected to one end of the secondary winding 1b at a node P and has the other end connected to one of the plurality of taps 30, thereby to become a reactor winding.

Next, the operation of the embodiment of another aspect of performance of this invention will now be described. First, it is assumed that the primary side transmission or distribution line, namely, the power source V_0 of a power station or the like be connected to the primary winding 1a in the state in which the tertiary winding 1c as the reactor winding is open as depicted in Fig. 15. Then, the magnetic flux 18A of a magnitude ϕ_0 is generated in the core 1d and interlinks with the primary winding 1a, secondary winding 1b and tertiary winding 1c in common. This state is the same as in the case of Fig. 11.

At this time, a voltage equal to the supply voltage V_0 is generated across the primary winding 1a, and voltages according to the numbers of turns N_1-N_3 of the respective windings 1a-1c are generated across the secondary winding 1b and tertiary winding 1c. The voltages generated across the windings 1a-1c, denoted by V_{10}-V_{30} respectively are expressed as follows:

$$V_{10} = K\phi_0 N_1 = V_0 \qquad (3)$$

$$V_{20} = K\phi_0 N_2 \qquad (4)$$

$$V_{30} = K\phi_0 N_3 \qquad (5)$$

where K: constant.

Accordingly, the secondary winding 1b can be used for the ordinary transformer when connected to the secondary side transmission or distribution line, namely, the external circuit. Besides, since the tertiary winding 1c is in the open state, it is merely generating the voltage V_{30} and does not execute the reactor function at all.

Subsequently, as depicted in Fig. 16, one end of the tertiary winding 1c is connected to one end of the secondary winding 1b through the node P, and the other end of the tertiary winding 1c is connected to one of the taps 30, whereby a tap voltage V_3 lower than the open-circuit voltage V_{30} as evaluated with Eqs. (3) and (5) is forcibly applied to the tertiary winding 1c. After the application of the tap voltage V_3, the magnitude ϕ of the magnetic flux 18B interlinking with the tertiary winding 1c becomes a value satisfying the equation:

$$V_3 = K\phi N_3$$

in which V_3 and ϕ are respectively substituted for V_{30} and ϕ_0 in Eq. (5). Accordingly,

$$\phi = V_3 / KN_3 \qquad (6)$$

holds.

On the other hand, the magnitude ϕ_0 of the magnetic flux 18A in the open-circuit condition becomes:

$$\phi_0 = V_{30} / KN_3 \qquad (7)$$

in accordance with Eq. (5). From Eqs. (6) and (7), the value ϕ of the magnetic flux 18B upon being connected to the tap is expressed relative to the value ϕ_0 of the magnetic flux 18A in the open-circuit condition as follows:

$$\phi = \phi_0 V_3 / V_{30} \qquad (8)$$

In addition, since the relation of the voltages V_3 and V_{30} is:

$$V_3 < V_{30}$$

the relation of the flux values ϕ and ϕ_0 becomes:

$$\phi < \phi_0$$

in accordance with Eq. (8). Accordingly, the magnitude $\Delta\phi$ of a leakage flux 18C to flow through the magnetic space 19 is expressed by:

$$\Delta\phi = \phi_0 - \phi$$

In this manner, upon being connected to the tap illustrated in Fig. 16, the leakage flux 18C of the magnitude $\Delta\phi$ flows through the magnetic space 19, whereby predetermined magnetic energy is generated to effect the shunt reactor function.

Here, it is understood that, by altering the tap 30 of the secondary winding 1b to which the other end of the tertiary winding 1c is connected, to charge the tap voltage V_3 in Eq. (8), the value ϕ of the magnetic flux 18B interlinking with the tertiary winding 1c varies in proportion to the tap voltage V_3. At this time, the value $\Delta\phi$ of the leakage flux 18C flowing through the magnetic space 19 changes simultaneously, so that the magnitude of the magnetic energy of the magnetic space 19 changes to change the capacity of the shunt reactor. In particular, the state in which the tap voltage V_3 is rendered zero is the same as the case illustrated in Fig. 12. The value ϕ_0 of the magnetic flux 18A in the open-circuit condition flows entirely to the magnetic space 19 upon being connected to the tap and the capacity of the shunt reactor becomes the maximum.

While the above embodiment has referred to the three-winding transformer by way of example, it is needless to say that, quite similarly to the case of the three-winding transformer, an electromagnetic induction apparatus comprising a shunt reactor of variable capacity can be realized even with a transformer of four or more windings by using one of the windings as a reactor winding and another as a tap winding.

Besides, while the other end of the tertiary winding 1c has been connected to a proper one of the taps 30, a changer 31 for changing the taps 30 in an on-load condition may well be disposed between the other end of the tertiary winding 1c and the taps 30 as shown in a circuit diagram of Fig. 17. In this case, the change of the taps 30, in other words, the alteration of the capacity of the shunt reactor can be performed in the energized state. In this way, when the respective tap voltages V_3 at the plurality of taps 30 are properly changed-over and applied to the tertiary winding 1c, the capacities of the equivalent shunt reactor can be turned on and off stepwise, and hence, an instantaneous voltage fluctuation is not incurred in the power transmission or distribution system.

Besides, while the magnetic space 19 through which the leakage flux 18C passes has been illustrated as the air-core structure as depicted in Fig. 16, it may well be a gapped-core structure with a gap core 28 interposed therein as depicted in Fig. 18.

Further, while the transformer 1B as the electromagnetic induction apparatus has been illustrated as the shell type transformer, it may well be a core type one as shown in Fig. 19.

As described above, according to this invention, a short-circuit winding which is electromagnetically coupled to at least two windings is disposed. This produces the effect that a transformer having also a shunt reactor function for supplying "leading" reactive powers required by transmission or distribution lines can be realized, and that an electromagnetic induction apparatus which dispenses with facilities for a shunt reactor and which can reduce the construction cost of a substation and power loss is provided.

In another aspect of performance of this invention, a reactor winding which is electromagnetically coupled to at least two windings, one being a tap winding, and which is connected between one end of the tap winding and a tap is disposed, and the difference flux of respective magnetic fluxes appearing when the reactor winding is opened and is connected to the tap is generated in a magnetic space. This produces the effect that an electromagnetic induction apparatus in which the capacity of an equivalent shunt reactor is variable is provided.

Claims

1. An electromagnetic induction apparatus for use in power transmission and distribution systems, the apparatus comprising a transformer (1a) having at least two windings (1a, 1b) connected to external circuits characterised in that a short-circuit winding (1c) is provided, and said at least two windings and the short-circuit winding are wound on a single core as well as being electromagnetically coupled to each other.

2. An electromagnetic induction apparatus as defined in Claim 1, wherein a magnetic space (19) intervening between said short-circuit winding (1c) and each of said at least two windings (1a, 1b) forms an air-core structure.

3. An electromagnetic induction apparatus as defined in Claim 1, wherein a magnetic space (19) intervening between said short-circuit winding (1c) and each of said at least two windings (1a, 1b) forms a gapped-core structure (28).

4. An electromagnetic induction apparatus as defined in Claim 1, wherein a switching device (29) is connected to one end of said short-circuit winding (1c).

5. An electromagnetic induction apparatus for use in power transmission and distribution system the apparatus comprising a transformer (1A) having at least two windings (1a, 1b) connected to external circuits, characterised in that a reactor winding (1c) is provided and said at least two windings and the reactor winding are wound on a single core as well as being electromagnetically coupled to each other, one of said at least two windings (1a, 1b) being provided with a tap (30) to form this winding into a tap winding (1b), said reactor winding (1c) having one end thereof connected to one end of said tap winding (1b) and having the other end thereof connected to said tap (30).

6. An electromagnetic induction apparatus as defined in Claim 5, wherein a magnetic space (19) intervening between said reactor winding (1c) and each of said at least two windings (1a, 1b) forms an air-core structure.

7. An electromagnetic induction apparatus as defined in Claim 5, wherein a magnetic space (19) intervening between said reactor winding (1c) and each of said at least two windings (1a, 1b) forms a gapped-core structure (28).

8. An electromagnetic induction apparatus as defined in Claim 5, wherein said tap winding (1b) is provided with a plurality of taps (30).

9. An electromagnetic induction apparatus as defined in Claim 8, wherein a changer (31) for changing said taps (30) in an on-load condition is connected between the other end of said reactor winding (1c) and said taps.

Revendications

1. Appareil d'induction électromagnétique destinée à être utilisé dans des systèmes de transmission et de distribution d'énergie, l'appareil comprenant un transformateur (1a) possédant au moins deux enroulements (1a, 1b) reliés à des circuits externes, caractérisé en ce qu'un enroulement de court-circuit (1c) est prévu, et que lesdits au moins deux enroulements et l'enroulement de court-circuit sont enroulés sur un seul noyau ainsi que couplé électromagnétiquement les uns aux autres.

2. Appareil d'induction électromagnétique selon la revendication 1, caractérisé en ce qu'un espace magnétique (19) intervenant entre ledit enroulement de court-circuit (1c) et chacun desdits au moins deux enroulements (1a, 1b) forme une structure sans fer.

3. Appareil d'induction électromagnétique selon la revendication 1, caractérisé en ce qu'un espace magnétique (19) intervenant entre ledit enroulement de court-circuit (1c) et chacun desdits au moins deux enroulements (1a, 1b) forment une structure de noyau à entrefer (28).

4. Appareil d'induction électromagnétique selon la revendication 1, caractérisé en ce qu'un dispositif de commutation (29) est relié à une extrémité dudit enroulement de court-circuit (1c).

5. Appareil d'induction électromagnétique destiné à être utilisé dans des systèmes de transmission et de distribution d'énergie, l'appareil comprenant un transformateur (1A) possédant au moins deux enroulements (1a, 1b) reliés à des circuits externes, caractérisé en ce qu'un enroulement de réactance (1c) est prévu, et lesdits au moins deux enroulements et l'enroulement de réactance sont enroulés sur un seul noyau ainsi que couplés électromagnétiquement les uns aux autres, l'un desdits au moins deux enroulements (1a, 1b) étant pourvu d'une prise (30) pour conformer cet enroulement en un enroulement à prise (1b), une extrémité dudit enroulement à réactance (1c) étant reliée à une extrémité dudit enroulement à prise (1b) et l'autre extrémité de celui-ci étant reliée à ladite prise (30).

6. Appareil d'induction électromagnétique selon la revendication 5, caractérisé en ce qu'un espace magnétique (19) intervenant entre ledit enroulement de réactance (1c) et chacun desdits au moins deux enroulements (1a, 1b) forme une structure sans fer.

7. Appareil d'induction électromagnétique selon la revendication 5, caractérisé en ce qu'un espace magnétique (19) intervenant entre ledit enroulement de réactance (1c) et chacun desdits au moins deux enroulements (1a, 1b) forment une structure de noyau à entrefer (28).

8. Appareil d'induction électromagnétique selon la revendication 5, caractérisé en ce que ledit enroulement à prise (1b) est pourvu d'une pluralité de prises (30).

9. Dispositif d'induction électromagnétique selon la revendication 8, dans lequel un changeur (31) pour changer lesdites prises (30) dans une condition en charge est relié entre l'autre extrémité dudit enroulement de réactance (1c) et lesdites prises.

Patentansprüche

1. Elektromagnetischer Induktionsapparat zur Verwendung in Stromübertragungs- und Stromverteilungsanlagen, aus einem Transformator (1A), der mindestens zwei Wicklungen (1a, 1b) aufweist, die mit externen Stromkreisen verbunden sind, dadurch gekennzeichnet, daß eine Kurzschlußwicklung (1c) vorgesehen ist, und die besagten mindestens zwei Wicklungen und die Kurzschlußwicklung auf demselben Kern angeordnet sind und elektromagnetisch miteinander gekoppelt sind.

2. Elektromagnetischer Induktionsapparat gemäß Anspruch 1, dadurch gekennzeichnet, daß ein magnetischer Zwischenraum (19) zwischen der Kurzschlußwicklung (1c) und jeder der mindestens zwei Wicklungen (1a, 1b) eine Luftkern-

Struktur bildet.

3. Elektromagnetischer Induktionsapparat gemäß Anspruch 1, dadurch gekennzeichnet, daß ein magnetischer Zwischenraum (19) zwischen der Kurzschlußwicklung (1c) und jeder der mindestens zwei Wicklungen (1a, 1b) eine Luftspaltkern-Struktur (28) bildet.

4. Elektromagnetischer Induktionsapparat gemäß Anspruch 1, dadurch gekennzeichnet, daß die Schalt-vorrichtung (29) mit einem Ende der besagten Kurzschlußwicklung (1c) verbunden ist.

5. Elektromagnetischer Induktionsapparat zur Verwendung in Stromübertragungs- und Stromverteilungsanlagen, aus einem Transformator (1A) mit mindestens zwei Wicklungen (1a, 1b), die mit externen Stromkreisen verbunden sind, dadurch gekennzeichnet, daß eine Drosselwicklung (1c) vorgesehen ist, und die besagten mindestens zwei Wicklungen und die Drosselwicklung auf demselben Kern angeordnet sind und elektromagnetisch miteinander gekoppelt sind, wobei eine der mindestens zwei Wicklungen (1a, 1b) mit einer Anzapfung (30) versehen ist, um aus dieser Wicklung eine Anzapfungswicklung (1b) zu machen, und wobei ein Ende der Drosselwicklung (1c) mit einem Ende der Anzapfungswicklung (1b) verbunden ist, und das andere Ende der besagten Drosselwicklung mit der Anzapfung (30) verbunden ist.

6. Elektromagnetischer Induktionsapparat gemäß Anspruch 5, dadurch gekennzeichnet, daß ein magnetischer Zwischenraum (19) zwischen der besagten Drosselwicklung (1c) und jeder der mindestens zwei Wicklungen (1a, 1b) eine Luftkern-Struktur bildet.

7. Elektromagnetischer Induktionsapparat gemäß Anspruch 5, dadurch gekennzeichnet, daß ein magnetischer Zwischenraum (19) zwischen der Drosselwicklung (1c) und jeder der mindestens zwei Wicklungen (1a, 1b) eine Luftspaltkern-Struktur (28) bildet.

8. Elektromagnetischer Induktionsapparat gemäß Anspruch 5, dadurch gekennzeichnet, daß die Anzapfungswicklung (1b) mit einer Vielzahl von Anzapfungen (30) versehen ist.

9. Elektromagnetischer Induktionsapparat gemäß Anspruch 8, dadurch gekennzeichnet, daß ein Umschalter (31) zum Wechseln der Anzapfungen (30) im unbelasteten Zustand zwischen dem anderen Ende der Drosselwicklung (1c) und den besagten Anzapfungen angeschlossen ist.

FIG. 1

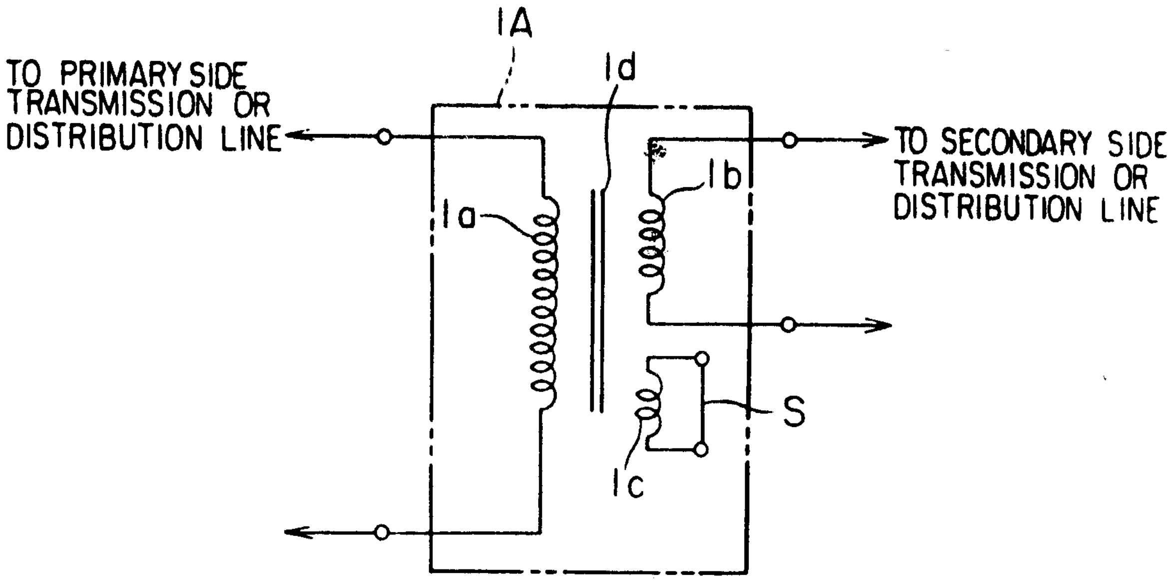
1A
1d
TO PRIMARY SIDE
TRANSMISSION OR
DISTRIBUTION LINE
TO SECONDARY SIDE
TRANSMISSION OR
DISTRIBUTION LINE
1b
1a
S
1c

FIG. 2

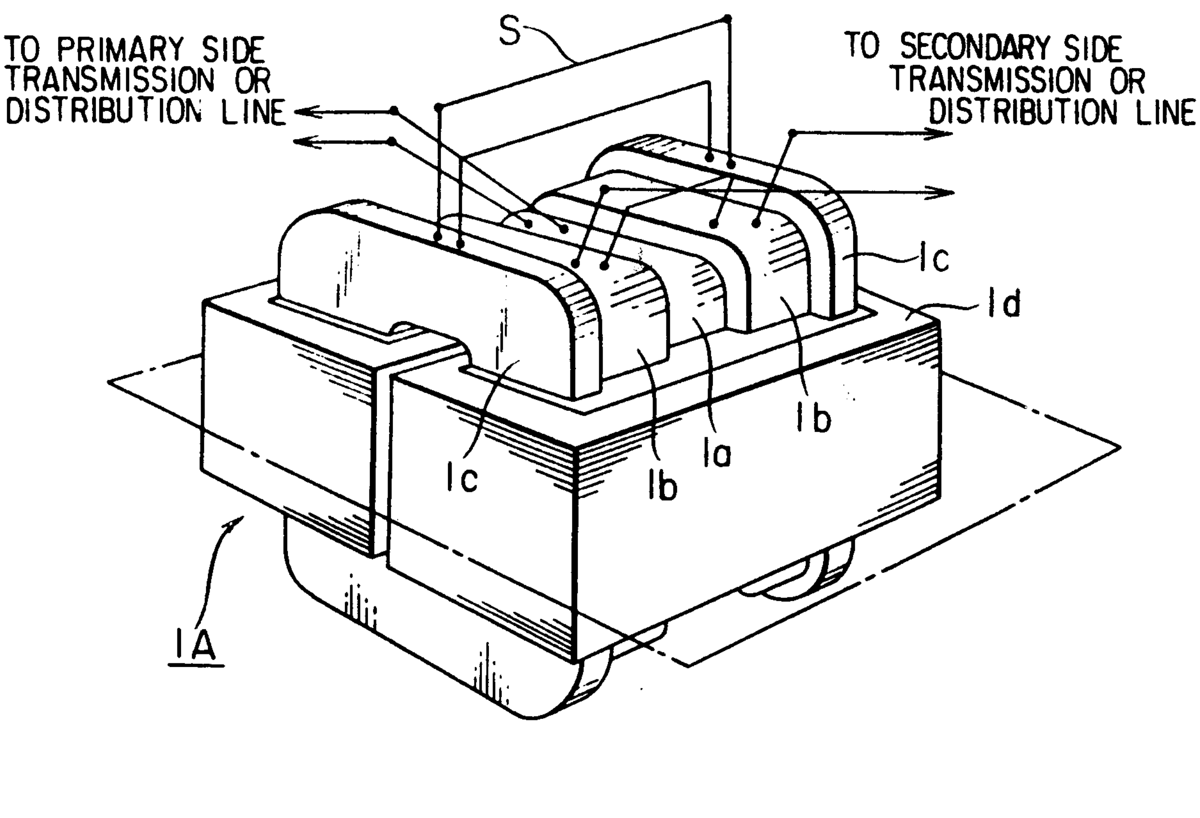
S
TO PRIMARY SIDE
TRANSMISSION OR
DISTRIBUTION LINE
TO SECONDARY SIDE
TRANSMISSION OR
DISTRIBUTION LINE
1c
1d
1b
1a
1c
1b
1A

FIG. 3

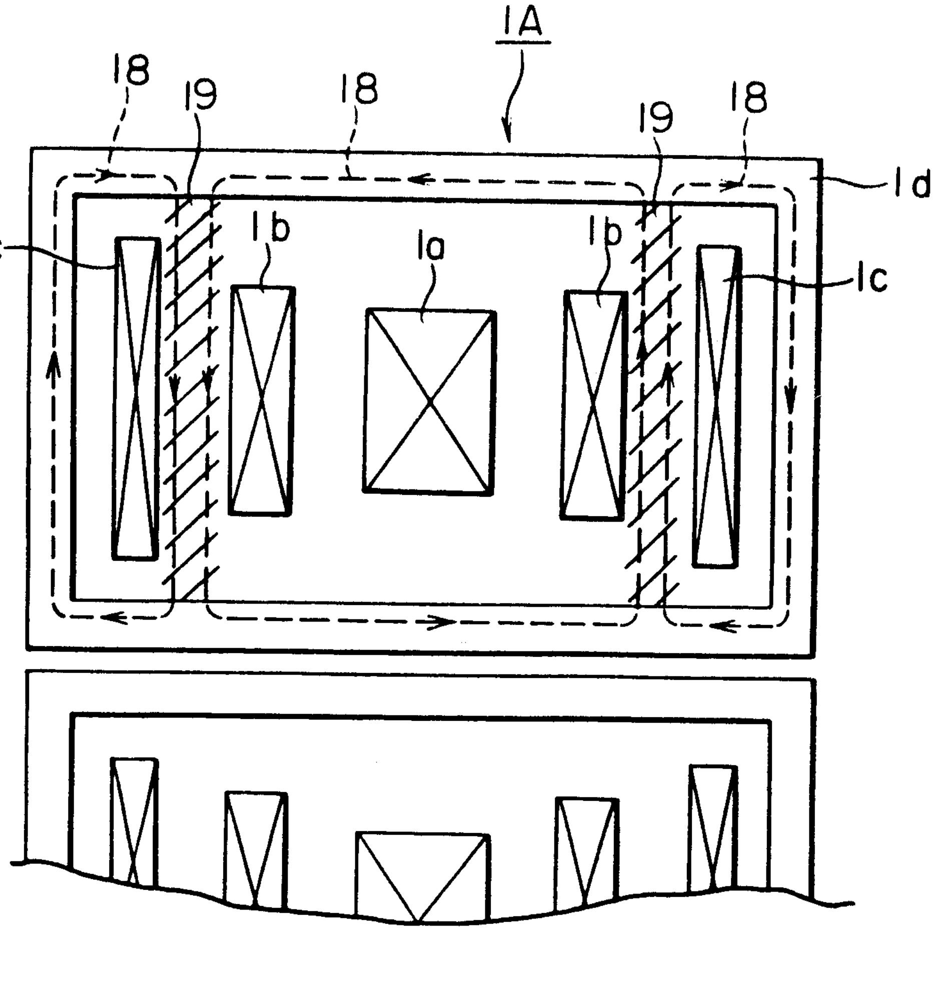

FIG. 4

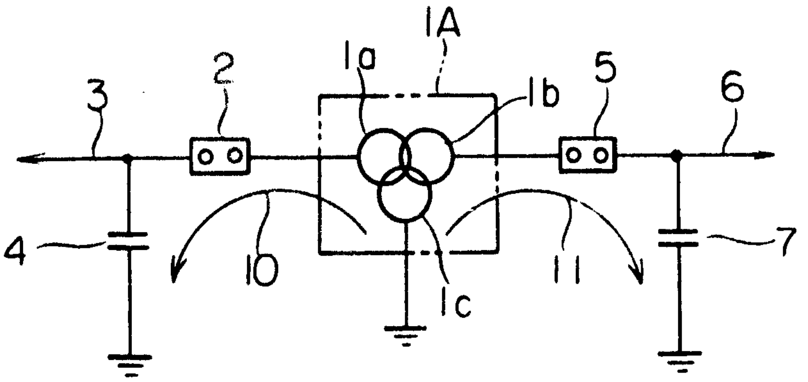

FIG. 5

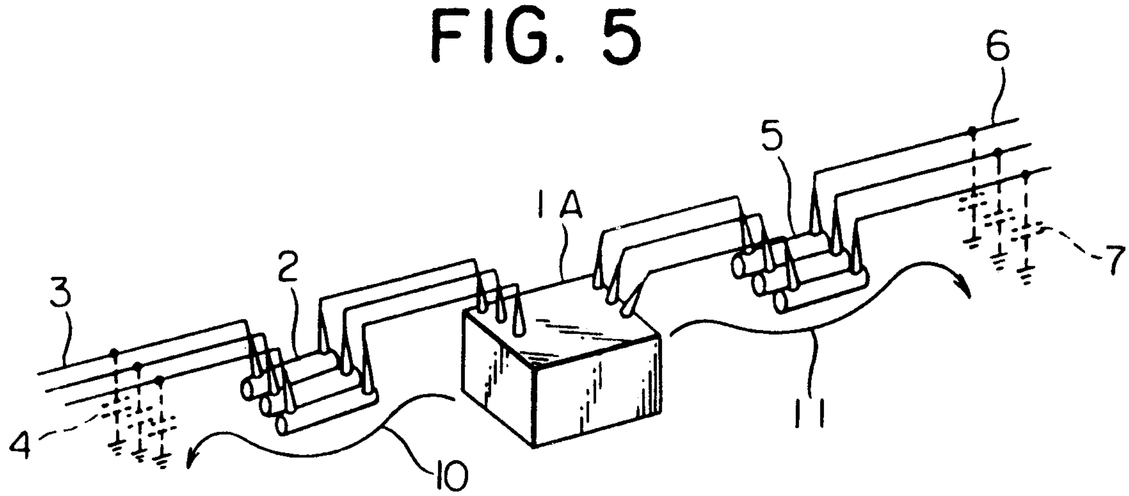

FIG. 6

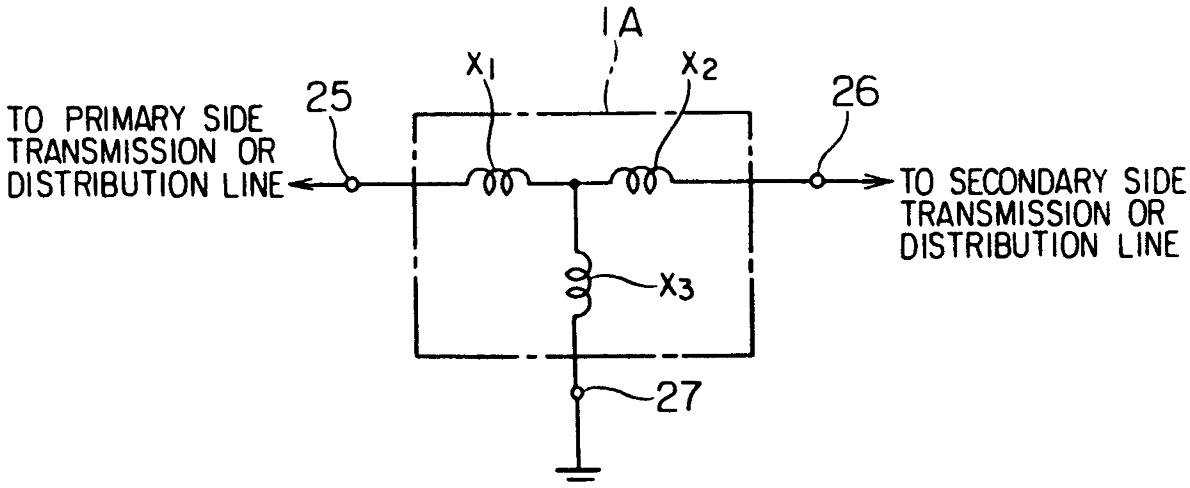

FIG. 7

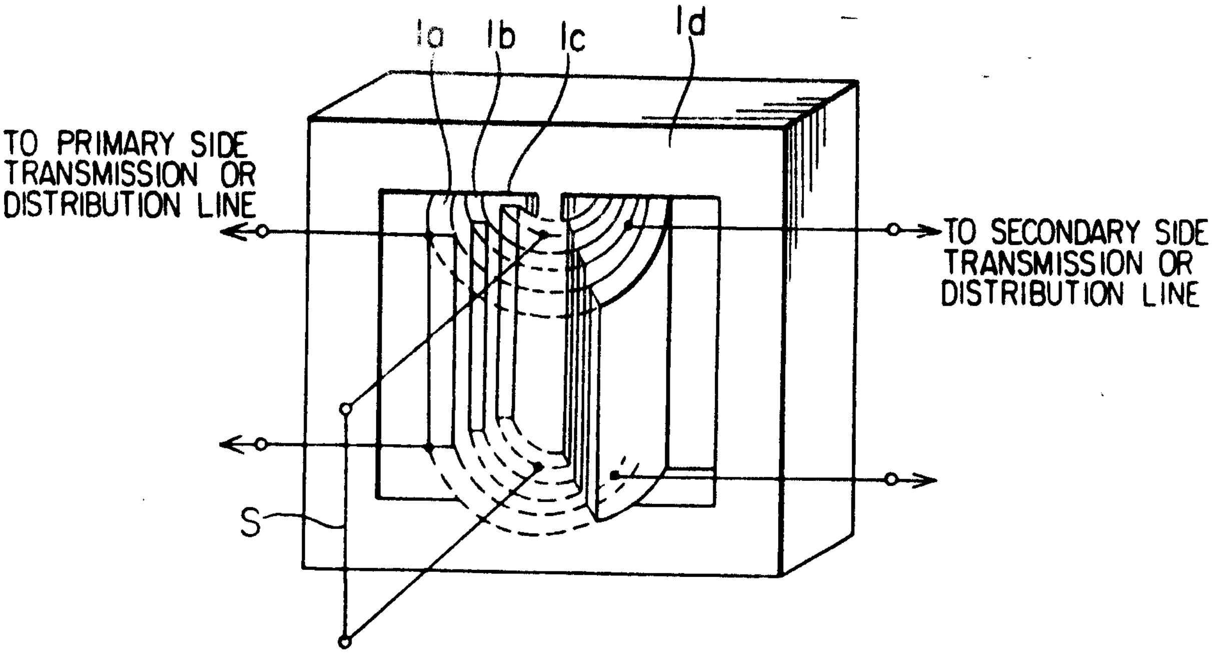
1a
1b
1c
1d
TO PRIMARY SIDE TRANSMISSION OR DISTRIBUTION LINE
TO SECONDARY SIDE TRANSMISSION OR DISTRIBUTION LINE
S

FIG. 8

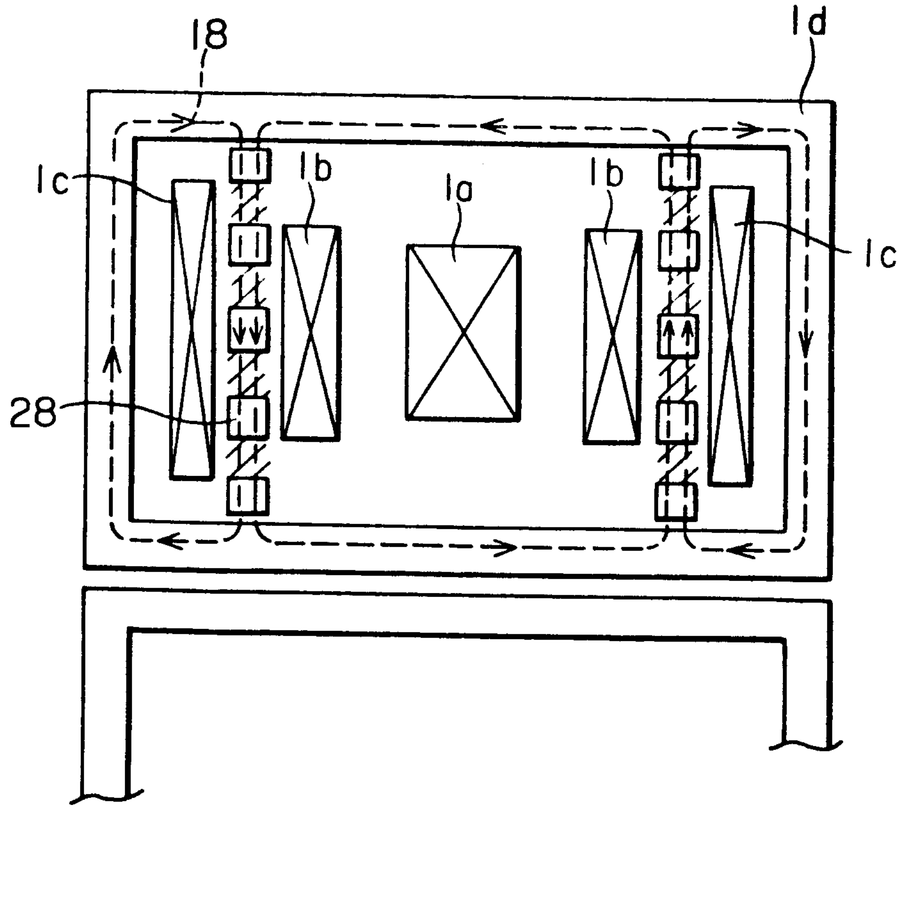
18
1d
1c
1b
1a
1b
1c
28

FIG. 9

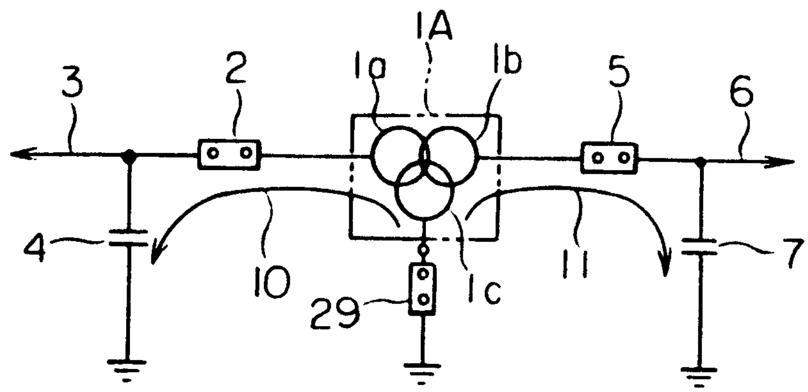

FIG. 10

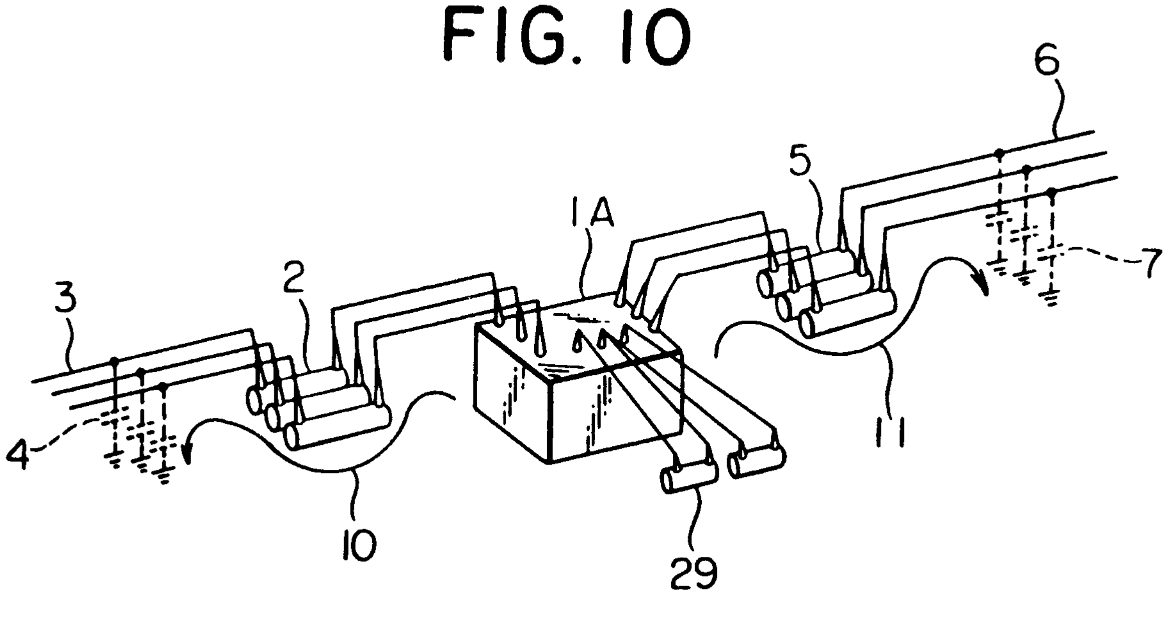

FIG. 11

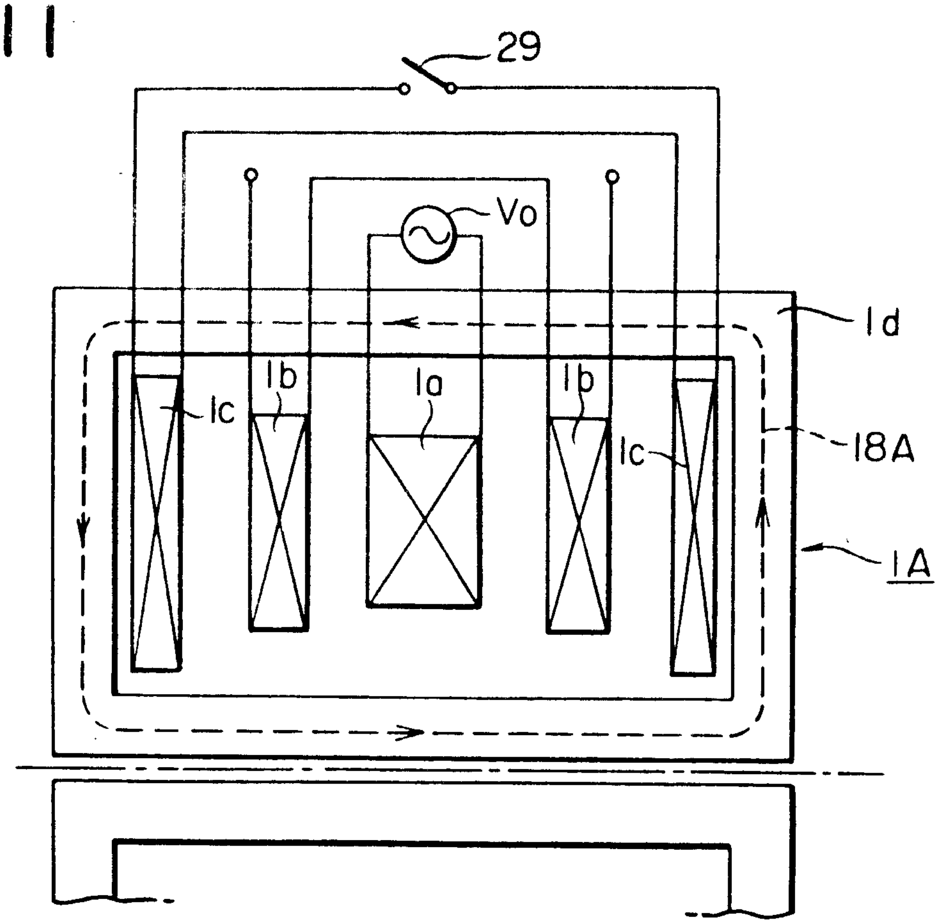

FIG. 12

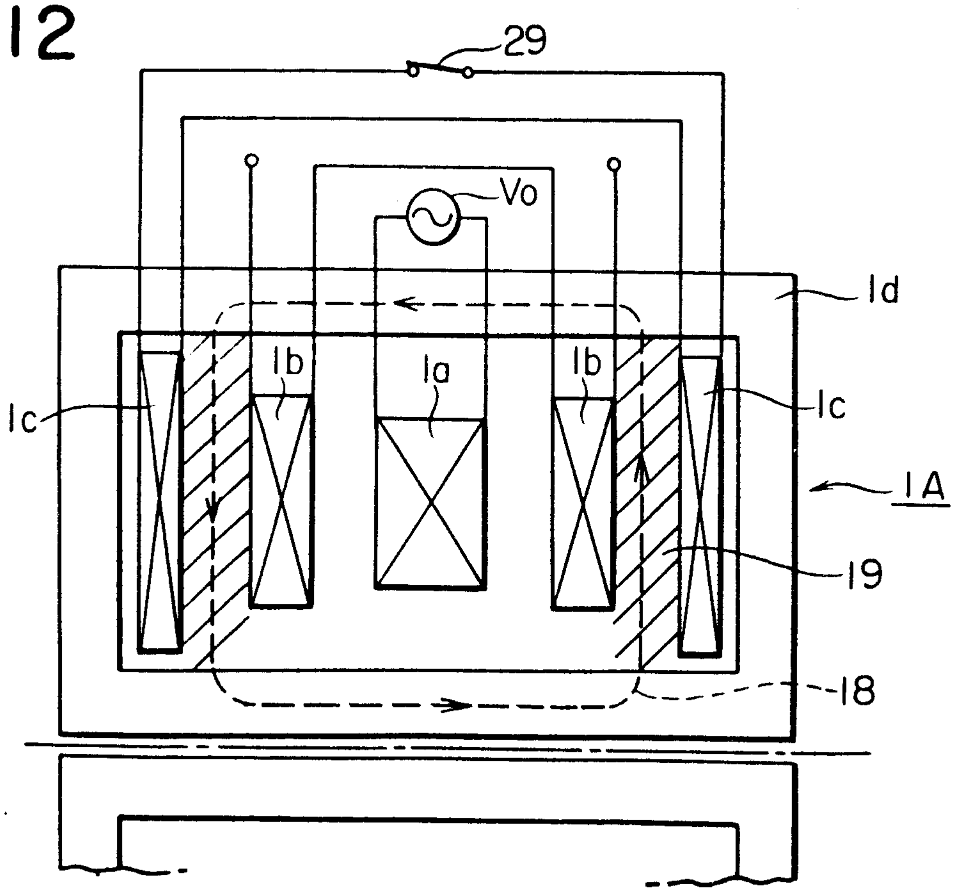

FIG. 13

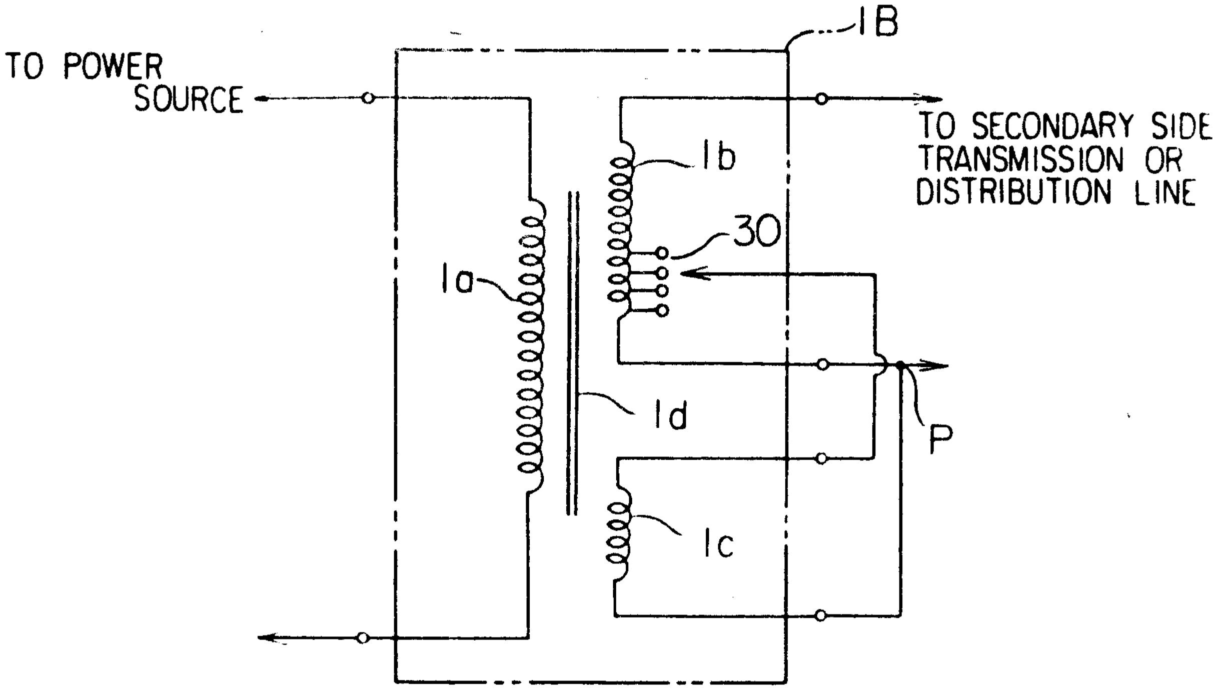
TO POWER
SOURCE
1B
TO SECONDARY SIDE
TRANSMISSION OR
DISTRIBUTION LINE
1b
30
1a
1d
P
1c

FIG. 14

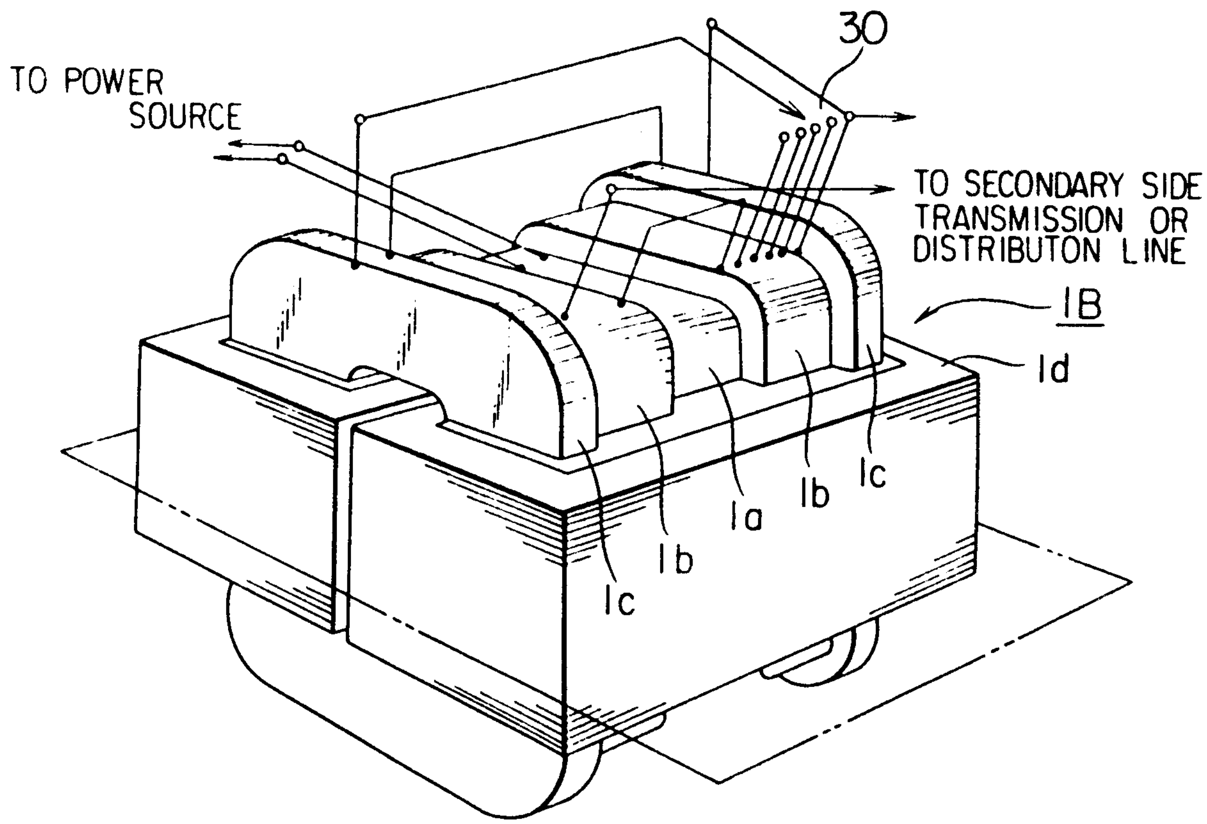
TO POWER
SOURCE
30
TO SECONDARY SIDE
TRANSMISSION OR
DISTRIBUTON LINE
1B
1d
1c
1b
1a
1b
1c

FIG. 15

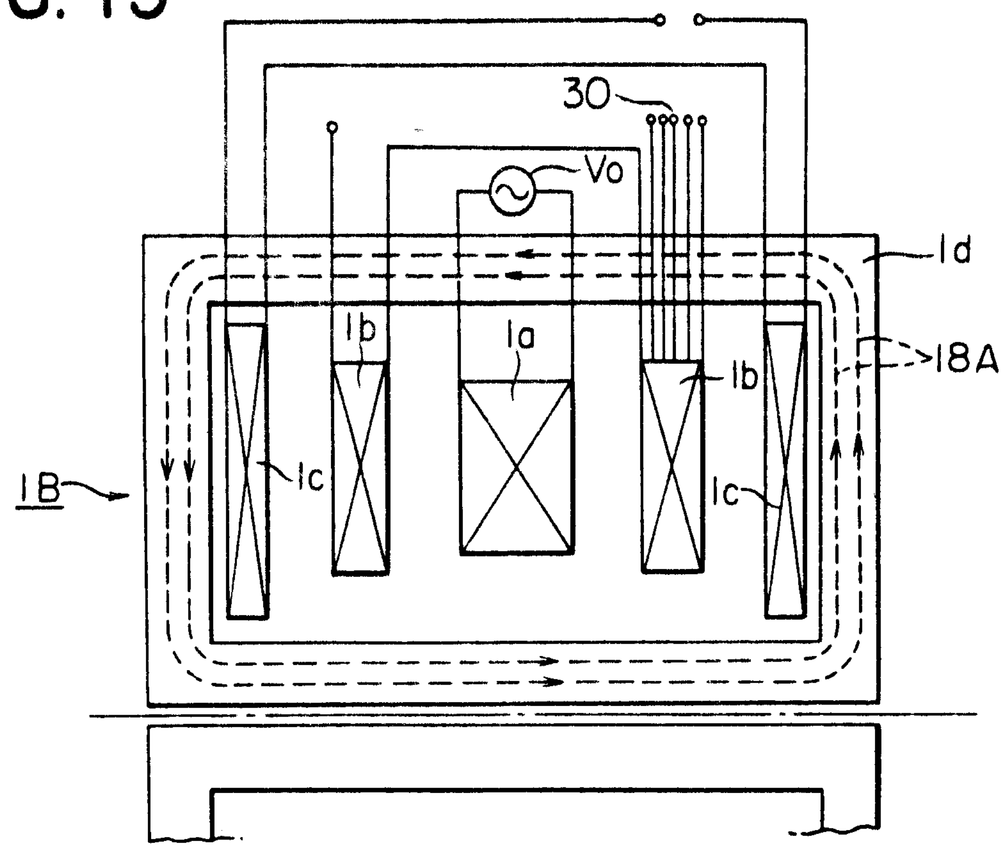

FIG. 16

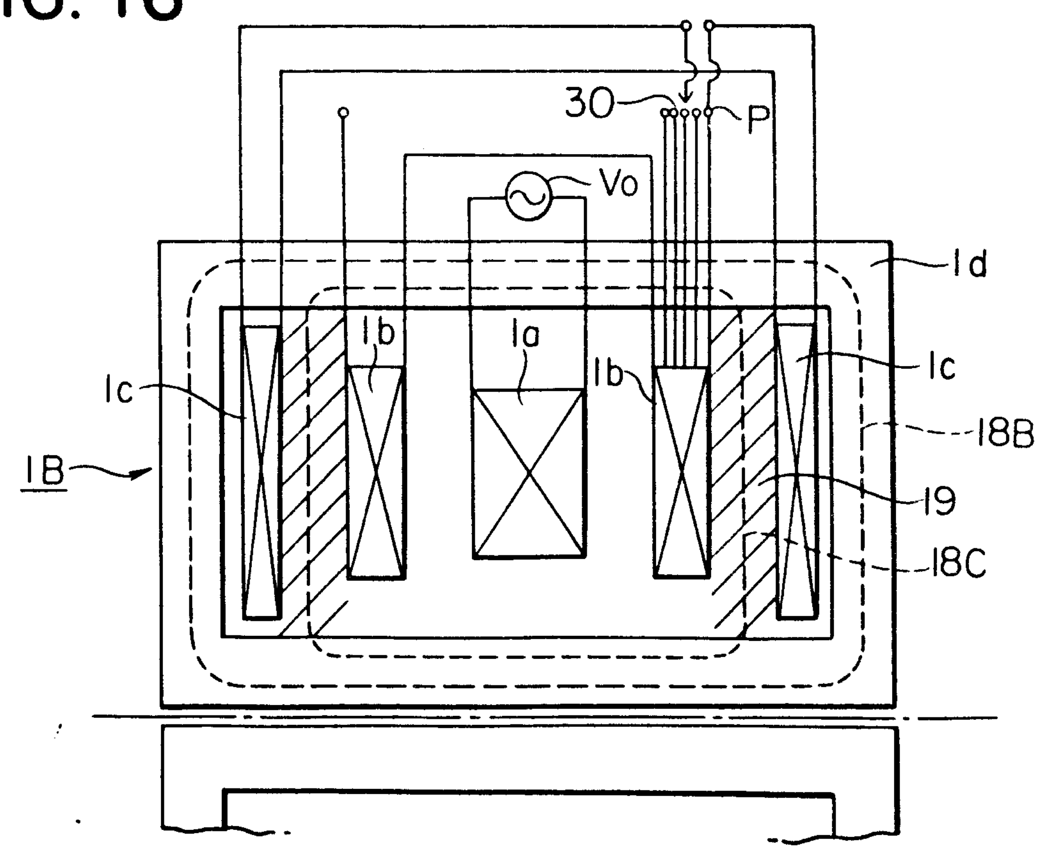

FIG. 17

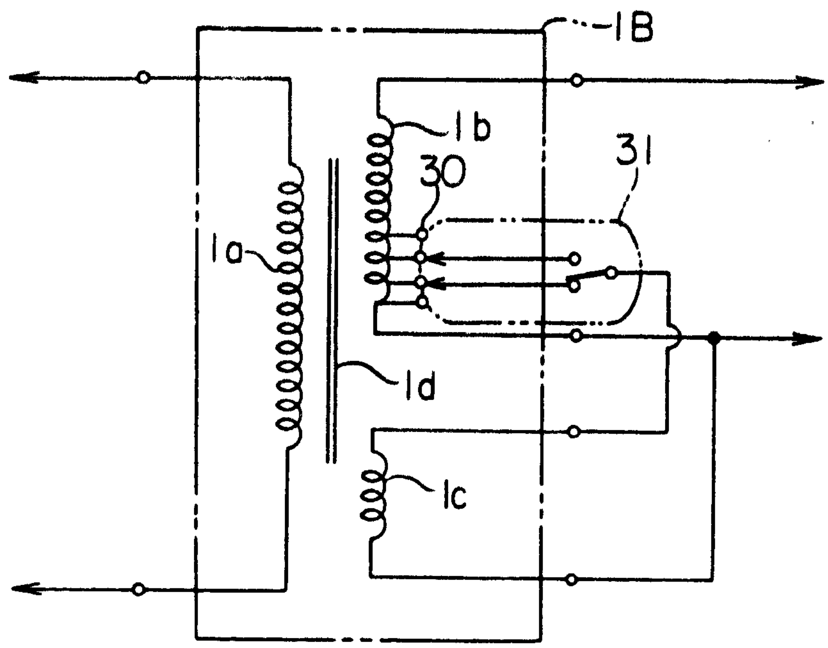

FIG. 18

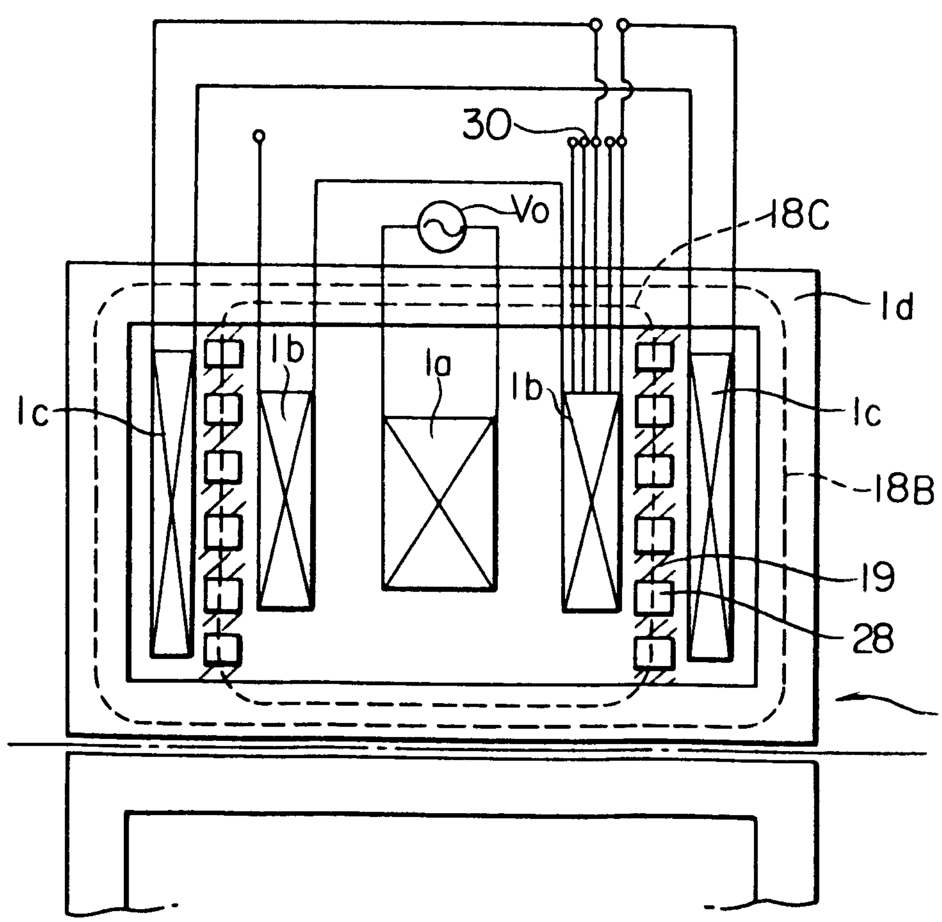

FIG. 19

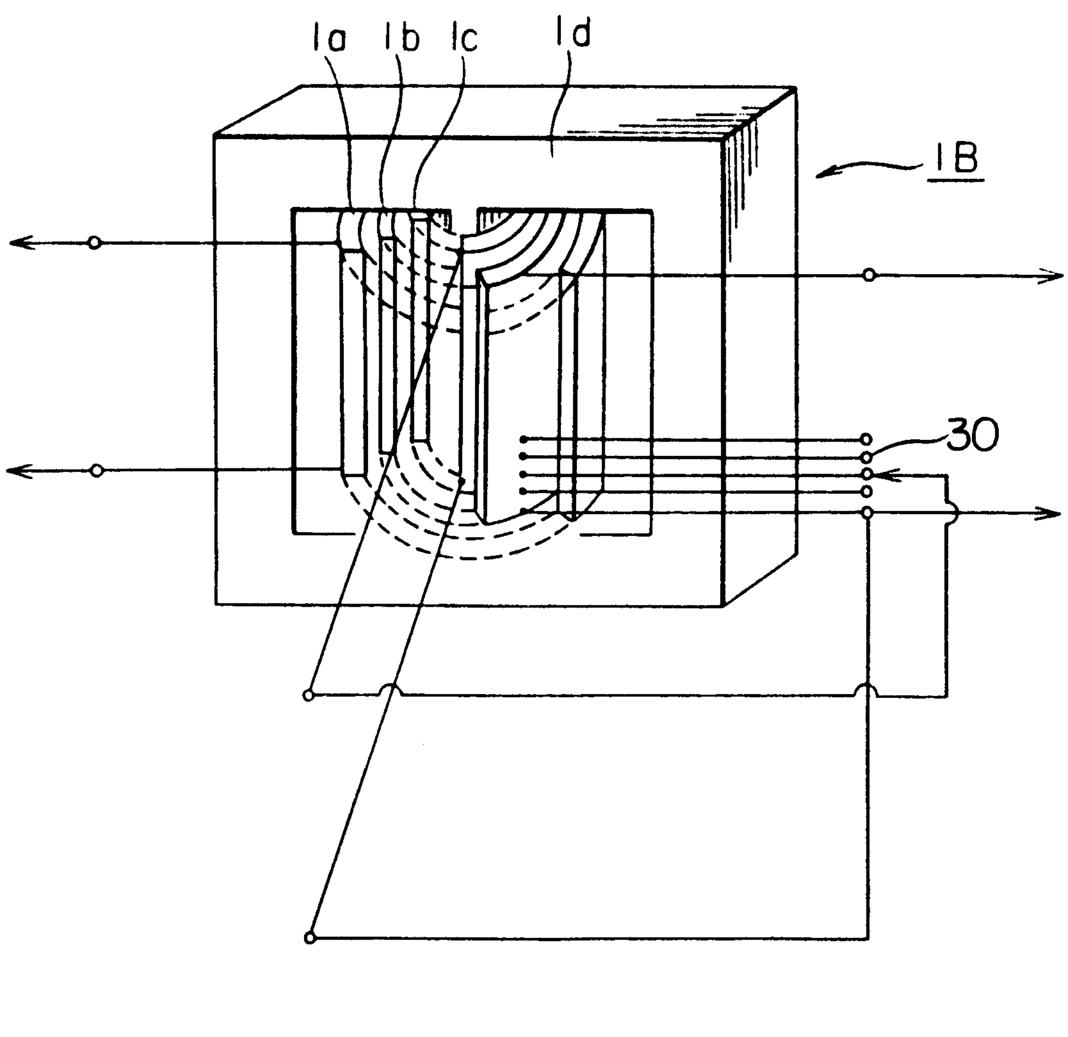

FIG. 20 PRIOR ART

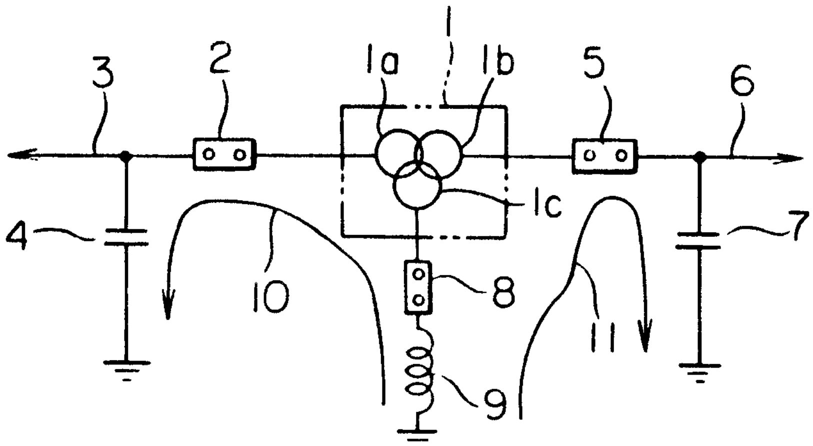

FIG. 21
PRIOR ART

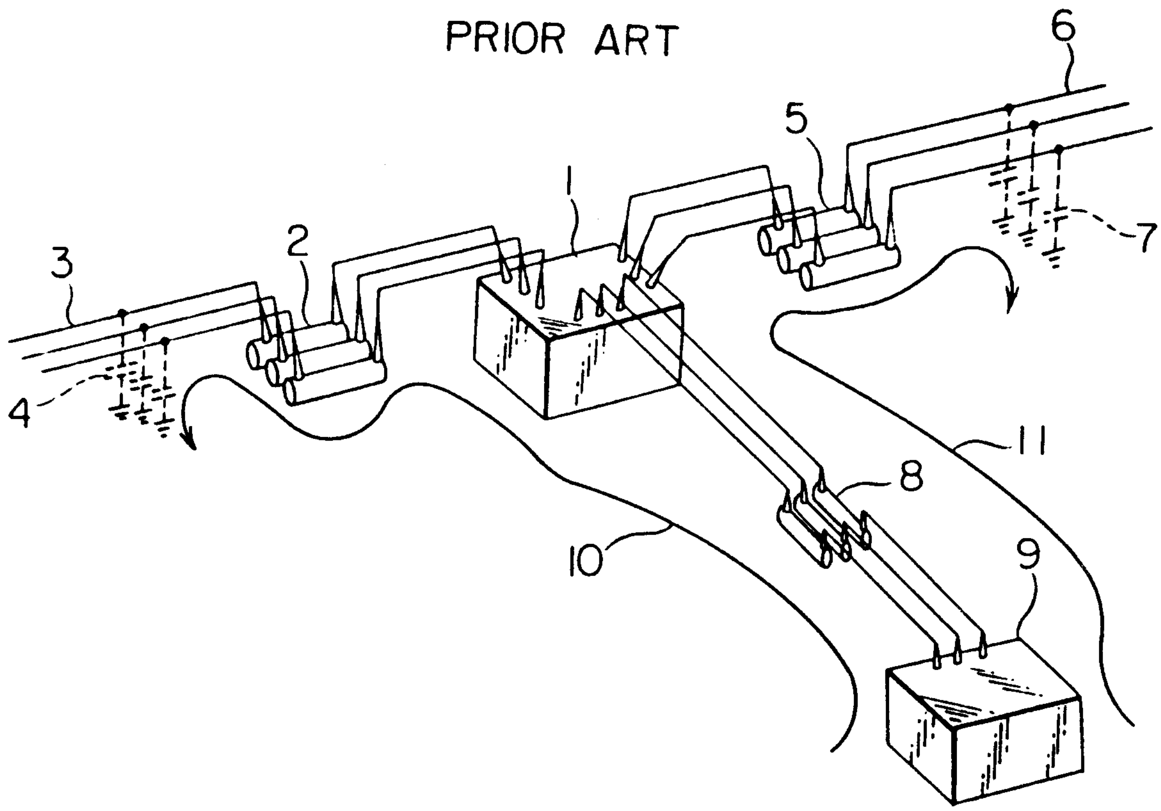

FIG. 22
PRIOR ART

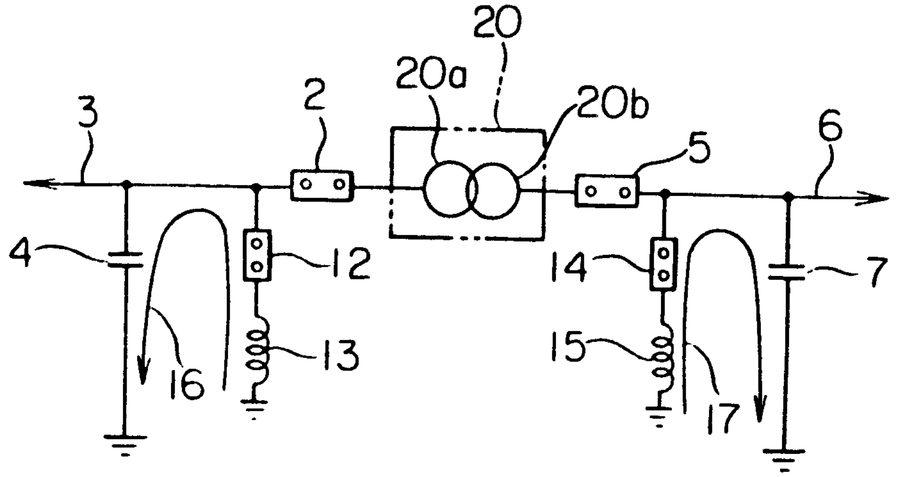

FIG. 23
PRIOR ART

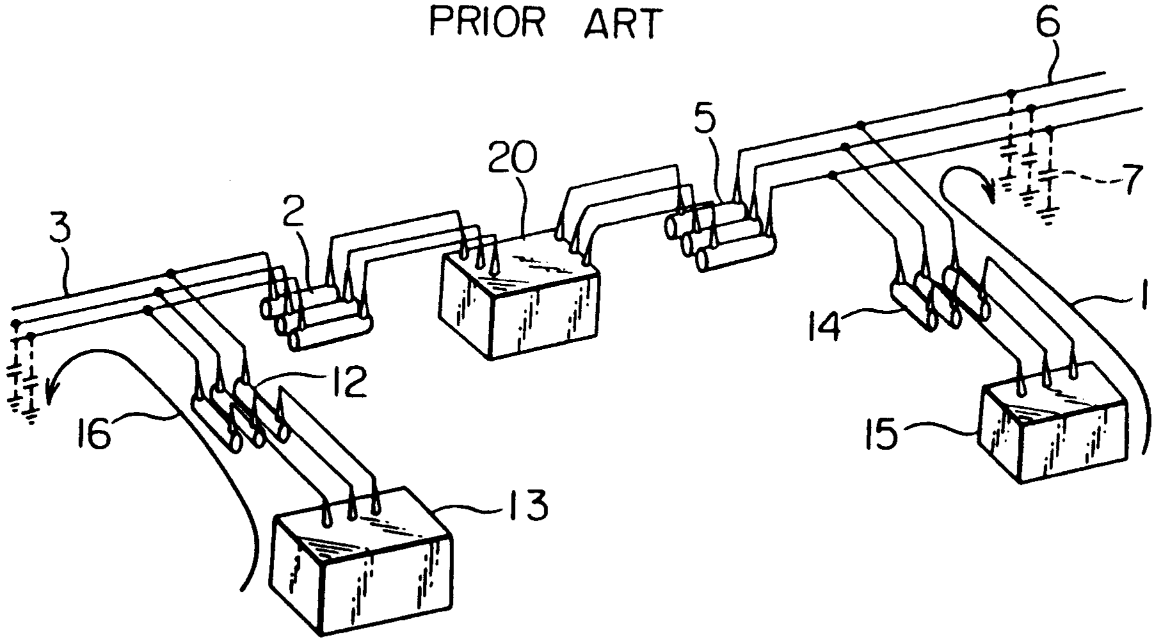

FIG. 24
PRIOR ART

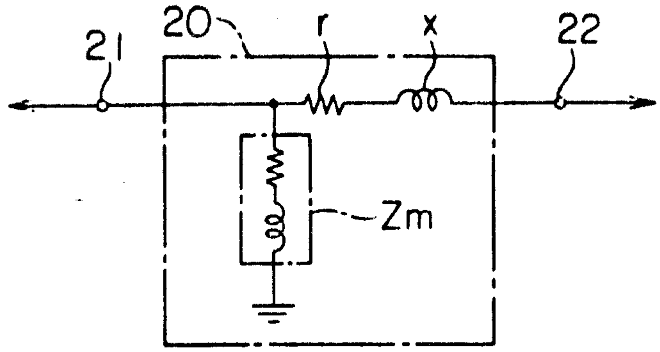

FIG. 25
PRIOR ART

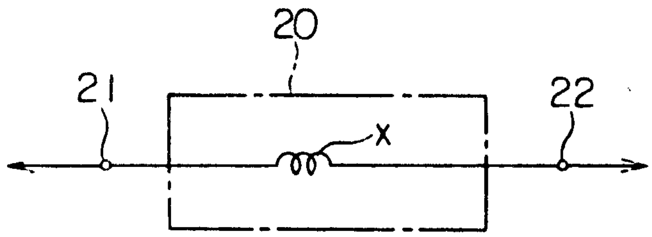

FIG. 26
PRIOR ART

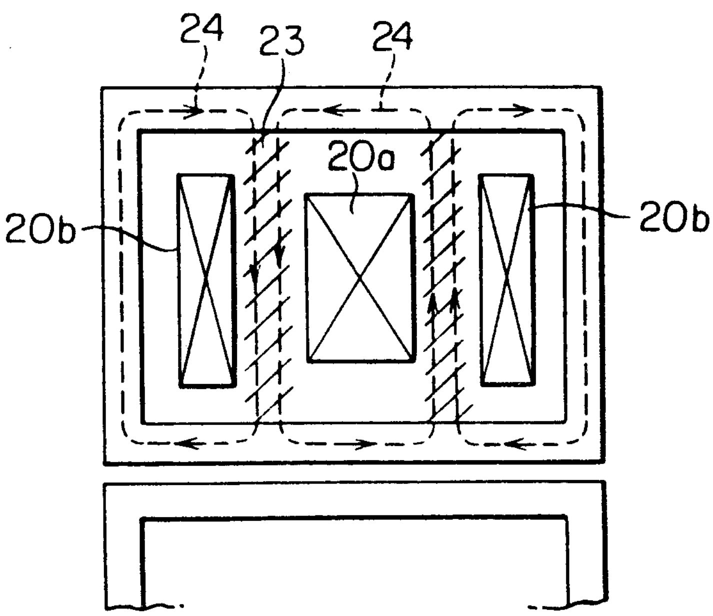

FIG. 27
PRIOR ART