May 20, 1952 A. U. WELCH, JR 2,597,689

ARC STARTING SYSTEM

Filed Feb. 23, 1951

Fig. 1.

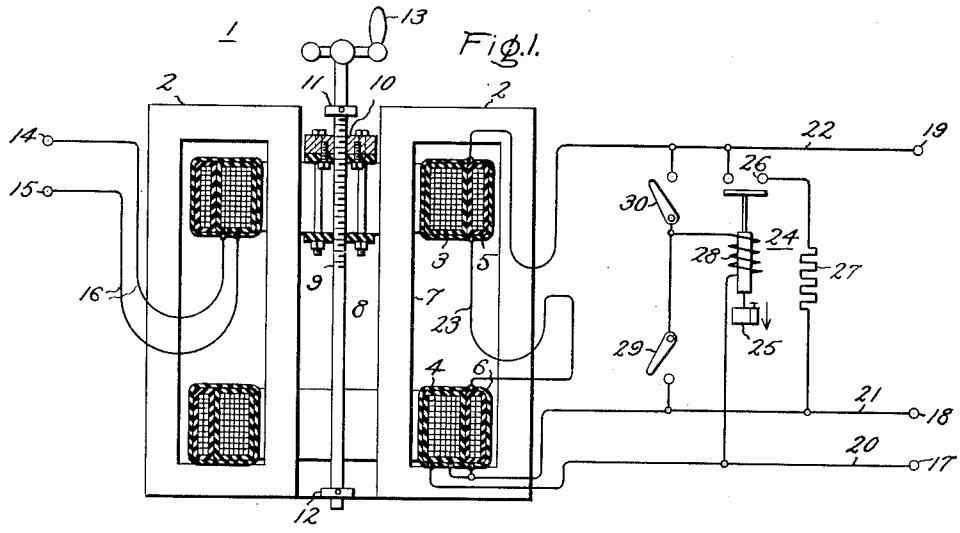


Fig. 2.

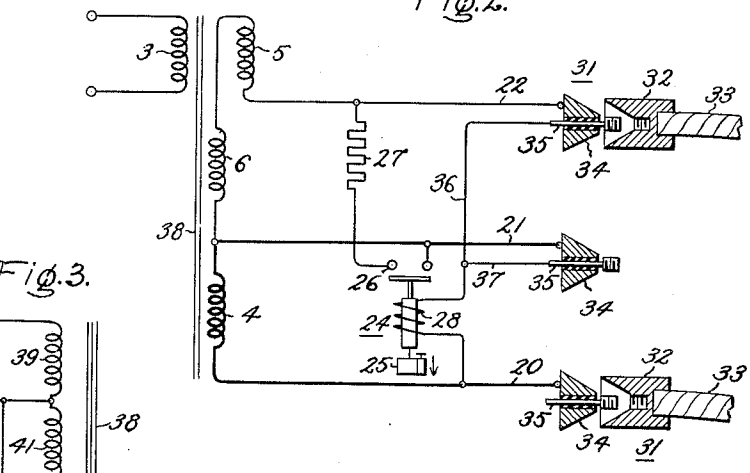
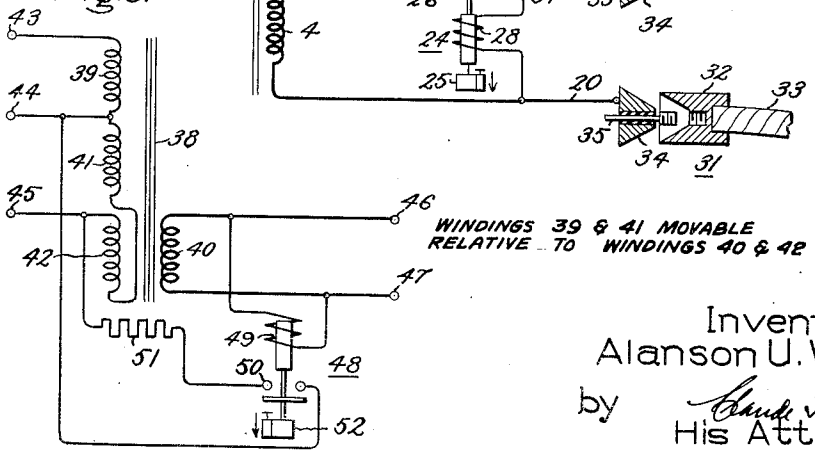


Fig. 3.



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ARC STARTING SYSTEM

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Application February 23, 1951, Serial No. 212,433

10 Claims. (Cl. 323—53)

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My invention relates to arc starting systems and more particularly to apparatus in which means are provided for automatically increasing, for a predetermined time during arc starting, the amount of current supplied by a reactance device which may be adjusted to control the desired flow of current to the arc for normal operation thereof. My invention is particularly applicable to arc welding.

In arc welding, as in related arts, some means must be provided for adjusting the arcing current to a value suitable for the operation to be performed. For example, in arc welding, less current is required to weld thin parts than for welding thicker parts. However, for arc starting, it is desirable to have a heavy current flow at the time of striking the arc in order to establish the molten pool of metal in the work and the fusing rate of the electrode when fusible electrodes are employed. A suitable arc striking current, if maintained, would however result in melt-throughs for thin work parts or an excessive consumption of a fusible electrode, which it is necessary to avoid. Consequently, systems have heretofore been proposed for temporarily increasing the current flow at the time of arc starting from that which it is desired to use after the arc has been started.

It is an object of my invention to provide systems which will temporarily increase, at the time of arc starting, the adjusted current flow delivered by variable reactance transformers of the type illustrated in and forming the subject matter of my United States Letters Patent 2,283,712, granted May 19, 1942.

Further objects of my invention will become apparent from a consideration of the following descriptions of the embodiments thereof shown in the three figures of the accompanying drawing. Fig. 1 of this drawing is a diagrammatic representation of my invention as applied to an adjustable reactance transformer having the physical structure illustrated and described in my above referred to patent. Fig. 2 is a diagrammatic representation of a system embodying my invention in which the physical structure of one form of output terminals therefor has been illustrated. Fig. 3 is a diagrammatic representation of another modification of my invention in which reactance control is secured on the primary side of the transformer in contradistinction to reactance control on the secondary side thereof as illustrated in Figs. 1 and 2.

The adjustable reactance transformer shown in my above identified patent is of particular utility

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in providing a wide range of current adjustments for a limited range of movement of the parts thereof. The relatively movable parts of such a transformer may be its primary and secondary windings, or a magnetic shunt or shunts located between these windings and adjustably movable relative to the magnetic structure about which these windings are located. In either case, the relative adjustment of the parts adjusts the leakage reactance of the primary and secondary windings of the transformer and the consequent current output thereof.

As pointed out in my patent above referred to, one range of movement of these parts provides one range of current adjustment, and an additional range of current adjustment is obtained for the same range of physical adjustment of the parts by connecting in circuit with the primary or secondary windings of the transformer a pair of auxiliary windings which are connected differentially relative to one another and one of which is located near the primary winding of the transformer and the other of which is located near the secondary winding thereof. These auxiliary windings may have fixed positions relative to the core of the transformer or to the primary and secondary windings with which they are associated. These auxiliary windings preferably have substantially the same electrical characteristics so that their differential connection will result in substantially no net voltage being induced in their part of their circuit under no load conditions of the transformer. The direction of connection is such that the ampere turns in the auxiliary winding closest to the secondary winding of the transformer are in the same direction as the ampere turns of that winding, and that the ampere turns in the auxiliary winding nearest the primary winding are in the same direction as the ampere turns of that winding. Consequently, when these auxiliary windings are connected in series circuit with either the primary or secondary winding of the transformer, more ampere turns are applied to the leakage reactance circuit, causing either additional leakage flux, or for the same leakage flux less current is required for the leakage flux. The result, therefore, is a higher reactance and another range of reactance adjustment for the same physical adjustment of the parts when these auxiliary coils are connected in circuit with either the primary or secondary windings of the transformer. Thus, without the auxiliary coils in circuit, one range of adjustment is obtained and, with them in circuit, a second range can be ob-

tained with a single range of adjustment of the physically movable parts of the transformer.

In accordance with the illustrated embodiments of my invention about to be described, a heavy flow of current is provided for arc striking by providing a temporary electrical coupling of these auxiliary windings of a variable reactance transformer of the type above described, in order to reduce the leakage reactance between the primary and secondary windings of the transformer and thereby produce a higher output current flow relative to that current flow set for normal operation by the adjustment of the parts of the transformer. The amount of current boost will be variable depending upon the adjustment of the parts of the transformer, and is high when the transformer parts are set for low normal current flow and is small when the transformer parts are set for high normal current flow. This is exactly what is required for easy arc starting.

My invention will be better understood from a description of the particular embodiments thereof illustrated in the figures of the accompanying drawing.

The adjustable reactance transformer 1 shown in Fig. 1 of the drawing has the same physical structure as that illustrated and described in my above-identified patent, to which reference may be made for a more detailed description thereof. It has a core structure 2, a primary winding 3, a secondary winding 4, and auxiliary windings 5 and 6, respectively associated with these primary and secondary windings. In the arrangement illustrated, these auxiliary twindings 5 and 6 are tightly fitted around the primary and secondary windings and secured thereto by insulation wrapping. Windings 3 and 5 are mounted for movement relative to windings 4 and 6 lengthwise of the winding leg 7 of the core structure 2 of the transformer. This winding leg 7 has a central longitudinal space 8 to accommodate an adjusting mechanism which includes a screw 9 and a traveling nut 10, which is threaded on this screw. The threads on the screw 9 extend along the major portion thereof and the ends of this screw are supported in thrust bearings 11 and 12, which may be mounted on the enclosure for the transformer, which enclosure has not been illustrated in the drawing. The nut 10 supports the windings 3 and 5 and moves these windings relative to the fixed windings 4 and 6 when the screw is rotated by means of the handle 13 attached to its upper end portion. It will be seen, therefore, that as the handle is rotated, the screw will rotate and, since it is prevented from moving longitudinally due to the thrust bearings 11 and 12, the nut 10 will travel along the screw and move the windings 3 and 5 of the transformer relative to the fixed windings 4 and 6 thereof.

A pair of input terminals 14 and 15 are connected through flexible conductor 16 to the ends of the primary winding 3. The primary winding of the transformer is excited by connecting these terminals 14 and 15 to a suitable source of alternating current supply such as the commercial frequencies readily available.

The transformer is provided with three output terminals 17, 18 and 19. Terminals 17 and 18 are connected through leads or conductors 20 and 21 to the ends of the secondary winding 4 of the transformer. Terminal 19 is connected through a lead or conductor 22 to one end of the auxiliary winding 5, whose other end is connected through a flexible conductor 23 to one end of the auxiliary winding 6, whose other end is connected to conductor 21 which leads to terminal 18. It will thus be seen that if the welding conductors are attached to terminals 17 and 18, current will be supplied directly from the secondary winding 4 of the transformer, and that when the welding conductors are attached to terminals 17 and 19, current is supplied from the secondary 4 of the transformer through the auxiliary windings 6 and 5, which are connected in series circuit therewith. These auxiliary windings 5 and 6 are provided for increasing the reactance of the transformer and consequently output terminals 17 and 18 are the high current range terminals, whereas terminals 17 and 19 are the low current range terminals, of this adjustable reactance transformer. Auxiliary winding 6 is connected to conduct current around the winding leg 7 of the transformer in the same direction as the current flow through the secondary winding 4 thereof, while current flow through auxiliary winding 5 is in the same direction as that through primary winding 3. These auxiliary windings 5 and 6 of the transformer preferably have substantially the same electrical characteristics, such as having the same number of turns, so that the total voltage at no load across the series circuit including the secondary and these auxiliary windings is substantially the same as that across the secondary winding alone.

In order to obtain the desired high current for arc starting, auxiliary windings 5 and 6 of the transformer are electrically connected in a localized closed circuit through the agency of a relay 24. This relay has a time delay dropout characteristic as indicated by the dashpot 25 and the arrow associated therewith in the drawing. When it is energized by the open circuit voltage of the welding circuit, it closes its normally open contacts 26 to complete the desired localized conductive connection of the auxiliary windings 5 and 6, which connection may include a resistor 27, which is employed to control the amount of current flow and consequently the amount of current boost obtained when the relay closes its contacts.

The operating winding 28 of relay 24 has one terminal connected to conductor 20 and consequently to output terminal 17, and its other terminal connected through switches 29 and 30 to either conductor 21 or conductor 22, and consequently to either output terminals 18 or 19, depending upon which of the switches 29 and 30 is closed and open respectively. Switches 29 and 30 may be hand-operated as illustrated but are preferably automatically operated in accordance with the connection of one of the welding conductors to output terminals 18 or 19. One such automatic arrangement is shown in Fig. 2 which will be described below. The automatic connection when used will be such that when a welding conductor is attached to output terminal 18, switch 29 will be closed and switch 30 left open, whereas when this welding conductor is attached to output terminal 19, switch 30 will be closed and switch 29 allowed to be open.

The operation of the apparatus just described is as follows. For the high current range, the operator will connect the welding leads to terminals 17 and 18. Maximum current in this range will be obtained when the primary winding 3 is located closely adjacent the secondary winding 4. In order to decrease the amount of current flow within this current range, the primary winding 3 will be moved away from the secondary winding 4 by adjusting the relative

position of these windings by means of the hand crank 13. The greater the separation between the primary and secondary windings 3 and 4, the greater will be the leakage reactance and consequently there will be an increase of reactance in the circuit with a consequent decrease in the amount of current flow supplied to the welding leads and consequently to the arc. The second range of reactance adjustment is provided by connecting the welding leads to output terminals 17 and 19. In this range, the maximum current output will be obtained as in the first range, when the primary winding 3 is closely adjacent the secondary winding 4. Thereafter the current may be decreased by increasing the reactance of the circuit by moving the primary winding 3 away from the secondary winding 4. In this low-current range with the welding conductors attached to output terminals 17 and 19, it will be noted that the auxiliary windings 5 and 6 are connected in series with one another and the secondary winding 4. This interconnection increases the number of turns acting upon the leakage magnetic flux path. Thus, if the change in reactance by moving the primary winding with the load connected across the secondary winding only is in the ratio of, for example 3 to 1, an additional change in reactance of, for example, 3 to 1, may be effected by connecting the load across the series circuit including the auxiliary windings and the secondary winding and again moving the primary winding from its lowermost to its uppermost position. The total range under such circumstances will be 9 to 1, and a relatively large ratio of maximum to minimum reactance may be obtained for a given size transformer unit.

The high current start feature of the system above described depends on the operation of relay 24. If the operator is using the low current range with the welding conductors connected to terminals 17 and 19, he will close switch 30 and permit switch 29 to remain open, thereby connecting the operating winding 28 of relay 24 across conductors 20 and 22 and the output terminals 17 and 19. This connects the operating winding of the relay to be responsive to the voltage condition of the welding conductors which is at a maximum on open circuit and at a reduced value on closed circuit as when striking the arc or supplying current to an established arc. If the welding conductors are open-circuited, no load voltage will appear across the operating winding 28 of relay 24 and this voltage, which for example may be 75 volts, will cause the relay to close its contacts 26 and thereby connect auxiliary windings 5 and 6 in a localized circuit including resistor 27. No appreciable current flows through the resistor and its circuit thus completed during this time, as the potential of conductors 21 and 22 is practically identical at no load, since the auxiliary windings 5 and 6 have substantially the same electrical characteristics and are differentially connected relative to one another. However, when the welding operator touches the electrode to the work and draws it away to strike an arc, substantial current flows through resistor 27, resulting in the welding current being much higher than normal, which is desired for easy arc starting. As previously stated, relay 24 is so designed that when the voltage between conductors 20 and 21 drops from no load voltage to short circuit or ordinary arc voltage, it is sufficiently de-energized to open its contact 26 after a predetermined time delay imposed

by the operating characteristics of the relay. Therefore, contacts 26 of the relay 24 open after a predetermined time interval subsequent to striking the arc to open the circuit through resistor 27 and allow normal current flow as established by the relative position of the primary and secondary windings 3 and 4 of the welding transformer.

If the operator is working on the high current range where the welding conductors are connected to output terminals 17 and 18 of the transformer system, he closes switch 29 and opens switch 30. This connects the operating winding of the relay across the welding conductors so that it is responsive to the voltage conditions of the welding circuit. The operation of the relay and the high current start resulting therefrom is the same with this connection as with the low range current connection above described.

A detailed description of why the output current is increased as a result of the connections employed is somewhat complicated but is subject to mathematical proof and in actual practice does occur. A simple approximate explanation which is applicable to both the high current and low current range connections is that by interconnecting the auxiliary windings electrically, these windings, which are already closely magnetically coupled, effectively reduce the leakage reactance between the primary and secondary windings of the transformer, and thus cause a high current output. It is this decrease in reactance which permits the increased current flow which provides the high current start feature of the system, which greatly facilitates arc starting.

The auxiliary windings 5 and 6 could be connected in a localized circuit with one another without employing the interposed resistor 27 which has been employed only in order to control the amount of current boost. For example, in one embodiment, the value of resistor 27 was so chosen as to give about 100 amperes starting current at a 30-ampere normal range setting down to 150 to 200 amperes at a 100-ampere normal range setting. It is thus seen that the amount of current boost is variable, depending upon the relative positions of the primary and secondary windings in either current output range, and quite advantageously works out so that the boost is higher when the welder is set for low currents, and is smaller when the welder is set for high currents. This is exactly what is required for easy arc starting.

Mathematics and tests have shown that a resistor is preferable to a reactor for connection in the localized circuit of the auxiliary windings 5 and 6. A reactor will operate satisfactorily during part of the current range but at certain settings of the adjustable primary winding will not function properly.

As pointed out above, the switching operation whereby winding 28 of relay 24 is connected across output terminals 17 and 18 or 17 and 19, depending on which pair of these terminals are connected to the welding leads, may be made automatic. One manner of accomplishing this result has been illustrated in Fig. 2, in which a diagrammatic representation of the same parts of Fig. 1 have been identified by the same reference numerals. Fig. 2 differs from Fig. 1 solely in the construction of the output terminals which form complementary parts of separable connectors whose other parts form terminal members of the welding conductors.

The separable connectors 31 shown in Fig. 2

comprising mating plug and socket members which form terminals for the conductors which are to be connected when the members engage one another. In the arrangement illustrated, socket members **32** form the terminals for the welding conductors **33**, while plug members **34**, **35** provide main terminals **34** for the transformer winding leads **20**, **21** and **22**, and auxiliary terminals **35** for conductors **36** and **37**, which are connected to one terminal of the relay operating winding **28** whose other terminal is connected to the transformer lead **20**. These main and auxiliary terminals **34** and **35** are electrically insulated from one another and provide contacts which are connected to one another when socket members **32** make engagement therewith. Terminals **32** and **34** have mating conical surfaces whose axes respectively correspond with the longitudinal axes of the threaded plugs of terminals **35** and the threaded sockets of terminals **32**. The plug portion of terminals **35** extends beyond the end portion of terminals **34**, and are threaded for engagement with the threaded portions of the sockets of terminals **32**. Thus, when the plug and socket members of the separable connector are brought together and given a partial turn relative to one another, the projecting plug of terminal **35** enters the socket of terminal **32**, bringing the terminals **32**, **34** and **35** into firm engagement with one another. The wedging action occurring at the conical surfaces of these members will maintain the connection. As an aid in making the connection rapidly without resorting to an extended turning movement to secure the desired engagement of the threaded members of these terminals, the threaded portions of each may be provided with multiple threads so that desired engagement and disengagement may be accomplished by a partial turn of them relative to one another. To provide interchangeability, each of the output terminals of the transformer may be of the same construction as are each of the socket members which are connected to the welding conductors **33**. This of course means that the lowermost plug member whose main terminal **34** is connected to the transformer lead **20** has no connection for the auxiliary terminal **35** forming part of this plug member.

It will thus be seen that by using the separable connectors of Fig. 2, or some equivalent therefor, that the operating winding **28** of relay **24** is automatically switched in the proper manner to the welding conductors **33** when these conductors are connected with the transformer leads **20**, **21** or the transformer leads **20**, **22**, for either the high or low current ranges respectively. This makes it unnecessary for the operator to manipulate switches such as **29** and **30** of Fig. 1, since the required switching operation is automatically performed at the time of plugging the welding leads with the output terminals of the transformer.

As pointed out above, the auxiliary windings of the transformer may be connected in series circuit with either the primary or secondary windings of the transformer for accomplishing the reactance control feature of the transformer. In Fig. 3, I have illustrated an embodiment of my invention in which these auxiliary coils are connected with the primary of the welding transformer. As there shown diagrammatically, the welding transformer **38** has a primary winding **39** and a secondary winding **40**, which it is to be understood are adjustable relative to one another as are the primary windings **3** and **4** of the embodiment shown in Figs. 1 and 2. Transformer **38** of Fig. 3 is provided with auxiliary windings **41** and **42** which in their controlling effect correspond to the auxiliary windings **5** and **6** of Figs. 1 and 2. Supply terminals **43**, **44** and **45** are provided so that when the supply conductors are connected to terminals **43** and **44**, only the primary winding **39** of transformer **38** is connected in circuit and so that when the supply conductors are connected to terminals **43** and **45**, the primary winding **39** and the auxiliary windings **41** and **42** are connected in series circuit with one another to the supply. Like auxiliary windings **5** and **6** of Figs. 1 and 2, auxiliary windings **41** and **42** are connected differentially relative to one another. The secondary winding **40** is provided with output terminals **46** and **47** which provide connections for the welding conductors which supply the welding arc. A relay **48** is provided for obtaining the high current starting feature of my invention. This relay has an operating winding **49** which is connected across the supply terminals **46** and **47** so that this winding is connected to be responsive to the open and closed circuit voltage of the welding circuit. It has a pair of normally open contacts **50** which, when closed, complete a localized circuit for the auxiliary windings **41** and **42** through a current setting resistor **51**. Relay **48** is constructed and arranged to pick up on open circuit voltage of the welding or output terminals **46** and **47** and to drop out after a time delay when terminals **46** and **47** are shorted during striking of the welding arc and when the voltage of these terminals is substantially that of the welding arc. The time delay feature of relay **48** has been indicated in Fig. 3 by the dashpot **52** and the arrow associated therewith. In view of the description previously given with regard to Fig. 1, the operation of the arrangement in Fig. 3 is believed quite obvious.

Although the description with regard to the embodiments illustrated have been for variable reactance transformers of the movable coil type, it is quite obvious that my invention is equally applicable to variable reactance transformers of the movable shunt type heretofore referred to in the introductory portion of this disclosure. Other means of obtaining the automatic switching operations of Fig. 2 for connecting properly the operating winding of the relay will occur to those skilled in the art, and are consequently considered within the scope of my invention.

Thus, while I have shown and described particular embodiments of my invention, it will be obvious to those skilled in the art that the above changes as well as others may be made without departing from my invention in its broadest sense. I therefore aim in the appended claims to cover all such changes and modifications as may fall within the true spirit and scope of my invention.

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

1. Apparatus comprising an adjustable reactance transformer having primary and secondary main windings, a pair of auxiliary windings, one of which is positioned near one of said main windings and the other of which is positioned near the other of said main windings, and means for connecting said auxiliary windings in series with one another and one of said main windings with said auxiliary windings being connected differentially relative to one another, means for adjusting the leakage reactance of said main

windings of said transformer, pairs of supply and load circuit terminals for said windings of said transformer, one of said pairs of terminals being connected across one of said main windings of said transformer and the other of said pairs of terminals being selected from a group of three terminals of which the first and second terminals are connected across the other of said main windings of said transformer and the second and third terminals of which are connected across said differentially connected auxiliary windings of said transformer which are connected in series with one another and said other of said main windings of said transformer, a relay having a pair of normally open contacts and means including an operating winding for closing said contacts in response to the open circuit voltage across said load circuit terminals and for opening said contacts after a predetermined time delay in response to the drop in voltage across said load circuit terminals upon the flow of load current, means for connecting said coil of said relay across said pair of load circuit terminals, and means including said contacts of said relay for completing an electrically conductive circuit between the terminals of said differentially connected auxiliary windings of said transformer which are connected to said second and third terminals of said group of three terminals.

2. Apparatus comprising an adjustable reactance transformer having primary and secondary main windings, a pair of auxiliary windings, one of which is positioned near one of said main windings and the other of which is positioned near the other of said main windings, and means for connecting said auxiliary windings in series with one another and one of said main windings, said auxiliary windings having substantially the same electrical characteristics and being connected differentially relative to one another so as to have substantially no net voltage induced in them under no load conditions of said transformer, means for adjusting the leakage reactance of said main windings of said transformer, pairs of supply and load circuit terminals for said windings of said transformer, one of said pairs of terminals being connected across one of said main windings of said transformer and the other of said pairs of terminals being selected from a group of three terminals of which the first and second terminals are connected across the other of said main windings of said transformer and the second and third terminals of which are connected across said differentially connected auxiliary windings of said transformer which are connected in series with one another and said other of said main windings of said transformers, a relay having a pair of normally open contacts and means including an operating winding for closing said contacts in response to the open circuit voltage across said load circuit terminals and for opening said contacts after a predetermined time delay in response to the drop in voltage across said load circuit terminals upon the flow of load current, means for connecting said coil of said relay across said pair of load circuit terminals, and means including said contacts of said relay for completing an electrically conductive circuit between the terminals of said differentially connected auxiliary windings of said transformer which are connected to said second and third terminals of said group of three terminals.

3. Apparatus comprising an adjustable reactance transformer having primary and secondary main windings, a pair of auxiliary windings, one of which is positioned near one of said main windings and the other of which is positioned near the other of said main windings, and means for connecting said auxiliary windings in series with one another and one of said main windings, said auxiliary windings having substantially the same electrical characteristics and being connected differentially relative to one another so as to have substantially no net voltage induced in them under no load conditions of said transformer, means for adjusting the leakage reactance of said main windings of said transformer, pairs of supply and load circuit terminals for said windings of said transformer, one of said pairs of terminals being connected across one of said main windings of said transformer and the other of said pairs of terminals being selected from a group of three terminals of which the first and second terminals are connected across the other of said main windings of said transformer and the second and third terminals of which are connected across said differentially connected auxiliary windings of said transformer which are connected in series with one another and said other of said main windings of said transformer, a relay having a pair of normally open contacts and means including an operating winding for closing said contacts in response to the open circuit voltage across said load circuit terminals and for opening said contacts after a predetermined time delay in response to the drop in voltage across said load circuit terminals upon the flow of load current, means for connecting said coil of said relay across said pair of load circuit terminals, a resistor, and means including said contacts of said relay for completing an electrically conductive circuit through said resistor to the terminals of said differentially connected auxiliary windings of said transformer which are connected to said second and third terminals of said group of three terminals.

4. Apparatus comprising an adjustable reactance transformer having primary and secondary main windings, a pair of auxiliary windings, one of which is positioned near one of said main windings and the other of which is positioned near the other of said main windings, and means for connecting said auxiliary windings in series with one another and one of said main windings, said auxiliary windings having substantially the same electrical characteristics and being connected differentially relative to one another so as to have substantially no net voltage induced in them under no load conditions of said transformer, means for adjustably positioning said main windings of said transformer relative to one another, pairs of supply and load circuit terminals for said windings of said transformer, one of said pairs of terminals being connected across one of said main windings of said transformer and the other of said pairs of terminals being selected from a group of three terminals of which the first and second terminals are connected across the other of said main windings of said transformer and the second and third terminals of which are connected across said differentially connected auxiliary windings of said transformer which are connected in series with one another and said other of said main windings of said transformer, a relay having a pair of normally open contacts and means including an operating winding for closing said contacts in response to the open circuit voltage across said load circuit terminals and for opening said con-

tacts after a predetermined time delay in response to the drop in voltage across said load circuit terminals upon the flow of load current, means for connecting said coil of said relay across said pair of load circuit terminals, and means including said contacts of said relay for completing an electrically conductive circuit between the terminals of said differentially connected auxiliary windings of said transformer which are connected to said second and third terminals of said group of three terminals.

5. Apparatus comprising an adjustable reactance transformer having primary and secondary main windings, a pair of auxiliary windings, one of which is positioned near one of said main windings and the other of which is positioned near the other of said main windings, and means for connecting said auxiliary windings in series with one another and one of said main windings, said auxiliary windings having substantially the same electrical characteristics and being connected differentially relative to one another so as to have substantially no net voltage induced in them under no load conditions of said transformer, means for adjustably positioning said main windings of said transformer relative to one another, pairs of supply and load circuit terminals for said windings of said transformer, one of said pairs of terminals being connected across one of said main windings of said transformer and the other of said pairs of terminals being selected from a group of three terminals, of which the first and second terminals are connected across the other of said main windings and said transformer and the second and third terminals of which are connected across said differentially connected auxiliary windings of said transformer which are connected in series with one another and said other of said main windings of said transformer, a relay having a pair of normally open contacts and means including an operating winding for closing said contact in response to the open circuit voltage across said load circuit terminals and for opening said contacts after a predetermined time delay in response to the drop in voltage across said load circuit terminals upon the flow of load current, means for connecting said coil of said relay across said pair of load circuit terminals, a resistor, and means for connecting said resistor in series circuit with said contacts of said relay and said series connected auxiliary windings of said transformer which are connected across said second and third terminals of said group of three terminals.

6. Apparatus comprising an adjustable reactance transformer having primary and secondary main windings, a pair of auxiliary windings having substantially the same electrical characteristics, one of which is closely coupled magnetically with one of said main windings and the other of which is closely coupled magnetically with the other of said main windings, and means for connecting said auxiliary windings in series with one another and said primary winding, said auxiliary winding being connected differentially relative to one another so as to have substantially no net voltage induced in their part of said series circuit under no load conditions of said transformer, first, second and third load circuit terminals, said first and second terminals being connected across said secondary main winding of said transformer and said second and third terminals being connected across said series connected auxiliary windings, a pair of supply circuit terminals connected across said primary main winding of said transformer, a relay having a pair of normally open contacts and means including an operating winding for closing said contacts in response to the open circuit voltage across a pair of said load circuit terminals which are connected in circuit with the secondary main winding of said transformer and for opening said contacts after a predetermined time delay in response to the drop in voltage across said pair of load circuit terminals upon the flow of load current, means for completing a conductive circuit through said contacts of said relay across said second and third load circuit terminals, and means for selectively connecting said operating winding of said relay across said first and second load circuit terminals and said first and third load circuit terminals according to which of said pairs of load circuit terminals are connected to the load circuit.

7. Apparatus comprising an adjustable reactance transformer having a magnetic core member, primary and secondary main windings on said core member, a pair of auxiliary windings having substantially the same electrical characteristics and each of which is also on said core member, one of said auxiliary windings being closely coupled magnetically with one of said main windings and the other thereof being closely coupled magnetically with the other of said main windings, and means for connecting said auxiliary windings in series with one another and said secondary main winding, said auxiliary windings being connected differentially relative to one another so as to have substantially no net voltage induced in their part of said series circuit under no load conditions of said transformer, first, second and third load circuit terminals, said first and second terminals being connected across said secondary main winding of said transformer and said second and third terminals being connected across said series connected auxiliary windings of said transformer, a pair of supply circuit terminals connected across said primary main winding of said transformer, a relay having a pair of normally open contacts and means including an operating winding for closing said contacts in response to the open circuit voltage across a pair of said load circuit terminals which are connected in circuit with the secondary main winding of said transformer and for opening said contacts after a predetermined time delay in response to the drop in voltage across said pair of load circuit terminals upon the flow of load current, a resistor, means for connecting said resistor and said contacts of said relay in series with one another across said second and third load circuit terminals, and means for selectively connecting said operating winding of said relay across said first and second load circuit terminals and said first and third load circuit terminals according to which of said pairs of load circuit terminals is connected to the load circuit.

8. Apparatus comprising an adjustable reactance transformer having a magnetic core member, primary and secondary main windings on said core member, a pair of auxiliary windings having substantially the same electrical characteristics, one of which is on said core member and closely coupled magnetically with one of said main windings and the other of which is also on said core member and closely coupled magnetically with the other of said main windings, and means for connecting said auxiliary windings in series with one another and said secondary winding, said auxiliary windings being connected

differentially relative to one another so as to have substantially no net voltage induced in their part of said series circuit under no load conditions of said transformer, means for adjustably positioning one of said main windings and its associated auxiliary winding relative to the other of said main windings and its associated auxiliary winding, three load circuit terminal members providing detachable connections with a pair of cooperating terminal members of a pair of load circuit conductors, said second and third terminal members having main and auxiliary contacts electrically insulated from one another and electrically connected with one another when said terminal members are coupled with a cooperating terminal member of said pair of load conductors, means for connecting said first load circuit terminal member and said main contact of said second load circuit terminal member across said secondary main winding of said transformer and said main contacts of said second and third load circuit terminal members across said series connected auxiliary windings, a pair of supply circuit terminals connected across said primary main winding of said transformer, a relay having normally open contacts and means including an operating winding for closing said contacts in response to open circuit load voltage of said transformer and for opening said contacts after a predetermined time delay in response to closed circuit load voltage of said transformer, a resistor, means for connecting said resistor and said contacts of said relay in series with one another across said main contacts of said second and third load circuit terminal members, and means for connecting one terminal of said operating winding of said relay to said first load circuit terminal member of said transformer and the other terminal of said operating winding to said auxiliary contacts of said second and third load circuit terminal members.

9. Apparatus comprising an adjustable reactance transformer having primary and secondary main windings, a pair of auxiliary windings, one of which is positioned near one of said main windings and the other of which is positioned near the other of said main windings, means for connecting said auxiliary windings in series with one another and said primary main winding with said auxiliary windings being connected differentially relative to one another, means for adjusting the leakage reactance of said main windings of said transformer, first, second and third terminals for applying a supply voltage to said transformer, said first and second terminals being connected across said primary main winding of said transformer and said second and third terminals being connected across said series connected auxiliary windings, a pair of load circuit terminals connected across said secondary main winding of said transformer, a relay having a pair of normally open contacts and means including an operating winding for closing said contacts in response to open circuit voltage of said secondary main winding of said transformer and for opening said contacts after a predetermined time delay in response to the drop in voltage across said secondary main winding upon the flow of load current therein, means including said contacts of said relay for completing an electrically conductive circuit between terminals of said differentially connected auxiliary windings of said transformer which are connected to said second and third terminals, and means for connecting said operating winding of said relay across said secondary main winding of said transformer so as to be responsive to the change in voltage thereof when a load is connected across said load circuit terminals.

10. Apparatus comprising an adjustable reactance transformer having primary and secondary main windings, a pair of auxiliary windings, one of which is positioned near one of said main windings and the other of which is positioned near the other of said main windings, and means for connecting said auxiliary windings in series with one another and said primary main winding, said auxiliary windings having substantially the same electrical characteristics and being connected differentially relative to one another so as to have substantially no net voltage induced in them under no load conditions of said transformer, means for adjustably positioning said main windings of said transformer relatively to one another, first, second and third terminals for applying a supply voltage to said transformer, said first and second terminals being connected across said primary main winding of said transformer and said second and third terminals being connected across said series connected auxiliary winding, a pair of load circuit terminals connected across said secondary main winding of said transformer, a relay having a pair of normally open contacts and means including an operating winding for closing said contacts in response to open circuit voltage of said secondary main winding of said transformer and for opening said contacts after a predetermined time delay in response to the drop in voltage across said secondary main winding upon the flow of load current therein, a resistor, means for connecting said resistor and the contacts of said relay in series with one another across said second and third terminals, and means for connecting said operating winding of said relay across said secondary main winding of said transformer so as to be responsive to the change in voltage thereof when a load is connected across said load circuit terminals.

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