April 17, 1934. C. E. BEACH 1,954,794

SIGNALING SYSTEM AND ELECTROMAGNETIC MECHANISM THEREFOR

Filed July 16, 1928 2 Sheets-Sheet 1

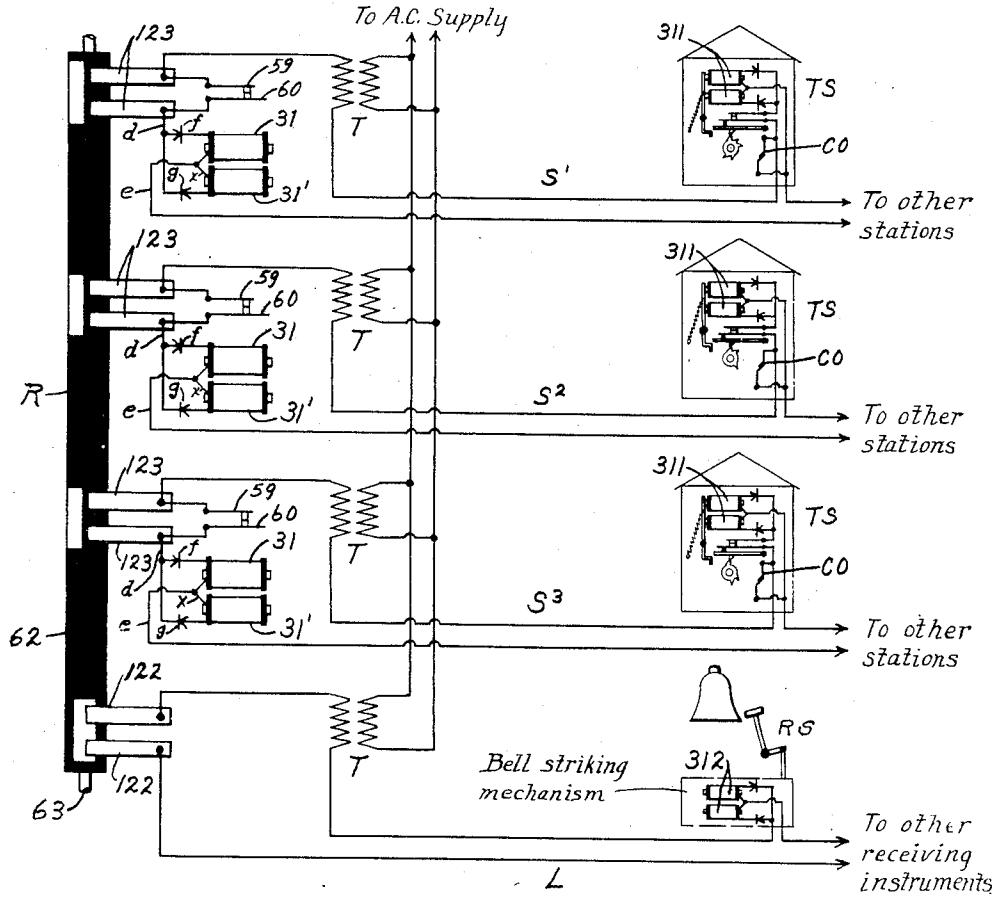


Fig.1

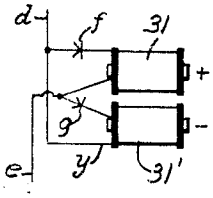


Fig.2

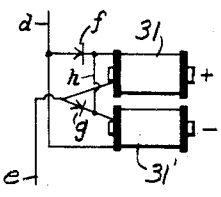


Fig.3

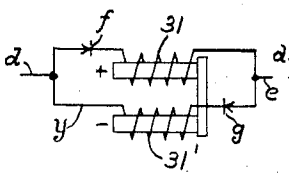


Fig.4

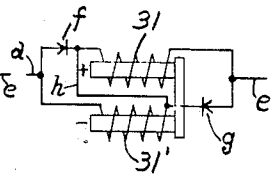


Fig.5

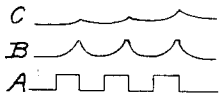


Fig.6

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SIGNALING SYSTEM AND ELECTROMAGNETIC MECHANISM THEREFOR

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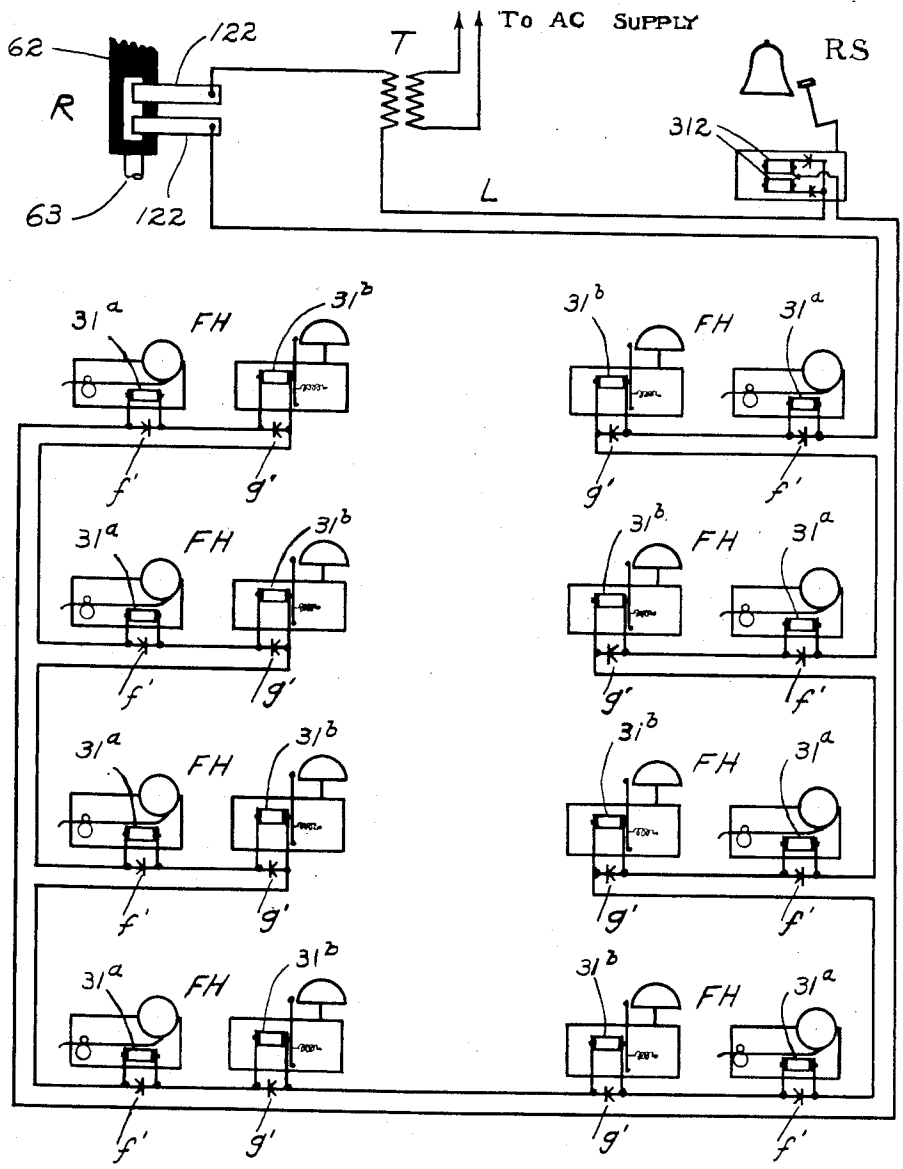


Fig. 7

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Patented Apr. 17, 1934 1,954,794

UNITED STATES PATENT OFFICE

1,954,794

SIGNALING SYSTEM AND ELECTROMAGNETIC MECHANISM THEREFOR

Clarence E. Beach, Boston, Mass., assignor to The Gamewell Company, Newton Upper Falls, Mass., a corporation of Massachusetts

Application July 16, 1928, Serial No. 293,068

13 Claims. (Cl. 175—320)

This invention relates to signaling systems and electromagnetic mechanism therefor; and, more particularly, to means and methods for conveniently and inexpensively rendering the electromagnets used in the series circuits of such systems and elsewhere, operable by alternating current in an efficient, reliable and quiet manner.

Electromagnets intended for energization by alternating current have heretofore been constructed in accordance with various methods, substantially all of which widely differ, in many details, from the methods employed in the construction of electromagnets intended for energization by direct current under similar conditions and to effect corresponding results. Examples of such differences are found in the use of laminated cores with a view of reducing the losses incident to direct application of alternating current to the energization of electromagnets; the use of so-called "shading coils" or their equivalents, with a view of reducing the chatter incident to such energization of such magnets; and the use of a transformer with two independent secondary windings connected through rectifying units with the respective ones of two windings of an electromagnet, with a view of hastening the release of the armature upon interruption of the circuit which furnishes the exciting current for the primary of the transformer. However, all such previous expedients with which I am acquainted have impaired, to an objectionable extent, the net operating efficiency of the electromagnets, as compared with that of magnets excited by a direct current circuit; and the use of all of such previous expedients in series circuits involving aggregate impedance far in excess of that of any one magnet and any rectifying mechanism associated therewith, has incurred objectionable characteristics well understood by those skilled in this art, certain of which will be hereinafter referred to in greater detail.

There has been an increasing tendency toward recognition of the desirability of utilizing alternating current for multi-circuit telegraph signaling systems such, for example, as municipal and institutional fire alarm systems. It is generally recognized that each such system should be subdivided into a plurality of circuits which are independent in such sense that, if impairments of insulation or so-called "crosses" affect two or more circuits, such faults will not be permitted to cooperate in effecting impairment of the functions of the system as a whole, as would be the case if a foreign potential entering the system on one circuit could escape to ground through another circuit or if defects simultaneously effective on two or more circuits could cause the disablement (by shunting out) of all or part of the signal initiating stations of the affected circuits; which disablement is likely to result from such conditions where a plurality of circuits are supplied from a single direct current source. With a view of safeguarding the situation indicated, it is customary to provide independent groups of battery cells for the respective circuits, storage batteries being ordinarily used for this purpose, and two groups of cells are customarily provided for each such circuit so that one group of cells may be working while the other group is being charged or being held in reserve after charge, as it has been found to be undesirable to connect the source of charging current to any battery while a working line is being supplied by it. Thus, it has been found that in a municipal fire alarm system of a city requiring say 100 circuits, supplied by an average of 30 working and 30 reserve battery cells per circuit, an aggregate on the order of 6,000 battery cells is needed, the cost of care and maintenance of which involves a very substantial sum and the conditions of operation of which are highly inefficient as compared with the storage and delivery of a like energy in a single group of cells of such size as to provide an ampere hour capacity sufficient to supply all of the circuits with alternating current through a motor generator for a time as great as that which any one circuit could be operated by both of the groups of the smaller cells which are associated therewith.

For economic reasons, it has been found undesirable and impracticable to utilize greatly increased electromotive forces or current intensities in the conductors of many such systems, and it has been generally recognized that, for like reasons, the series type circuit must be used. In determining how great a line current strength should be employed in a given series circuit, it is necessary to take into consideration the comparatively small size of line conductors which are usually available for the required service, with the resultant high line resistance and small current carrying capacity. Correspondingly, in determining how great an electromotive force can be safely applied to a given signaling circuit, it is necessary to take into consideration the continuous dependability of the effectiveness of the break gap of the contacts of available signal transmitting mechanisms, as well as safety to those of the public using such signaling systems and that of those employed in constructing and maintaining such systems.

In connection with the question of continuous dependability of effectiveness of insulation, it should be remembered that emergency signaling service of this character requires greater safeguarding in many respects than is necessary in signaling systems such, for example, as commercial telegraph and telephone systems, in which both the sender and receiver of the message is familiar with the normal operation of the system and may immediately ask for confirmatory repetition of all important messages, and in which messages are sent from all stations with sufficient frequency to insure timely disclosure of gradually developing faults. In contrast with such commercial systems, an emergency signaling system, such as a municipal fire alarm telegraph system, includes sending stations, individual ones of which may not be operated to call the fire department for many months—perhaps one or more years,—but, when needed to summon the fire department, failure of any such station is likely to result in loss of property of great value and to expose human beings to a likelihood of being maimed or killed. Furthermore, there are many signaling systems, of various kinds and types, operation of which by direct current is being continued only because it has been impracticable to so alter the instruments included therein as to adapt them to successful operation in connection with an alternating current source applied in accordance with prior art practice, but which could otherwise be so operated more dependably, efficiently, inexpensively and satisfactorily than they now are.

In emergency signaling systems, using circuits in which the sending stations are serially connected, the importance of the problem of avoiding a high line voltage is emphasized by the fact that although the potential applied between the conductor leading to a given transmitting station and the conductor leading from that station to the next, is normally of a negligible magnitude, because it merely represents the fall of potential at normal line current strength across the resistance or impedance of the current path through that station,—the voltage between such conductors rises to a value as great as or exceeding that of the current source supplying the circuit (depending upon the presence and extent of inductance of magnet windings in the circuit) at times when the circuit is interrupted at a given sending station for the purpose of formulating a signal therefrom. It is therefore evident that insulation between the conductors leading to and from any sending station, although sufficient to avoid breakdown for an indefinitely long time during which the mechanism of that station does not act to break the line circuit, may nevertheless be insufficient to prevent its breakdown when subjected to the added strain of station activity; and it is obvious that such breakdown will impair or destroy the effectiveness of the sending station mechanism in so breaking the line circuit as to cause intended response of signaling instruments at a time when effectiveness is of utmost importance.

It is an important object of this invention to provide electromagnetic structure and associated means adapted for operation in an alternating current circuit more efficiently, reliably and quietly than heretofore.

It is a further important object to provide structure and means having the aforesaid characteristics, which may be made and used in an inexpensive and convenient manner.

It is a further object to provide, in electromagnetic structure, the characteristic of minimizing variations in the impedance offered thereby incidental to movement of an associated armature toward or away from the magnetic poles of such structure.

It is a further object to provide means and methods which can be conveniently and inexpensively applied, whereby electromagnets of the type ordinarily utilized in direct current signaling circuits may be suited for use in an alternating current circuit.

With the aforesaid objects in view, this invention consists of the novel combinations, arrangements of parts and methods hereinafter described in their preferred embodiments, pointed out in the claims, and illustrated in the annexed drawings, in which

Figure 1 is a diagrammatic representation of a signaling system embodying one aspect of this invention;

Fig. 2 represents electrical connections of windings of an electromagnet functionally corresponding to those of the magnets of Fig. 1;

Fig. 3 shows magnet winding connections, corresponding to those of Fig. 2, together with those of another aspect of this invention;

Figs. 4 and 5 are simplified diagrammatic representations of the arrangements of Figs. 2 and 3, respectively, indicating the direction of magnet windings;

Fig. 6 is a diagram representing the characteristics of the magnetic excitation resultant from recurrent circuit closures through windings of an electromagnet arranged in accordance with the preceding figures; and

Fig. 7 is a diagrammatic representation of a circuit of alarm responsive instruments, such as circuit L of Fig. 1.

A signaling system representative of commonly used types of municipal fire alarm systems is shown in Fig. 1. This system comprises three so-called "street" or transmitting station circuits S^1, S^2 and S^3, each suited for inclusion therein of a plurality of transmitting stations, such as the stations TS, one of which is symbolically represented in connection with each of said circuits; a so-called "local" or receiving instrument circuit L for controlling a plurality of receiving instruments such as are ordinarily provided at the various fire houses or other alarm receiving stations, one such receiving station being indicated at RS by a symbolic representation of a tower bell striker; and an automatic repeater R, through the action of which signals originating at any transmitting station in any one of the circuits S^1, S^2 or S^3 will be automatically retransmitted into the others of said circuits and into the local circuit L, in a manner well understood by those skilled in this art.

At each of the transmitting stations TS is shown the winding spools 311 of a U-magnet, control of the signal transmitting contacts by which magnet is symbolically indicated in a manner representative of such relationship as is ordinarily established by the so-called "non-interference magnet" in well known commercial types of what are commonly termed "perfect non-interference and succession fire alarm boxes". A cut-out CO is indicated at each station TS to symbolically represent the automatic switch provided in the types of commercial fire alarm transmitting stations in general use, for the purpose of shunting out the windings of the non-interference magnet when the mechanism is inactive, the shunt of which cut-out is automatically broken

upon initiation of the operation of the transmitting mechanism and thereafter remains broken until such mechanism comes to rest. It should be understood that any desired number of additional transmitting stations may be correspondingly included in the circuits S^1, S^2 and S^3 to meet the service conditions.

In the interests of simplicity, the representation of the automatic repeater R is confined to those parts which may be included in the respective circuits; but the structural characteristics of the parts shown are such as to suit them for embodiment in a repeater of the kind indicated in U. S. Patent No. 1,613,018, dated January 4, 1927, to Edward J. Butler, to which reference is had for other detailed structural characteristics of such repeaters; the parts here shown being identified by the reference numbers used for the identification of the corresponding parts of the repeater of said patent.

The system thus far described is representative of a large number of fire alarm systems now in use by municipalities and various private and public institutions. All of the existing systems of the type represented are, however, as hereinbefore pointed out, utilizing direct current for their operation and, in most instances, the direct current is supplied by storage batteries of which two sets are provided for each circuit, to the end that the batteries for all of the various circuits may be simultaneously charged without connecting the source of charging current to the signaling lines and without establishing interconnections between such lines. Such avoidance of interconnections assures that any one fault (such as an insulation break down to the ground or to a foreign circuit) will not impair the operability of more than the circuit upon which it occurs, be that circuit a street or transmitting station circuit, a local circuit, or the circuit from which charging current for the storage batteries is derived.

The provision of separate current sources is also of great importance in that it enables the various street or transmitting station circuits and local circuit, or circuits to be temporarily connected in series with each other in the event that it is necessary or desirable to temporarily suspend the use of the automatic repeater (as for routine cleaning, lubrication, or emergency repairs). The purpose of such a series connection is to assure that, in the absence of grounds or crosses between circuits, the initiation of a signal at any transmitting station will cause such signal to be manifested by the receiving instruments of the local circuit or circuits and will react upon other transmitting stations in the same or other circuits substantially as if the repeater was in circuit. The purpose of reaction or so-called "reflex action" between transmitting station circuits is to assure that, should the mechanism of any transmitting stations be set in motion during the formulation of the signal of another station, or simultaneously therewith, there will be no interference or mutilation of signals but the signals of the various transmitting stations will be manifested by the receiving instruments at the receiving stations, one after another, through the functioning of the so-called "perfect non-interference and succession mechanism" of the various transmitting stations, in a manner well understood by those skilled in this art.

Commercial forms of transmitting stations, of the perfect non-interference and succession type hereinbefore referred to, have not heretofore been found to be suited for operation upon circuits energized by alternating instead of direct current; and the same is true of automatic repeaters of commercial types such, for example, as that hereinbefore referred to. Pursuant, however, to this invention, the circuits indicated may each be independently energized from one source of alternating current supply, through inductive coupling, as by the transformers T, T, T, T, so as to avoid establishing any connections between said circuits such as might permit a fault on one circuit to impair the operability of another. To this end, the connections to the windings 31, 31' of the electromagnets of the repeater R, and of the corresponding windings of the electromagnets 311 of each of the transmitting stations TS and of the electromagnet 312 of the receiving instrument RS are arranged so as to provide two current paths in parallel. Rectifying means are included in respective ones of said paths, said means being so connected that the application of an alternating electromotive force between the respective connected ends of said paths will result in the flow of effective energizing current alternately in one and the other of the magnet windings. Such rectifying means may be of any desired type arranged to act to facilitate current flow in one direction and to oppose—almost to the point of complete suppression—flow of current in the opposite direction. For convenience, the rectifying means of each of the respective paths will be termed a "rectifying unit"; and wherever this term is hereinafter used, it is intended to define a structure which will facilitate the flow therethrough of current in one direction and will obstruct the flow of current therethrough in the opposite direction, such, for example, as a unit comprising one or more copper oxide discs of such characteristics and so associated as to provide so-called asymmetric units.

The relative arrangement of windings and rectifying units, as indicated in Fig. 1, is one which is particularly convenient both for illustration and for application to the electromagnet windings of existing instruments heretofore operated from direct current sources. As shown in connection with the portion of the repeater R which is responsive to circuits S^1, one end of the winding 31 is connected to one end of the winding 31', (as for direct current operation) and the remaining ends of said windings are serially connected through the rectifying units *f* and *g*, which units are so relatively connected as to cooperate in facilitating a circulating current through said electromagnet windings. One of the line terminals is applied to said first named connection and the other line terminal is applied to said last named connection intermediate said rectifying units. As the connections shown for the windings 31 and 31' associated with circuits S^2 and S^3, as well as those for the electromagnets 311 and 312 are identical with those of the repeater magnet windings 31 and 31' for circuit S^1, a repetition of the detailed description of same at this point is unnecessary.

It should be understood that one end of the magnet core portion enclosed by one of the windings of any given magnet is connected to the adjacent end of the core portion enclosed by the other winding of such magnet, by the usual yoke or strap so as to collectively form a conventional U-shaped magnet, and that suitable armatures cooperate with the free poles of respective ones of such magnets; but, in the interests of clear-

ness and simplicity, such strap or yoke portions of the magnet cores are omitted in Figs. 1, 2, 3 and 7, and the armatures are omitted other than in the representations of the transmitting stations of Fig. 1.

The operation of the signaling system of Fig. 1 is as follows:

Assuming all parts to be in their normal positions and that a source of alternating current supply is applied to the terminals provided therefor, as indicated on the drawings,—alternating current flow will be induced in the various circuits S^1, S^2, S^3 and L, through the transformers T, T, T, T, in a well known manner, thus supplying all of said circuits from a single source while avoiding interconnecting current paths between such circuits.

Inasmuch as the cut-outs CO of the transmitting stations TS, TS, TS of circuits S^1, S^2 and S^3 are in closed condition, substantially all of the line current will be shunted around the magnets 311 of said stations. Inasmuch as the effect of the current flow upon each of the other magnets shown will be alike, it will be described in detail for but one of said magnets. Considering, therefore, the effect of the current flow in circuit S^1 through the windings 31 and 31′ of the electromagnet of the repeater R which is associated with said circuit:

During a given half cycle, substantially all of such current will flow through one or the other of the associated rectifying units, say, for example, the unit *f* and its associated winding 31; and the remainder of such current, if any, will pass through the other of the associated rectifying units, say the unit *g* and its associated winding 31′. Such current as may, at any such time, flow through said winding 31′, will tend to neutralize the effect of the current then flowing through the associated winding 31; but, inasmuch as the action of said rectifying unit *g* will serve during such half cycle to almost, if not completely, suppress current flow through said winding 31′, the effect of such adverse current flow will be inappreciable, and said rectifying unit *f* will, throughout such half cycle, facilitate the flow of practically all (if not all) of said line current through the winding 31.

As the line current flow decays during the latter portion of such half cycle, the inductive tendency toward persistence of current flow through said winding 31 will result in the development of a flow of circulating current, say from one terminal of said winding 31, through the direct connection therewith of one end of said winding 31′, thence through said winding 31′ in such direction as to induce, in that limb of the magnet core which is enclosed by said winding 31′, a magnetomotive force cooperative in direction to that induced in the other limb of said core by the flow of line current through the coil 31 during the early portion of such half cycle, and from the other end of said winding 31′, through rectifying units *g* and *f* to the remaining end of said winding 31.

During the first portion of the next succeeding half cycle, the rectifying unit *g* will correspondingly facilitate current flow through the winding 31′ in such direction as to supplement the effect of current flow during the first half cycle, and the fall of potential due to the impedance presented to the line current flow by said winding 31′ and its associated rectifying unit *g*, will result in the complete termination of appreciable current flow in the direction of the first described half cycle through the associated winding 31, while the action of the rectifying unit *f* associated with said winding 31 will minimize, if not completely prevent, appreciable reversal of current flow through said winding.

From the foregoing it will be observed that provision is made for the maintenance of a circulating current through the windings and rectifying units, sufficient to prevent armature retraction during the subsidence and suspension of line current flow in one direction and until line current flow in the opposite direction has developed to an appreciable extent. It will also be noted that the arrangement is such that the circulating current induced by the winding last energized appears to be rapidly choked by the inductance of the other winding, so as to assure rapid demagnetization responsive to interruptions of the signaling circuit.

In any event, it has been found that electromagnets of signaling instruments, when connected in an alternating current circuit as indicated by Fig. 1, will afford dependable operability in response to series of impulses having duration and interimpulse open circuit intervals as short as any to which the instruments were designed to operate when connected in a direct current circuit, and with a substantially corresponding factor of safety.

In the use of alternating currents of frequencies of from 25 to 60 cycles, as ordinarily found in commercial distribution systems, it would appear that the density of the magnetic lines of force does not have time to become uniform throughout the solid core of a U-shaped electromagnet, the windings of which are connected as shown in Fig. 1. For example, at the time of maximum current flow through winding 31, the portion of said core enclosed by said winding has induced therein lines of force of a density exceeding that which is communicated therefrom to the armature at the one end or through the strap or center of the U-shaped core to the other limb so that, at the time the current flow through the winding 31 is decreasing, during the second portion of the half cycle when current flow is in the direction facilitated by rectifying unit *f*, the magnetomotive force in the portion of the core within the winding 31′ is still rising. While such a condition prevails, the electromotive force induced in the winding 31′ will oppose the flow of circulating current then induced in winding 31, due to the decay of the half wave current flow, and the resultant decrease in magnetization of the portion of the core enclosed by the winding 31. Obviously, the action just described takes place in a corresponding manner just after each maximum current flow through the winding 31′ so that, although the arrangement of rectifiers and connections here shown brings about an operating condition which minimizes vibration due to passing the zero point during reversals in direction of line current flow, and thereby renders such vibration inappreciable, if at all present,—such arrangement also assures sufficiently prompt demagnetization to provide for correct response to signaling impulses at sufficiently rapid timing to meet the requirements of most classes of signaling.

In the event of the operation of the mechanism of one of the transmitting stations TS, TS, TS,—upon breaking of the shunt at CO, the magnet 311 of such station will be energized in a manner corresponding to that just described for the magnet of the repeater R associated with circuit S^1.

The operation of the system, incident to the formulation of a signal at any one of the stations TS will (aside from difference in manner of current flow through electromagnet windings, as hereinbefore described) be substantially the same as that incident to the formulation of a signal in a municipal fire alarm system of a commonly used type, such as that shown in Fig. 1, and as such operation is well understood by those skilled in this art, a recital in this specification of the details of such operation seems unnecessary.

The arrangement of Fig. 2 is identical in functional effect with that indicated in Fig. 1, but its application to existing magnets cannot ordinarily be accomplished with as great facility as that indicated by Fig. 1. This is because the windings of U-shaped electromagnets are customarily connected through the free ends of the inner layers of the respective windings, and the free ends of the outer layers are used for the respective line connections. Thus, in order to include a rectifying unit in the connection between the inner layers of the respective windings, (as indicated in Fig. 2) it would be necessary to open the previously existing connection and to splice out both of the disconnected ends, while the corresponding portion of the arrangement indicated by Fig. 1 may be obtained by merely splicing one conductor to the previously connected free ends of the inner layers. Furthermore, there are certain types of magnets having but one spool for the winding, so that it is likely to be inconvenient to obtain separate access to ends previously connected between desired divisions of the winding, although it may be that a connection can be readily applied to a portion of such a single winding substantially midway between the ends thereof, in which case the arrangement indicated by Fig. 1 can be applied with much greater facility.

Differently stated, it will be noted that, in the arrangement of Fig. 1, the rectifying unit *g* is situated in a position corresponding to that of the lead *y* of the winding 31′ of Fig. 2; while in Fig. 2 the rectifying unit *g* is situated in a position corresponding to that of the lead *x* of the winding 31′ of Fig. 1.

In order to more clearly disclose the relative directions of the windings when connected as in Figs. 1 and 2, same are diagrammatically indicated in Fig. 4, in which it will be noted that two parallel paths are provided from the line wire *d*, one of which paths includes the rectifying unit *f* which is so connected as to facilitate current flow from wire *d*, through winding 31 in counter-clockwise direction (looking at the pole of the magnet to which this winding is applied), and thence to wire *e*; while the other path is through conductor *y*, through winding 31′ in a corresponding counter-clockwise direction, and through rectifying unit *g* to line wire *e*; said rectifying unit *g* being so arranged as to facilitate current flow from wire *e* to wire *d*.

Because of the foregoing arrangement, it will be evident that, at an instant when the electromotive force between wire *d* and *e* is building up in the direction to cause current flow from the former to the latter, substantially all current flow will be through rectifying unit *f* and the winding 31, thus tending to induce a magnetomotive force in such direction as to develop a plus or north polarity at the free pole of the limb of the magnet core to which the winding 31 is applied and to develop a minus or south polarity at the free pole of the limb of the magnet core to which the winding 31′ is applied. As such potential between wires *d* and *e* decreases, during the latter part of the half wave, a circulating current may persist from the winding 31, through the rectifying unit *g*, the winding 31′, the conductor *y* and the rectifying unit *f*, such as will assist in retaining the armature in attracted position while the electromotive force between conductors *d* and *e* passes zero.

Correspondingly, when electromotive force is building up in the direction to cause current flow from wire *e* toward wire *d*, substantially all of the resultant current flow will be through rectifying unit *g* and winding 31′, and hence in a direction tending a develop a minus or south pole at the free end of the limb of the core to which said winding is applied; such current flow being in a direction to cooperate with that induced by the decay of the current flow through winding 31 and the magnetomotive force induced thereby being in the same direction as that induced by the current flow through the winding 31 during the preceding half cycle. Furthermore, the inductance of said winding 31 will cooperate with the rectifying unit *f* in opposing current flow therethrough in such direction as would tend to impair the building up of magnetism in the magnet core responsive to current flow through the winding 31′.

It will be noted that, with arrangements such as those here shown, it is unnecessary to provide rectifying units suited for withstanding the total electromotive force of the line current source, but it will suffice if such units are suited for withstanding the maximum fall of potential which is developed across the windings with which they are to cooperate. In any event, however, each unit should be such as to dependably withstand the fall of potential developed at full line current strength across the other associated rectifying unit and the winding in the current path parallel therewith. If provision should be made for comparatively high speed operation, the characteristics of each of the parallel current paths should be correspondingly altered.

For example, using a commercial form of copper oxide disc in each of the rectifying units, and with a given electromagnet and an associated armature with fixed operating load, it has been found that movement of the armature from retracted to attracted position can be as dependably effected by the use of two copper oxide discs per rectifier unit as by the use of any greater number, and the energy absorption in a constant-current series circuit, when using two discs per unit is on the order of 0.5 volt-amperes, as compared with 1.15 volt-amperes when employing 15 discs per unit. If, however, it is required that the armature of the electromagnet shall be dependably responsive to circuit closures no longer than 0.048 seconds, it will become necessary to so increase the line current that the energy absorption of the magnet and its associated units will be on the order of not less than 1.25 volt-amperes, for any number of discs used, from two to ten; and will only increase to a value on the order of 1.6 volt-amperes if 15 discs per unit are employed. With same magnet and armature, with breaks of 0.048 second and closures of like duration, the permissible increase in line current strengths at which dependable drop-away would occur, above that causing absorption of 1.25 volt-amperes, has been found to be such as to result in energy absorption by the associated windings and units, as follows: for five discs per unit, 2.5 volt-amperes; for six discs per unit, 3.625 volt-

amperes; for seven discs per unit, 4.7 volt-amperes; for eight discs per unit, more than 5.25 volt-amperes. Furthermore, if it is required that the armature of the electromagnet shall respond to both breaks as well as closures which are as short as 0.033 seconds, dependable service will require the use of eight discs per circuit and, if the line current strength is subject to considerable variation, the use of a larger number of discs will be desirable. For example, using the same magnet and armature, it was found that with ten discs per unit the armature would be dependably moved from retracted to attracted position during closures of 0.033 seconds at line current strength such as would result in absorption by the magnet and its associated units of not less than 1.35 volt-amperes, while drop away of the armature could not be dependably obtained when the line current was so increased that such energy absorption exceeded 1.6 volt-amperes; while, with fifteen discs per unit, line current strengths such as would cause absorption of 1.625 volt-amperes or more would assure attractive movement of the armature during closures of 0.033 seconds and failures to retract during breaks of like length would not occur at any line current strength causing absorption of not more than 2.75 volt-amperes.

Under certain operating conditions, it has been found to be desirable to minimize, as far as practicable, both the energy absorption of each winding and its associated rectifying units; and, under other conditions, to minimize the required operating current strength for a given magnet winding, irrespective of savings in energy absorption. For example, if it is proposed to change the current supply source of a given signaling circuit from direct to alternating current, and such circuit includes a number of electromagnets and their associated rectifying units so great that the alternating current energy absorption thereof will be a substantial proportion of that of the entire circuit, then the question of the amount of energy absorbed by each winding and its associated rectifying units becomes a prime consideration if the total energy absorption for the circuit must be limited.

On the other hand, if a corresponding change is to be made in a circuit of which the impedance provided by resistance of line wire is a far more important factor than that resulting from the inclusion of the required number of electromagnets and their associated rectifying units, it may become of prime importance to minimize, as far as practicable, the line current required to obtain dependable operation, even if the energy absorption for the magnets and their associated rectifying units is not correspondingly decreased, on account of the saving of energy absorption which will result from minimizing of line current strength, because of the preponderance of the resistance of the line wire and cable conductors in the total line impedance. To provide for the latter class of cases, the arrangement shown by Figs. 3 and 5 may be substituted for that shown by Figs. 2 and 4. The difference between the arrangement of Figs. 2 and 4 and that of Figs. 3 and 5 is, as will be most clearly seen by Fig. 5, the provision of the conductor *h* which connects the current path through the rectifying unit *f* and the winding 31, at a point between said unit and said winding, with a corresponding point in the parallel current path through the winding 31' and unit *g*.

By such use of the conductor *h*, it has been found that movement of the armature from retracted to attracted position can be as dependably obtained with an energy absorption of 0.25 volt-amperes as is dependable without the conductor *h* with an absorption on the order of .5 volt-amperes, one rectifier disc per unit being as dependably effective when the conductor *h* is thus used with a weak operating current as by using two discs per unit without this conductor.

The savings in energy for a corresponding number of discs with the conductor *h*, as compared with the energy consumption without that conductor, have been found to be from about 0.15 volt-amperes using two discs to about 0.025 volt-amperes using fifteen discs. It has been found, however, that as the line current is increased, the characteristics of rectifiers connected in accordance with Figs. 3 and 5 must be revised under circumstances such as would not require revision if connected in accordance with Figs. 2 and 4.

For example, in the use of rectifying units composed of a commercial form of copper oxide discs, it has been found that, with a given magnet connected in a signaling system such as that indicated by Fig. 1, although a line current strength such as would cause an energy absorption of 0.25 volt-amperes in the magnet and its associated rectifiers would cause the armature to move from retracted to attracted, using one disc per unit, and with an energy absorption on the order of 0.32 volt-amperes using two discs,—if the line current strength is so increased as to correspondingly result in an absorption of energy to the extent of 0.85 volt-amperes dependable operation will require at least two, and preferably three discs per unit; although if the conductor *h* of Figs. 3 and 5 is not used, the dependability of operation will not be impaired as the line current is increased so as to cause energy absorption from a minimum on the order of 0.5 volt-amperes to a maximum of nearly 2.0 volt-amperes.

It seems probable that the ability thus indicated of the arrangement without the conductor *h* to dependably operate with fewer discs than that with the conductor *h*, is because of the lack, in the arrangement with said conductor, of the inductive effect of the windings which, in the absence of the conductor *h*, tends to decrease strain upon the rectifiers; but which does not so protect the rectifiers when this conductor is used. Correspondingly, a given speed of operation requires a different circuit condition if the conductor *h* is used. For example, if the conductor *h* is used in connection with rectifying units composed of the commercial form of copper oxide discs hereinbefore referred to, response to signal formulation using a series of closures and breaks as short as 0.048 seconds, requires, for dependable pick-up and drop away of the armature, a line current strength which will result in energy absorption per magnet and its associated rectifying units not less than the lower and not higher than the highest of the following volt-ampere values: For three discs, 0.77 to 1.3; for four discs, 0.9 to 1.6; for five discs, 1.0 to 2.3; for six discs, 1.2 to 2.3; for seven discs, 1.13 to 2.75. If the minimum periods of closure and break are reduced to 0.033 seconds, other conditions remaining the same, dependable operation has been found to require at least nine discs, and with ten discs the line current strength must be such as will cause an

energy absorption of at least 1.45 and not to exceed 1.5 volt-amperes; while with twelve discs it may not be less than 1.75 or more than 1.85, while for fifteen discs, it may not be less than 2.0 or more than 2.65 volt-amperes.

Considered now from the standpoint of required operating current, it has been found that the use of the conductor *h* effects an economy on the order of 30% in current required to pick up on closures of a given duration.

The relative operating characteristics of a given magnet when subjected to closures and breaks of like duration, with and without the conductor *h*, is further illustrated in Fig. 6,—in which the line A is representative of the breaks and closures of the exciting circuit, the curve B is representative of the changes in the magnetomotive force if the conductor *h* is not used, while curve C is representative of the magnetomotive force if the conductor *h* is used. It will be here noted by reference to curve B, that, without the conductor *h*, the flux decreases during breaks, to an extent which brings it down almost to the strength effective before the first circuit closure of the series, and rises during each closure to substantially maximum strength. With conductor *h* in use, the increases in the flux, as represented by curve C, are somewhat cumulative, while the decreases during breaks lack more and more, following succeeding closures, from returning to the strength effective before the first closure of the series. The discrepancies both as to quickness in attaining full energization and quickness in deenergization when the conductor *h* is used may doubtless be traced, in large part, to the fact that, when the conductor *h* is used, there is an independent path for the circulating current in each of the separate windings while, without the conductor *h*, all circulating current must traverse both windings.

When attempts have heretofore been made to utilize alternating current for the excitation of the controlling magnets of signaling instruments in a series circuit, one of the serious difficulties encountered has arisen because the armatures of some of the signaling instruments do not respond to circuit closures as quickly as those of other instruments, and, when those most quickly acting have moved in response to the excitation of their associated magnet windings, the resultant change in impedance has caused a substantial decrease in line current strength so that, if a reasonable factor of safety was to be maintained for the slower acting instruments, it has been necessary to either provide an electromotive force such as would cause an objectionably large current flow prior to the movement of the armatures from retracted position or else to add such an amount of non-inductive resistance to each circuit that the aggregate of the impedance of all of the magnets included therein will represent but a minor portion of that of the entire circuit; thus correspondingly requiring the use of an electromotive force greatly in excess of what would otherwise be needful,—or, if practical conditions require that the total electromotive force per circuit shall fall within certain limits, requiring distribution between a plurality of circuits, of the magnets which could otherwise have been included in one circuit. Obviously, all such expedients are objectionable for a variety of reasons.

In a signaling system having circuits in which the magnet windings are co-related with rectifying units in the manner hereinbefore described and as indicated in the accompanying drawings, it will be found that the impedance offered to flow of current in the circuit, at any given strength, by the windings of any given magnet and its associated rectifying units, will not change to an objectionable extent, and usually not to an appreciable extent, upon movement of the associated armature from retracted to attracted position.

For example, in a circuit supplied with energy from a constant potential transformer and serially including the electromagnet windings and the associated rectifying units of such type and number of instruments that the impedance thereof will be several times that of comparatively non-inductive circuit components (such as line wire),—the line current strength will not become appreciably impaired because of the movements of the armatures of instruments most quickly responsive to circuit closures, thereby assuring maintenance of a current flow of adequate strength to cause the armatures of all of the instruments to move to attracted position.

The description of various embodiments of this invention has, up to the present point, been particularly directed to forms thereof in which full wave rectification is effected, as such rectification is usually deemed far preferable, if readily obtainable, for effecting the energization of electromagnets of signaling systems such, for example, as that indicated by Fig. 1. Inasmuch, however, as the broader aspects of this invention render its utilization advantageous in classes of service where half wave rectification accomplished in accordance with this invention will give entirely satisfactory results, it is pointed out that such rectification may be effected pursuant to this invention by merely connecting a rectifying unit having suitable characteristics (as hereinbefore more fully explained) in parallel with the winding of each electro-magnet.

For example, referring to the arrangement shown by Fig. 5,—the winding 31′ and the rectifying unit *f* could be omitted, so that there would be two current paths between conductor *d* and conductor *e*, which paths would be connected in parallel at the ends thereof, one path including the winding 31 (or, if desired, both the windings 31 and 31′ in series) and the other current path including one rectifying unit as, for example, the unit *g*. In Fig. 7, electromagnets are shown arranged as just indicated.

When a circuit is arranged for half wave rectification, as just indicated, if a substantial portion of the total circuit impedance is that of the included electromagnets and their associated rectifiers, it is desirable that substantially one-half of the magnets shall be connected to use one-half of the wave and the remainder of the magnets to utilize the other half of the wave. In any event, rectifying units employed in accordance with this invention are not at any time subjected to an electromotive force exceeding that resultant from the impedance of the electromagnet winding in parallel therewith; each winding, considered by itself, is subjected to half wave energization supplemented by the flow of a circulating current through a current path such as to tend to maintain the magnetomotive force throughout the intervals between half wave impulses imparted by the exciting circuit and which circulating current path has such characteristics as to prevent continuation of such circulating current for a time so great as to unduly retard the demagnetization of the core follow-

ing interruption of the exciting circuit; and alternative current paths are so arranged that, during each half wave of all cycles, one or the other of such paths will be independently available.

Fig. 7 shows a circuit such as might be utilized for connecting the bells and registers used for manifesting alarms in fire houses connected by a circuit such as the circuit L in Fig. 1; the tower bell striker at receiving station RS being connected in the circuit as shown in Fig. 1, but the receiving instruments represented as being at the various fire houses FH, FH, etc., are arranged so that the rectifiers f' cause their associated electromagnet 31^a at part of such instruments to be energized by a given half-wave and the rectifiers g' correspondingly cause their associated electromagnets 31^b at the remaining instruments to be energized by the succeeding half-wave.

From the foregoing it will be apparent that types of signaling apparatus which are at present commercially available, and which are suited for operation in direct current circuits, may be adapted for use in alternating current circuits without change in the physical characteristics of the electromagnets and without any such change in impedance or in the energy required for their effective excitation as to render them unsuited to uses corresponding to those to which they have heretofore been put. Thus, for example, in the case of a signaling system such as that of Fig. 1, the circuits S^1, S^2, S^3 and L may be supplied from a single alternating current source. If the use of storage batteries is desired, but one battery will be needed which, operating in any well known manner, as through a suitable motor generator, will supply the needed alternating current for the excitation of the transformers T, T, T, T; a duplicate battery not being needed as such battery could be floated or charged while being discharged without interconnecting the signaling circuits or exposing them to connection with any foreign circuit, to the end that no current path would be established between the circuits notwithstanding their ultimate dependence, at any given time, upon a single storage battery.

The avoidance of using individual transformers in connection with each of the various electromagnets as well as the avoidance of the losses incident to the use of four rectifying units (connected in bridge instead of two, in association with each of the line magnets) contributes materially in rendering it possible to utilize alternating current for the supply of circuits such as S^1, S^2 and S^3, in which the non-interference magnets 311 of the various transmitting stations are normally shunted by their respectively associated cut-outs CO, so that it is important that the line current strength shall not be unduly diminished by the inclusion of any required number of such magnets in their circuit. The importance of this feature is better understood when it is recalled that, in the case of a fire alarm system such as that indicated by Fig. 1, the sudden bursting forth of a spectacular fire may result in the mechanism of numerous transmitting stations being set in motion at or about the same time, with a resultant inclusion of the impedance of many non-interference magnets in a series line circuit. Obviously, if the cumulative effect of the insertion of such impedances is to decrease the line current to a strength below that at which the automatic repeater or other receiving instruments will respond, or below that at which the armatures of the non-interference magnets will be held during signal formulation of their associated stations, the signal for such fire may be completely lost.

It is believed that, with the foregoing explanations, the operation of this invention will be fully understood by those skilled in this art, and a further detailed recital thereof will, therefore, be omitted.

Although, in a more specific sense, this invention relates to emergency signaling and communication systems employing series circuits such, for example, as those indicated in Fig. 1; the broader features of this invention are not limited to the specific embodiments thereof which are shown in the annexed drawings and are described in detail in the foregoing specification, but are suited for use under practically every condition in which it is desirable to effect the excitation of an electromagnet by the use of alternating current.

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

1. An electromagnetically controlled instrument including a U-shaped magnet with windings on the respective limbs thereof, an end of one of said windings connected to such a one of the ends of the other that current flow through said windings from one to the other of the remaining ends thereof will effect intended magnetization; in combination with an interconnection between said remaining ends, rectifying means serially included in said interconnection, said rectifying means substantially opposing current flow toward one, and away from the other of said remaining ends, and energizing current taps applied to said interwinding connection and between the terminals of said rectifying means.

2. A signaling instrument including a magnet winding and its associated core in combination with rectifying means having extreme terminals and an intermediate terminal, connections providing a closed loop serially including said winding and said means whereby the circulation of current in said loop will induce a magnetomotive force in said core and said means will oppose flow in one direction of a circulating current through said loop, an energizing alternating current tap applied to said loop intermediate the ends of said winding, and a second alternating current tap applied to said loop intermediate the extreme terminals of said means.

3. A signaling instrument including an electromagnet having two windings, connections providing a closed loop serially including said windings, rectifying means serially included in said connections to oppose current flow in said loop in a given direction, an energizing current tap applied to said loop between a terminal of one winding and the rectifying means of one of said connections, and a second energizing current tap applied to said loop between a terminal of the other winding and the rectifying means of the other of said connections.

4. A signaling instrument including an electromagnet having two windings, connections providing a closed loop serially including said windings, rectifying means serially included in said connections to oppose current flow in said loop in a given direction, an energizing current tap applied to said loop between a terminal of one winding and the rectifying means of one of said connections, a second energizing current tap applied to said loop between a terminal of the other wind-

ing and the rectifying means of the other of said connections, and an interconnection between the remaining ends of said windings.

5. In an electric current rectifying system adapted for supplying rectified current directly from a source of alternating current, the combination comprising an electro-magnet having a winding split into two parts conductively connected together, a circuit including a half-wave rectifying device connected to energize one part of said winding and having conducting connections with said source, and a second circuit having a conductor in common with the first circuit and a second half-wave rectifying device disposed to have opposite polarity to the first, said second circuit being connected to energize the other part of said winding and conductively connected to said source.

6. In an electric current rectifying system adapted for supplying rectified current from a source of alternating current, a supply circuit, an electro-magnet having a single magnetic path with two windings cumulatively acting upon said path and conductively connected in and serially related to said circuit in parallel branches to each other to form a closed loop, and a rectifier in each branch, said rectifiers being in cooperative relation within said loop.

7. In an electric current rectifying system adapted for supplying rectified current from a source of alternating current, a supply circuit, an electro-magnet having a single magnetic path with two windings cumulatively acting upon said path, each winding being conductively connected in and serially related to said circuit and in parallel relation each to the other, rectifying means associated with one winding to oppose current flow in a certain direction therethrough with relation to said source, and rectifying means associated with the other winding to oppose current flow in the opposite direction therethrough.

8. In an electric current rectifying system adapted for supplying rectified current to an electro-magnet directly from a source of alternating current, a magnet having a single magnetic path with two windings cumulatively acting thereupon, an alternating current supply circuit serially connecting said windings in such a manner that parallel current paths are provided through the two windings, a rectifying unit connected to a terminal of one winding to oppose current flow in a certain direction therethrough, and a rectifying unit connected to a terminal of the other winding to oppose current flow therethrough other than in a direction to cooperate with unopposed current flow in the first named winding.

9. A device of the character described comprising, in combination, a pair of alternating current leads, duplicate magnet coils wound on a common core for cumulative action thereupon and conductively and oppositely connected in said leads, and a rectifier in each coil circuit, said rectifiers being in opposed relation so as to permit flow of current in the respective coils during opposite alternations in the line current.

10. A device of the character described comprising, in combination with alternating current leads, duplicate magnet coils wound on a common core for cumulative action thereupon and oppositely connected in said leads, and a rectifier in each coil circuit, said rectifiers being in opposed relation so as to permit flow of current in the respective coils during opposite alternations of the line current.

11. A device of the character described comprising, in combination with alternating current leads, duplicate magnet coils wound on a common core for cumulative action thereupon and oppositely connected in said leads, a rectifier in each coil circuit, said rectifiers being in opposed relation so as to permit flow of current in the respective coils during opposite alternations of the line current, and means for reducing the alternating current voltage.

12. In an electric current rectifying system adapted for supplying rectified current directly from a source of alternating current, the combination comprising an electromagnet having a single magnetic path with a winding split into two parts and provided with three taps arranged to supply said separate energizing portions for cumulative action upon said magnetic path, a conducting circuit having in series therewith a half-wave rectifying device connected to energize one winding portion of said electro-magnet, said circuit being conductively connected to said source, a second circuit having a rectifying device connected in series therewith conductively connected to energize a second portion of the windings of said electro-magnet, conductively connected to said source, and having a polarity with respect to the first rectifying device such that the magneto motive force in said portions is the same, said first and second circuits having a portion in common.

13. In an electric current rectifying system adapted for supplying rectified current directly from a source of alternating current, the combination comprising an electro-magnet having a single magnetic path, a winding provided with two end terminals and a mid-point terminal, a conductor having in series therewith a half-wave rectifying device connected to one of said end terminals, a second conductor having a second half-wave rectifying device in series therewith connected to the other end terminal, and arranged to have a polarity opposite to the first, a third conductor connecting together the free poles of said rectifying devices and adapted to be connected to one side of the alternating current source of supply, and a fourth conductor connected to said mid-point terminal and adapted to be connected with the other side of said alternating current source.

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