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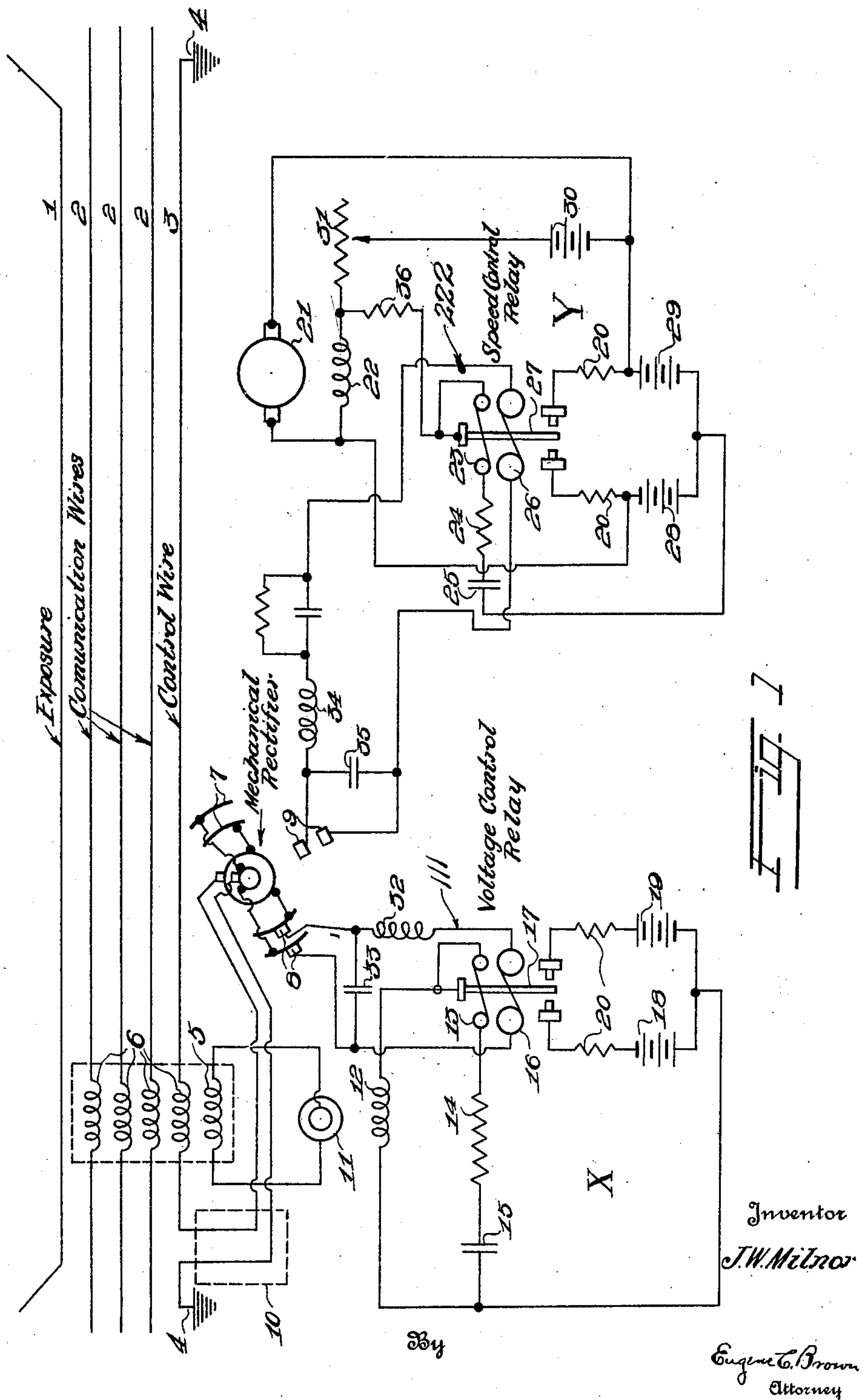
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J. W. MILNOR

MEANS OF AND METHOD FOR NEUTRALIZING ALTERNATING CURRENTS

Filed April 5, 1927

3 Sheets-Sheet 1



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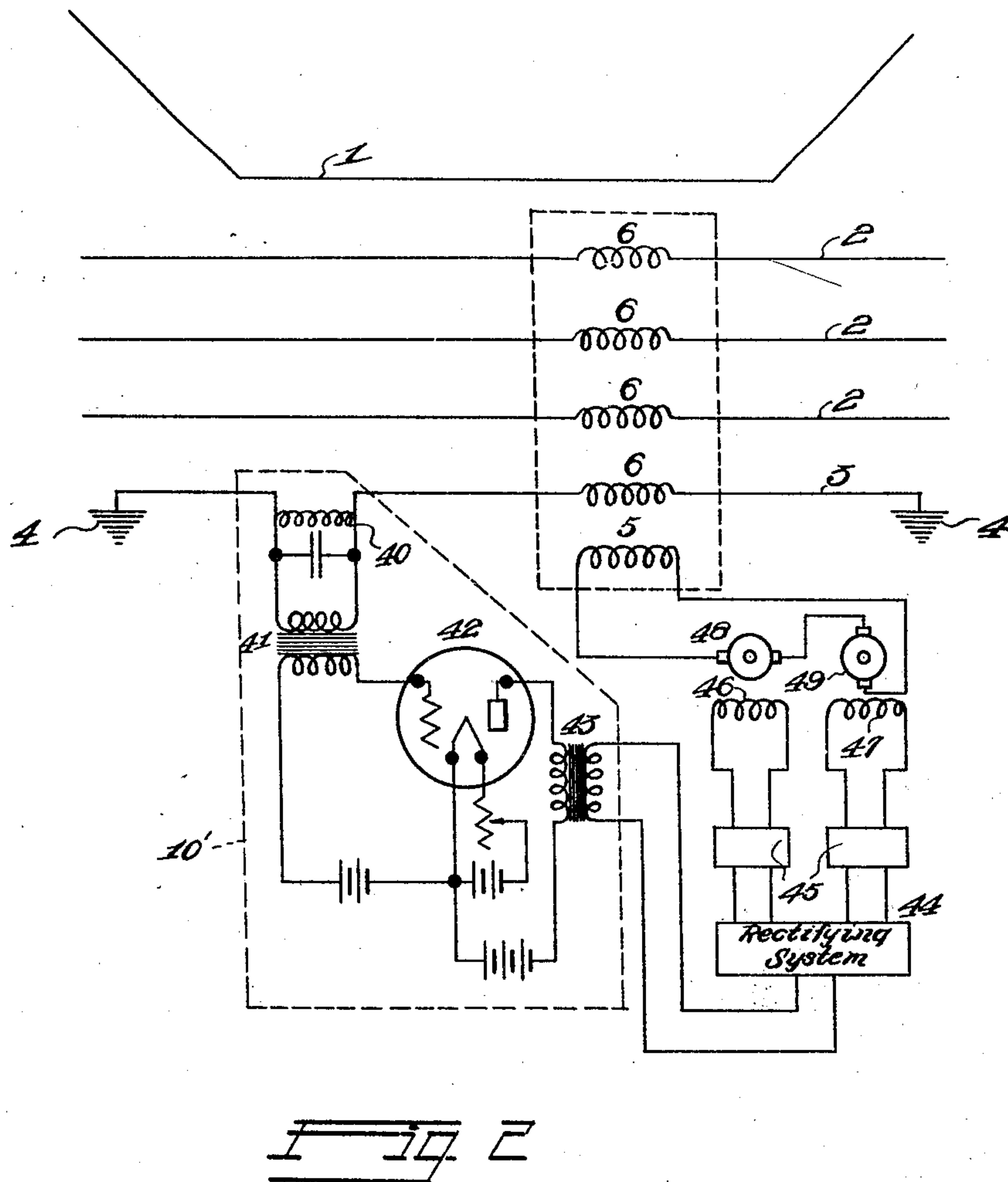
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3 Sheets-Sheet 2



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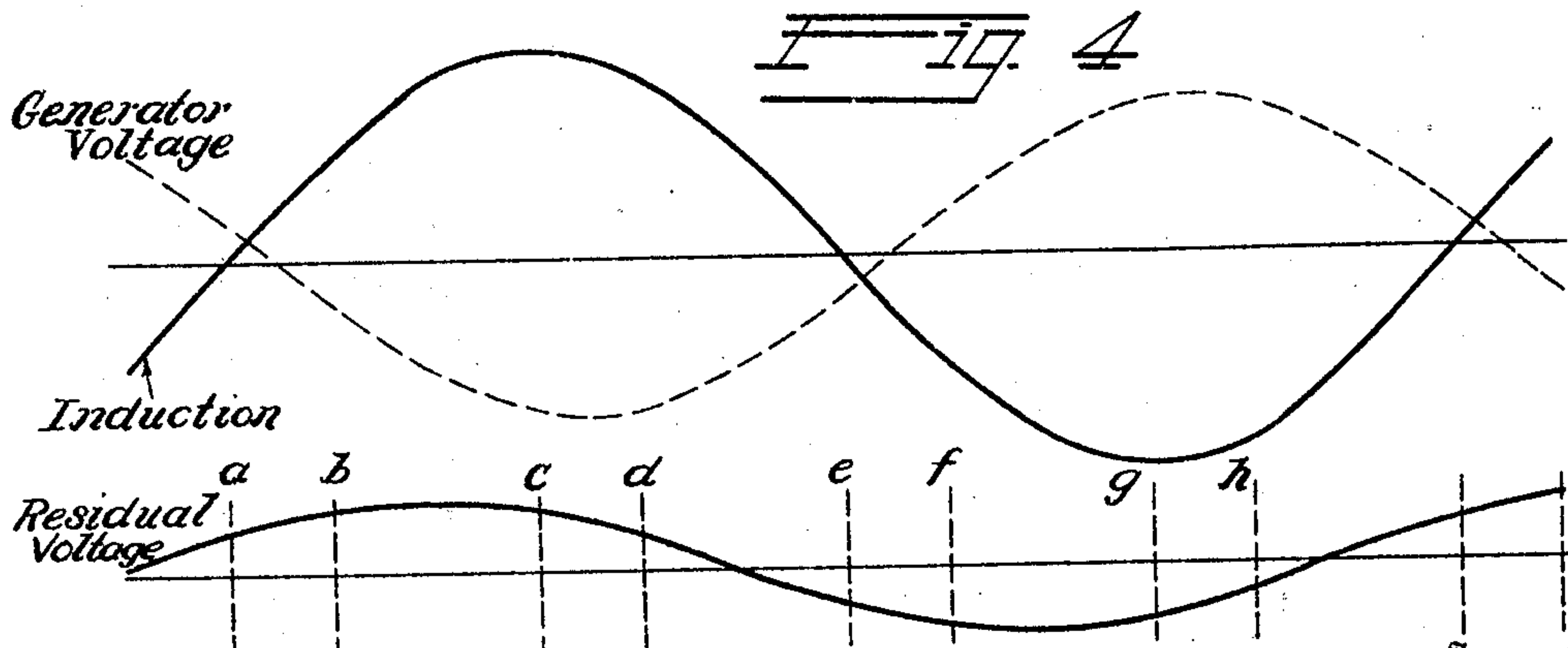
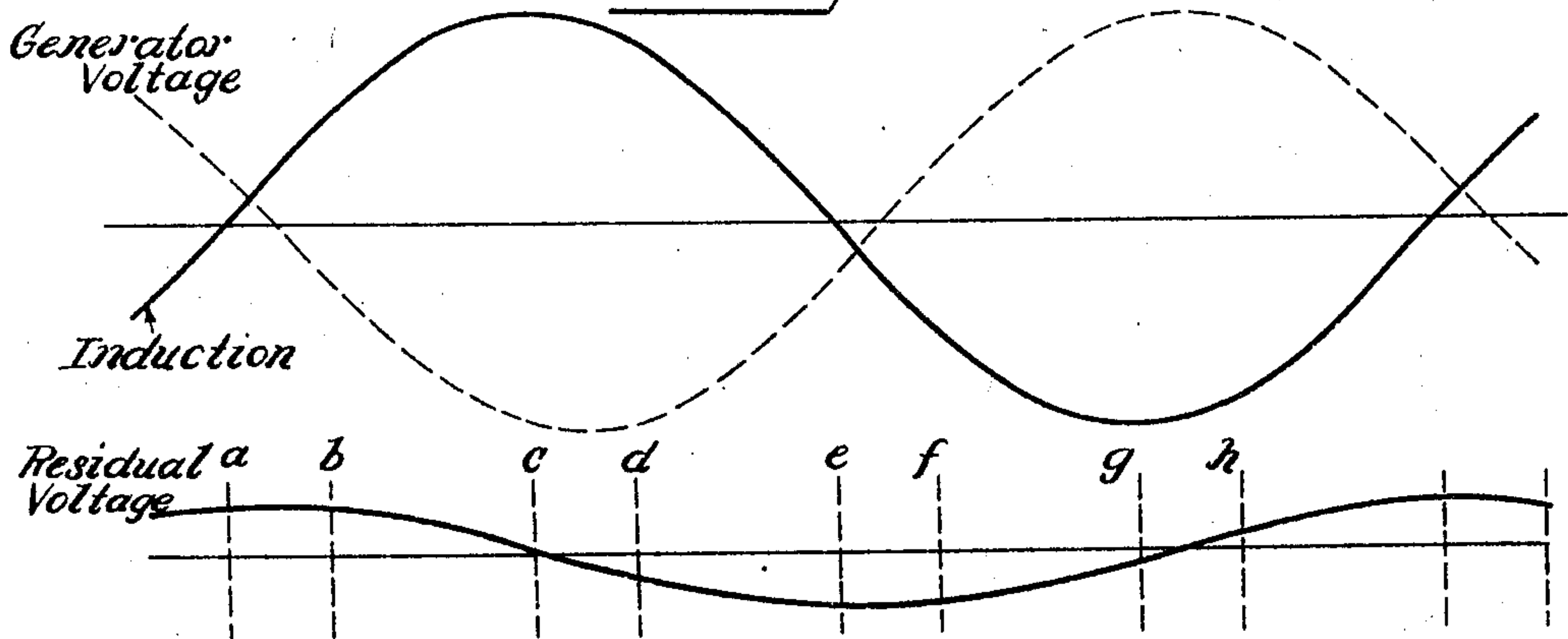
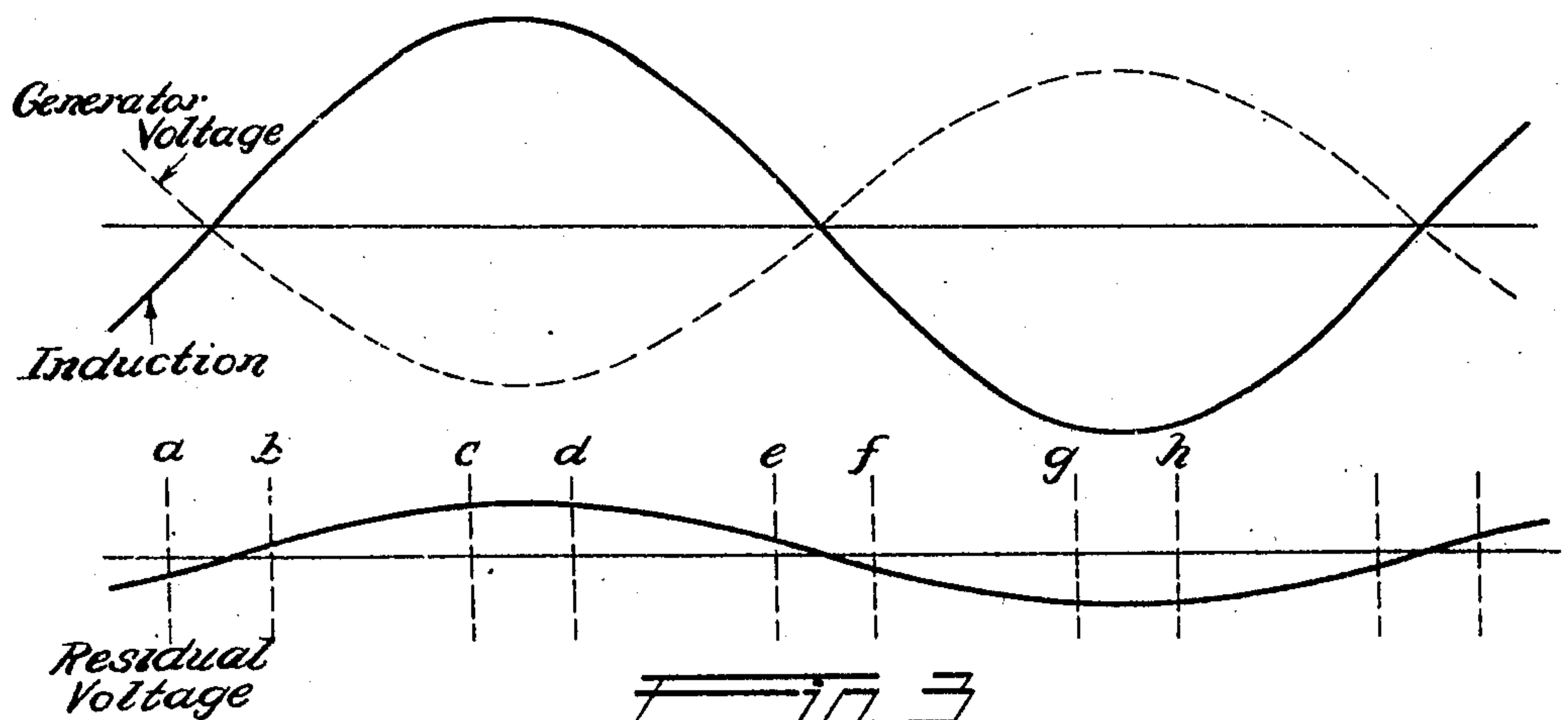
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MEANS OF AND METHOD FOR NEUTRALIZING ALTERNATING CURRENTS

Filed April 5, 1927

3 Sheets-Sheet 3



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1,688,735

UNITED STATES PATENT OFFICE.

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MEANS OF AND METHOD FOR NEUTRALIZING ALTERNATING CURRENTS.

Application filed April 5, 1927. Serial No. 131,149.

My invention relates to a system of neutralizing induction from power systems. It includes a method of and means for correcting for alternating current potentials of a disturbing nature in systems of electrical communication such, for example, as telegraph or telephone systems.

More particularly, my invention relates to an improved method of and means for automatically adjusting the magnitude, phase and frequency of a voltage generated for the purpose of neutralizing a disturbing potential, so as to produce, in the communication circuits to be protected, a resulting potential of zero or negligible magnitude.

The present invention comprises improvements over the system disclosed in my U. S. Patent No. 1,254,831, dated January 29, 1918. That patent covers a system consisting of two alternating current generators, mechanically connected so that their phase differs by ninety degrees, with means for controlling the voltage of each generator in such manner that the voltage and phase of the interfering voltage are substantially neutralized. The control of the generators is effected with the aid of a control wire extending through the length of the exposure. Under certain circumstances, i. e., where the driving motor is of the synchronous type, one of the correcting generators can be dispensed with.

The two-generator system described above has the following disadvantages: The output of the generators is not utilized efficiently; there is no automatic control for adjusting the generator frequency to the frequency of the disturbing source; and the system tends to cause a certain amount of crossfire between the communication circuits. A neutralizing system, common to a plurality of communication circuits, inherently causes crossfire between the various circuits, since the neutralizing system and the communication wires are interconnected through a transformer. This effect may be made practically negligible however, by having the effective output impedance of the neutralizing system low in comparison to the impedance of the communication circuits. The single-generator system described above while having lower output impedance than the two-generator system, has the disadvantage that it does not provide an automatic control for adjusting the phase of the neu-

tralizing voltage in accordance with variations in phase of the disturbing voltage, other than those originating in the inducing source.

For the above reasons, it is desirable and it is the purpose of the present invention to provide a neutralizing system of low effective output impedance having automatic controls for adjusting the amplitude, frequency and phase of the neutralizing voltage with respect to the disturbing voltage.

A further disadvantage inherent in systems involving one or more generators of the general type disclosed in my Patent 1,254,831, is that such systems may be insensitive to small induced voltages and may therefore be inefficient to produce neutralization under such conditions. Moreover, even when used to neutralize voltages of considerable magnitude the system may, unless properly designed, be ineffective to reduce the residual or uncorrected voltage to a value sufficiently small to be inappreciable. Since, ultimately, operation of the correcting apparatus is limited by the sensitivity of the apparatus to the small residual voltages present in the control wire, it is obvious that the effectiveness of the correction will depend upon the effectiveness of this residual voltage in initiating operation of the correcting relays and associated apparatus. In order to make the control circuit more sensitive, it is, according to the present invention, equipped with a vacuum tube amplifying circuit adapted to increase the residual control current to a value sufficient to provide effective operation of the correction apparatus. By this means a small residual voltage is utilized in its amplified state to produce a voltage, or a change in voltage, of the order of magnitude of the original small residual voltage.

Accordingly, the outstanding specific objects of my invention are as follows:

To provide, in a neutralizing generator system, automatic means for controlling the frequency and phase relation and the magnitude of the generator voltage;

To provide, in a neutralizing system involving one or more neutralizing generators, a method of and means for causing operation of the correction generator or generators by a voltage of a magnitude substantially less than that of the minimum voltage effective by hitherto known methods and apparatus for producing neutralization;

To provide separate adjustment of the magnitude and phase of the neutralizing voltage by utilizing different portions of the current cycle of the residual voltage in the control wire, to operate separate correction apparatus for separately adjusting the voltage of the generator and the phase angle of the generator.

To reduce to a minimum that tendency to cause crossfire between communication wires which may be inherent in a system providing protection for a plurality of communication wires by a common neutralizing means, while maintaining accurate regulation of the phase as well as magnitude of the neutralizing voltage.

Other objects will become apparent from the following description of the annexed drawings in which:

Figure 1 represents one embodiment of my invention in the form of a neutralizing system utilizing a single generator, in which the control arrangement consists of two parts, one of these parts controlling the voltage supplied by the generator and the other part controlling the speed of the generator.

Figure 2 represents another related type of system embodying certain features of my invention, whereby the sensitivity of the neutralizing apparatus to small induced voltages is increased.

Figures 3, 4 and 5 are graphical representations showing the manner in which the induced voltage and the generator voltage combine to produce a residual control voltage, different portions of the current cycle of which may be utilized to effect separate regulation of the magnitude and phase of the neutralizing voltage.

In Figure 1, 1 represents the source of disturbing induction, which may be a power line, and 2—2 represent conductors of a system or systems subject to induction from circuit 1. A control wire 3 parallels the conductors 2—2, which latter may be the line wires of a telephone, telegraph or other communication system. This control wire may be carried upon the same pole line as conductors 2—2 throughout that portion of the system which is subjected to the disturbing induction, and provision is made for grounding the control wire at each end at points 4, 4 preferably somewhat beyond the ends of the exposed region. The circuit of the control wire is extended through a secondary coil 6 of a transformer having other secondaries 6—6 in each of the conductors to be protected.

The neutralizing system comprises, in addition to the control wire 3 and transformer 5—6, a mechanical rectifier 7 and separate control means indicated generally at X and Y. The brushes 8—8 and 9—9 of the mechanical rectifier are spaced approximately ninety electrical degrees from each other for a pur-

pose which will be explained hereinafter. The mechanical spacing of the brushes depends upon the type of the generator 11, i. e., whether two-pole or four-pole, etc., and upon the speed of rotation of the rectifier with respect to the speed of the generator. As here illustrated with the rectifier and generator driven at the same speed and the generator assumed to be of the two-pole type, the mechanical spacing is also ninety degrees. The rotating part of the rectifier comprises segments cooperating with the sets of brushes to establish a connection from the control wire alternately with the control means X and Y, each control means being connected to the control wire twice during each cycle of the generator voltage.

The rectangle 10 represents a connection from the control wire to the rotary rectifier, which may include a vacuum tube amplifier, such as is shown in the dotted line enclosure 10' in Fig. 2. This amplifier is used in systems in which it is desired to reduce the value of uncorrected voltage to a point such that its effect in the communication circuit is inappreciable, or in which the disturbing voltages are originally of so small a value that they are insufficient to cause positive operation of the control apparatus directly but must first be reinforced.

The function of control means X is to regulate, through the action of control relay 111, the field of the correcting generator, in a manner described fully in my United States Patent No. 1,254,831. The function of control means Y is to regulate, through the action of control relay 222, the speed of the motor which drives the generator and the rotary mechanical rectifier, all three of these elements being mounted, in the usual manner, on a common shaft.

The field 12 of the generator 11 is supplied with current from the tongue of voltage controlling relay 111 which is maintained in rapid vibration through the action of coil 13 connected in series with resistance 14 and condenser 15. The vibration of the relay is also under the control of a second coil 16 which is connected to the control wire 3 through the mechanical rectifier 7 and, when used, the vacuum tube amplifier. When the generator voltage is at its correct value the relay tongue 17 of voltage control relay 111 vibrates continuously, the relative lengths of time the tongue rests upon either contact being such that the correct value of exciting current is supplied to the generator field 12. Oppositely poled current sources 18 and 19 supply current to the generator field through relay tongue 17 by way of resistances 20 whose function it is to limit the amount of current which may be drawn respectively from sources 18 and 19.

The speed of the motor 21 which drives generator 11 and rectifier 7 is controlled by

the speed controlling relay 222, the motor being so arranged that if the relay exerts no control upon it the motor will run at approximately the correct speed to neutralize the induction. The circuit from control relay 222 is such that the relay can increase the field current flowing in field coil 22 of the motor or can decrease it within certain limits. In this manner, relay 222 can change the speed of the motor within certain limits, the limits being sufficient to care for any ordinary variations in the frequency of the power induction.

The speed-controlling relay 222 is maintained in rapid vibration through the action of current in coil 23 in series with resistance 24 and condenser 25. A second coil 26 of the relay is connected to the control wire 3 through mechanical rectifier 7. Relay tongue 27 makes contact from one side of the motor field coil 22 to conductors connected to the oppositely poled current sources 28 and 29, the other terminals of these sources being connected together and to condenser 25 of the system which tends to maintain the relay in continuous rapid vibration. Normally the field 22 of the motor is supplied from sources 28, 29 and 30 through a regulating resistance 31 adjusted to such a value that the current through the motor field maintains the speed at an average value, current being supplied from the speed control relay to take care of variations from the average value. Current supplied in one direction or the other through the relay tongue causes a change in the speed of the motor which acts to adjust the frequency and phase of the generator voltage.

For the purpose of improving the action of the mechanical rectifier, smoothing-out devices may be provided for the rectified current, in the form of inductances 32, 34 in series, and condensers 33, 35 in shunt, in the respective circuits of control means X and Y.

The manner of operation of the system will be apparent from consideration of the various possible conditions existing in the control wire as represented graphically in Figs. 3 to 5.

If the generator voltage is not correct and the phase relation of the generator voltage and the induction is correct there will be a residual voltage in the control wire as shown in Fig. 3. Sections *c—d*, *g—h*, etc. near peaks of the residual voltage waves in the control wire will be rectified, and rectified current will flow through coils 16 of control relay 111, when brushes 8—8 make contact with the rotating segments of mechanical rectifier 7. Energization of coil 16 tends to hold the tongue 17 of the voltage control relay against one contact or the other a sufficient length of time for the generator voltage and induction to become equal in magnitude. In the same current cycle, sections *a—b*, *e—f*, near points where the residual voltage wave crosses

the axis, will be rectified when brushes 9—9 make contact with the rotating segments of the rectifier. The resultant rectified current flowing in coils 26 will be zero or nearly so, There will be little or no force exerted upon the tongue 27 of the speed control relay and consequently little or no change in the current from the relay tongue through resistance 36 and the motor field 22, the phase relation already being correct.

If the generator voltage is correct and the phase relation of the generator voltage and the induction is not correct, there will be a residual voltage in the control wire as shown in Fig. 4. Sections *c—d*, *g—h*, etc., near points where the residual voltage waves cross the axis, will be rectified when brushes 8—8 contact with the segments of the rectifier and will in turn cause only a very small current to flow in coil 16 of voltage control relay 111, the force exerted upon the tongue 17 of the relay being small. The generator voltage which was correct, as shown by Fig. 4, will therefore be changed a negligible amount. Sections *a—b*, *e—f*, etc., in Fig. 4, near the peaks of the residual voltage waves in the control wire 3 will be rectified when brushes 9—9 contact with the segments of the rectifier, causing rectified current to flow in coils 26 of the speed control relay 222, thus holding or tending to hold the relay tongue 27 against one contact or the other a sufficient length of time for the system to readjust itself to the correct speed and phase relation.

If the generator voltage and phase relation of generator voltage and induction are both incorrect, there will be a residual voltage in the control wire as shown in Fig. 5. Sections *c—d*, *g—h*, etc., will be rectified, thus causing a current to flow in coils 16 of the voltage control relay which will hold or tend to hold the tongue 17 of the relay against one contact or the other a sufficient length of time for the generator voltage to become correct in value. At the same time sections *a—b*, *e—f*, etc., will be rectified and will in a similar manner cause a flow of current in coils 26 of the speed control relay, causing the system to readjust itself to the correct speed and phase relation.

When a difference in frequency between the induction and the neutralizing voltage occurs, caused for instance by a frequency change in the paralleling power system, the neutralizing system readjusts itself to the proper frequency in the same manner as described above for phase adjustment. The two adjustments differ only in that phase correction requires a momentary change in the motor speed while frequency correction requires that the motor operate at the new speed until further frequency changes occur.

It will be understood that when the system as a whole is working properly, there will be practically no residual voltage and

consequently no current flowing in the control wire. The induction in the main control wire is neutralized in the same manner that the system neutralizes induction in all the other wires along the pole line, the control wire being carried through the same transformer. If the system does not correctly neutralize the induction, there will be a current flowing in the control wire which acts on the relays in such a way as to correct the action of the system.

The action of the amplifier 10 in the system according to Figure 1 is, in general, similar to its action in Fig. 2, which shows this feature of my invention applied to a system of the type disclosed in my Patent 1,254,831.

In Figure 2 the same numerals are used to designate apparatus corresponding to similar apparatus in Figure 1. In this figure, a resonant circuit 40, tuned to the frequency of the disturbing current, serves to exclude from the correcting apparatus currents other than the one it is desired to neutralize. This circuit is not essential, though desirable, and if used, may be any of the well-known forms of resonance or wave filter circuits. The tuned circuit is coupled by transformer 41 to the input circuit of vacuum tube 42.

The vacuum tube amplifier is shown diagrammatically as a single stage amplifier, but it is obvious that the amplification may be increased to any desired value by increasing the number of stages. It is apparent also that the number of stages used may be so chosen as to adjust the residual or uncorrected voltage to any desired minimum value, or to increase the sensitivity of the apparatus so as to produce operation of the correction apparatus for as small an induced voltage as it may be desirable or necessary to correct.

The output circuit of the amplifier is connected through transformer 43 to the mechanical rectifier or rectifiers, diagrammatically shown at 44, and these in turn are connected to the systems of control relays herein shown diagrammatically at 45. The control relays 45 regulate the neutralizing generator system herein shown as comprising two generators 48, 49 with fields 46, 47 under control of relay systems 26. Since the exact structure of the rectifying system and of the control relays, etc., forms no essential part of this feature of the present invention, no attempt is made to show them otherwise than diagrammatically, but it is apparent that they may take any of the forms shown in my Patent 1,254,831. Or they may, as indicated above, take the form of the rectifier and control relay systems shown in Fig. 1.

The operation of the system according to Fig. 2 is obvious and may be described briefly as follows:—A small induced voltage, definitely interfering with the communication circuits but not sufficient to cause positive operation of the control apparatus directly, is

amplified to the desired amount and then rectified by the rotary mechanical rectifier 44. The rectified current controls the operation of relays 45 which in turn control the excitation of the generator fields 46 and 47. The system automatically adjusts itself so that the combined output of the generators, which are preferably displaced in phase by 90° , is of the correct voltage, frequency and phase relation to neutralize the induced voltage when applied to the communication wires through the transformer 5—6.

The primary coil 5 of the transformer may have any desired ratio of turns with respect to coils 6—6. This ratio has usually been unity. However, the effectiveness of a neutralizing generator system, especially of the improved system described herein, may be increased by having the number of turns of coil 5 as high as practicable with respect to the number of turns on coils 6—6, and by having generators of low armature impedance. This results in a large reduction of the cross-fire or interference between communication circuits which has been inherent in previous neutralizing systems.

I claim:

1. In a system for neutralizing alternating current induction, an alternating current generator designed to supply an equal and opposite neutralizing voltage, control means for regulating the value of the neutralizing voltage produced by said generator, and separate control means for regulating the speed of the said neutralizing generator.

2. In a system for neutralizing alternating current induction, an alternating current generator designed to supply an equal and opposite neutralizing voltage, control means for regulating the value of the neutralizing voltage produced by said generator, and separate control means for regulating the phase angle of the said neutralizing voltage.

3. In a system for neutralizing alternating current induction, a generator designed to supply an equal and opposite neutralizing voltage, means for controlling the flow of current in the field of the generator to regulate the value of the neutralizing voltage, a motor arranged to drive said generator, and means for controlling the speed of the motor for regulating the frequency and phase relation of the neutralizing voltage.

4. In a system for neutralizing alternating current induction, a generator designed to supply a neutralizing voltage, a motor arranged to drive said generator and separate means for regulating the fields of said generator and said motor in accordance with a control current varying with variations in the disturbing induction, so as to cause said generator to produce a neutralizing voltage of proper frequency, phase and value.

5. In a system for neutralizing alternating current induction, a generator designed to

supply a neutralizing voltage, a motor arranged to drive said generator, separate means for varying the field of said generator and the speed of said motor, and a common control circuit arranged to supply energy to operate said separate means.

6. A system for neutralizing disturbing induction from a power line comprising a control circuit exposed to induced voltages similar to the disturbing induction, a generator designed to generate a neutralizing voltage, a motor arranged to drive said generator, a field for said motor and means for regulating the current supplied to said field in accordance with variations in voltage in said control circuit.

7. In a system for neutralizing alternating current induction, a generator designed to supply a neutralizing voltage, a control circuit for said generator exposed to induced voltages similar to the disturbing induction, a motor arranged to drive said generator, said motor being connected to a source of current supply, and means controlling said current supply in accordance with variations in voltage in said control circuit.

8. The combination of a system of communication comprising a transmission conductor and a control conductor, said conductors being similarly exposed to the inductive influence of a disturbing alternating current, a single generative means arranged to superpose upon the disturbing voltage in said conductors an induced voltage for neutralizing the said disturbing voltage, and means operated by the resultant flow of current through the control conductor for separately regulating the magnitude and the phase of the voltage produced by said generative means.

9. The combination in a system of communication of an alternating current generator comprising means for opposing the voltage generated thereby to alternating current voltage otherwise present in said system, means for rectifying the combined opposed voltages, field control means and driving means for said generator and means for separately controlling said field control and driving means by said rectified resultant voltage to cause the generator to produce an opposing voltage corresponding in phase and value to the said alternating current voltage otherwise present in the system.

10. The combination in a system of communication of a main line conductor, a source of alternating current comprising means for opposing the voltage produced thereby to alternating current voltages of small magnitude otherwise present in said system, a control conductor for said source similarly exposed with said main line conductor to the disturbing influence of the alternating current voltages of small magnitude, means for increasing alternating current voltages in said control circuit to an order of magnitude greater

than that of the disturbing alternating current voltages in the main line conductor, and means for utilizing said magnified voltages to adjust the output of said source to a value substantially equal to the value of the disturbing alternating current voltages of small magnitude.

11. The combination with a system of communication of a control conductor, an alternating current generator comprising means for opposing the voltage generated by it to alternating current voltage otherwise present in said system and control conductor, a motor arranged to drive said generator, a field-control relay system for said generator, a speed-control relay system for said motor, means for rectifying current flowing through said control conductor and for separately supplying rectified current to said field-control and speed-control relay systems.

12. The combination with a system of communication of a control conductor, alternating current generating means comprising means for opposing the voltage generated by it to alternating current voltage otherwise present in said system and control conductor, driving means for said generating means, means for controlling the field of the generating means in accordance with instantaneous current values at a given point in the cycle of the control voltage in said control conductor, and means for controlling current supply to said driving means in accordance with instantaneous current values at a point in the cycle removed by substantially ninety electrical degrees from the said given point.

13. The combination with a system of communication of a control conductor, alternating current generating means comprising means for opposing the voltage generated by it to alternating current voltage otherwise present in said system and control conductor, field control means for said generating means comprising relay means controlling duration and direction of current flow through the field, driving means for said generating means and a source of current supply for said driving means adjusted to supply to said driving means current of a value to cause said generator to produce a neutralizing voltage of proper frequency, and further relay means for varying the current supply to said driving means in accordance with variations in voltage in said control conductor.

14. The combination with a system of communication of a control conductor, an alternating current generator comprising means for opposing the voltage generated by it to alternating current voltage otherwise present in said system and control conductor, field control means for said generator comprising relay means controlling duration and direction of current flow through the field, a motor arranged to drive said generator, field control means for said motor comprising re-

lay means varying the current flow through the field, a rectifier provided with means for establishing connection alternately to said field control means for said generator and
 5 for said motor, and a connection from said rectifier to the control conductor by way of a vacuum tube amplifier.

15. The method of regulating the generation of a neutralizing voltage in a system in
 10 which the neutralizing voltage is combined with the disturbing voltage for the production of a control voltage proportional to the combined voltage, which comprises rectifying different portions of the current cycle of
 15 the control voltage and separately controlling the magnitude and the phase of the neutralizing voltage by said rectified different portions.

16. The method of regulating the generation of a neutralizing voltage which comprises combining with the disturbing voltage
 20 a neutralizing voltage of approximately equal magnitude and opposing phase to produce a residual voltage of small magnitude,
 25 amplifying said residual voltage to an order of magnitude commensurate with that of the disturbing voltage, rectifying the magnified residual voltage, and controlling generation of the neutralizing voltage by simultaneous
 30 phase-displaced portions of said rectified voltage to produce closer adjustment of the neutralizing voltage to the disturbing voltage in magnitude and phase.

17. The method of regulating the generation of a neutralizing voltage which comprises combining with the disturbing voltage
 35 a neutralizing voltage of approximately equal magnitude and opposing phase to produce a residual voltage of small magnitude,
 40 amplifying said residual voltage to an order of magnitude commensurate with that of the disturbing voltage, rectifying different portions of the current cycle of the magnified residual voltage, and separately controlling
 45 the magnitude and the phase of the neutralizing voltage by said rectified voltage to produce closer adjustment of the neutralizing voltage to the disturbing voltage in magnitude and phase.

50 18. The method of lowering the minimum response voltage of a system of alternating voltage neutralization in which a disturbed line is paralleled by a control line subjected to a disturbance similar in kind and magnitude, which comprises producing in said control line and in the disturbed line a neutral-

izing voltage and combining it with the disturbing voltage therein to produce a residual voltage, amplifying the magnitude of the residual control voltage in the control line as
 60 compared with that of the residual voltage in the disturbed line and utilizing said residual control voltage to reduce the magnitude of the residual voltage in the disturbed line.

19. The method of neutralizing alternating current voltages of small magnitudes in systems of communication which comprises producing in the region of disturbance a control voltage of substantially the same order
 70 of magnitude as that of the disturbing alternating voltage, generating a neutralizing voltage of substantially the same magnitude and frequency and of substantially opposite phase to said disturbing voltage, combining
 75 it with said control voltage to produce a resultant voltage, amplifying the resultant voltage, and regulating said neutralizing voltage by said amplified voltage in accordance with variations of the disturbing voltage.

20. The method of neutralizing alternating current voltages of small magnitudes in systems of communication which comprises producing in the region of disturbance a control voltage of substantially the same order
 85 of magnitude as that of the disturbing alternating voltage, generating a neutralizing voltage of substantially the same magnitude, frequency and phase as said disturbing voltage, opposing it to said disturbing and control
 90 voltages, and amplifying the resultant control voltage, and regulating the magnitude, frequency and phase of said neutralizing voltage by said amplified voltage in accordance with variations in magnitude, frequency and phase of said control voltage.

21. In a system for neutralizing alternating current induction, a generator system for producing a neutralizing voltage, control means for regulating the magnitude of the
 100 neutralizing voltage and separate control means for regulating the frequency and phase relation of the neutralizing voltage.

22. The method of neutralizing alternating current induction which comprises amplifying a control voltage, regulating an alternating current generator system by the amplified voltage to produce a neutralizing
 105 voltage, and opposing the neutralizing voltage to the induction.

In testimony whereof I affix my signature.
 JOSEPH W. MILNOR.