

May 7, 1940.

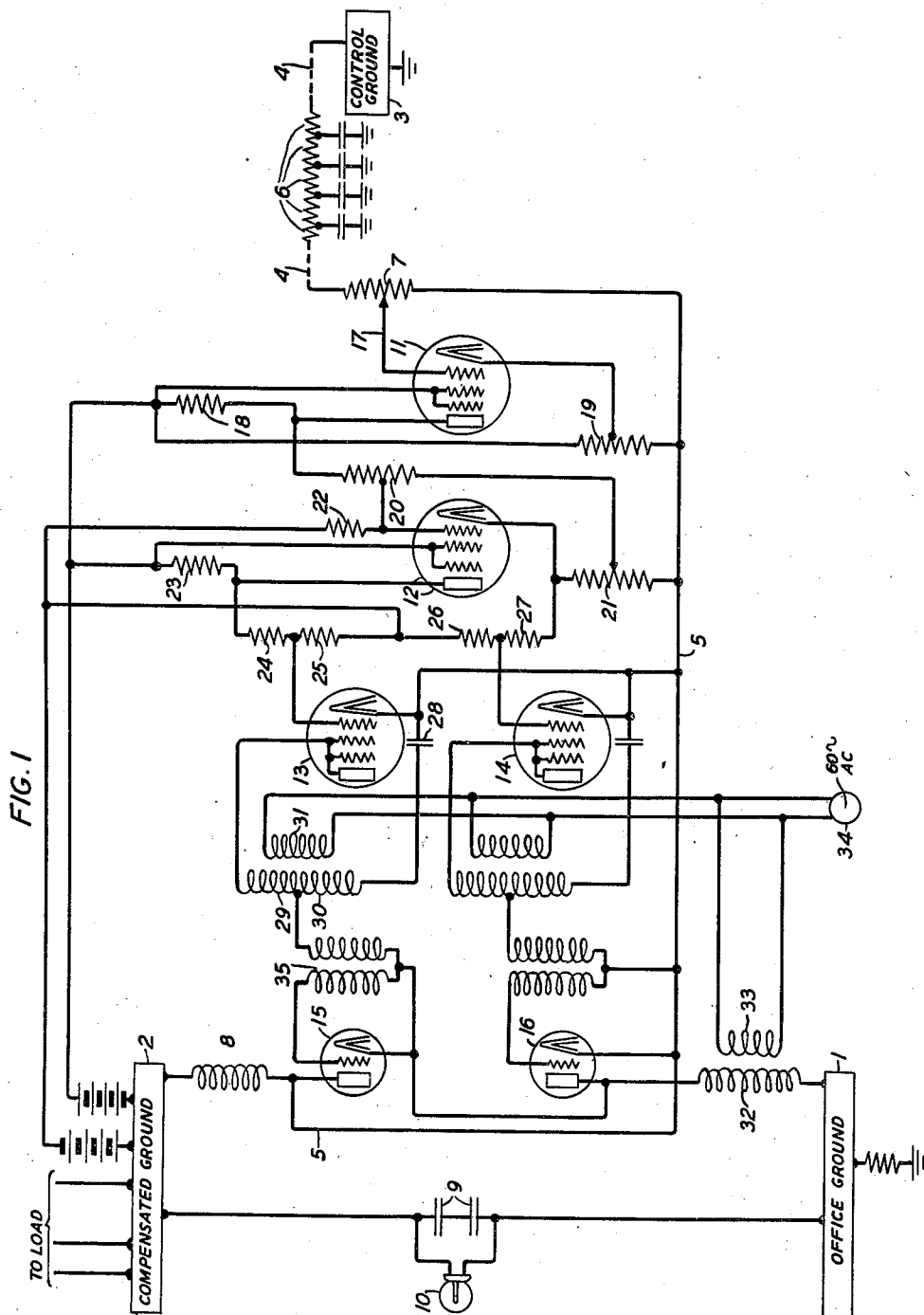
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2,199,558

GROUND POTENTIAL COMPENSATOR

Filed April 7, 1939

2 Sheets-Sheet 1



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FIG. 3

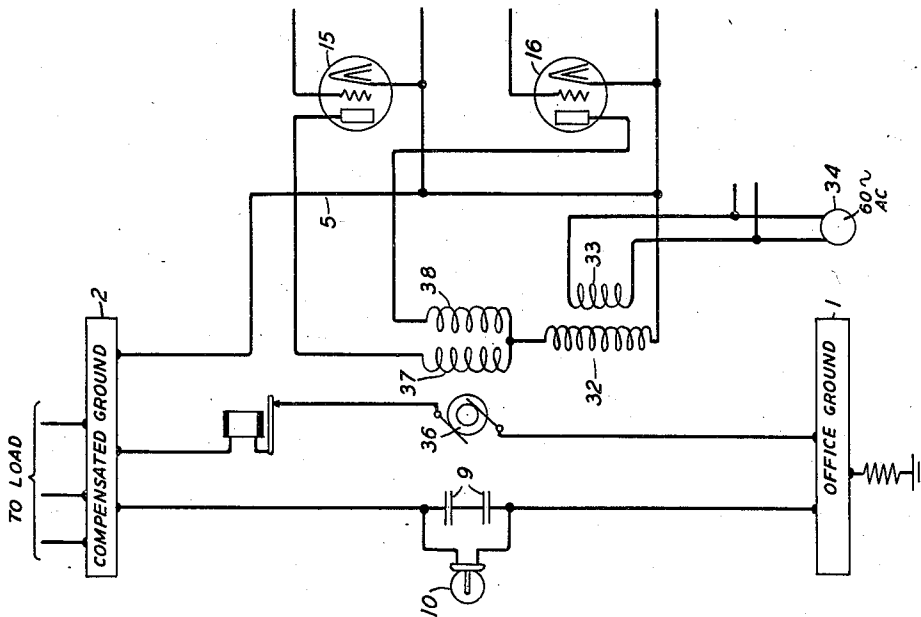
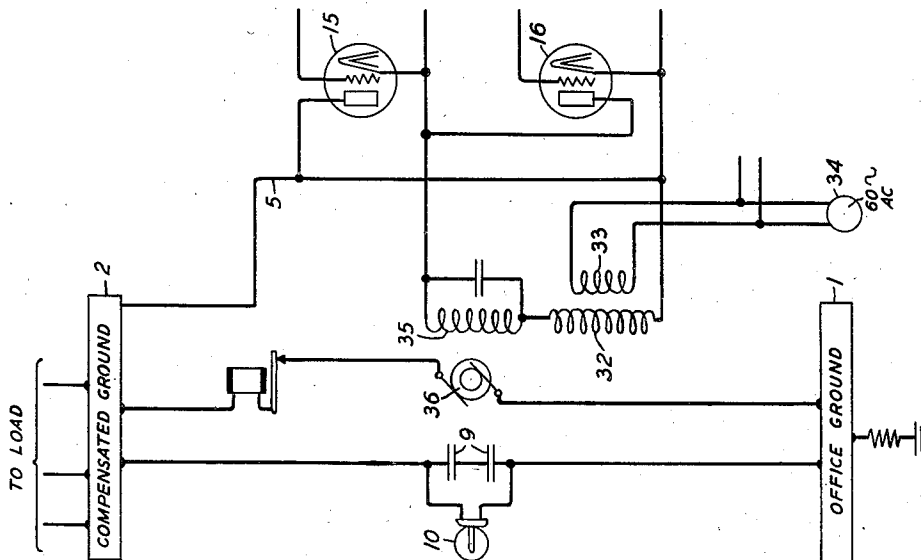


FIG. 2



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2,199,558

GROUND POTENTIAL COMPENSATOR

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Application April 7, 1939, Serial No. 266,666

9 Claims. (Cl. 178—69)

This invention relates to regulating systems and particularly to devices used in communication systems for maintaining the potential at one point substantially equal to the potential at a distant point so that communication between such points will not be disturbed by ground potentials.

It is usual to employ an artificial ground connection and to regulate this in accordance with the potential of the earth at a distant office. Heretofore, direct current generators have been employed and means controlled from the distant office have been used to excite the fields of these generators.

The object of the present invention is to improve this general arrangement by regulating the potential of the artificial or compensated ground by supplying to it either plus or minus direct current by rectifying alternating current. Since the ground potential at the distant control point may shift rapidly and from one extreme to another, the rectifying means here used must be equally rapidly shifted.

A feature of the invention is a pair of rectifying tubes, one for supplying direct current in one direction and the other for supplying direct current in the opposite direction which may be rapidly controlled so that one at a time is effective and over a wide range.

Another feature of the invention is an alternating current phase shifting bridge circuit for controlling the rectifying tube. When two such bridge circuits are used, one to control each rectifying tube, the transition from operation at peak value of one rectifying tube through non-operation of both tubes to operation of the other may be smooth and rapid and, in fact, may be instantaneous.

In accordance with another feature of the invention, a potentiometer circuit is formed between the control ground and the compensated ground and a vacuum tube amplifier is employed to amplify potential changes as they may occur to in turn control the phase shifting bridge circuits.

In one form of the invention, the rectified alternating current is used to excite a ground compensating generator. In another form, the rectified alternating current is fed directly into the compensated ground whereby the delay in following the potential changes due to inductance in the generator field circuits is avoided. With compensation carried out by vacuum tube circuits alone, the changes are practically instantaneous and the compensation is, therefore, more nearly perfect than it has heretofore been possible to attain.

The drawings consist of two sheets, the first containing Fig. 1 and the second containing Figs. 2 and 3.

Fig. 1 is a circuit diagram illustrating the preferred embodiment of the present invention; and

Figs. 2 and 3 are skeleton circuit diagrams illustrating variations of the invention, only enough of the circuits being shown to explain such variations.

Fig. 1 shows one embodiment of the invention. Here is shown an office ground 1 which, because of some resistance to ground, is unsatisfactory as a connection for communication circuits extending to a distant point. At some other point there is another ground connection, here designated as a control ground 3. Between the office ground 1 and other distant stations there exists a varying ground potential. To overcome the effects of this and render the operation of communication circuits between these points stable, a compensated ground 2 is provided and the circuits of this figure illustrate a means for maintaining the potential of the compensated ground 2 constantly at the same level as the potential of the control ground 3 which is so chosen as to have zero ground potential.

Essentially, this means consists of a source of rectified alternating current connected between the office ground 1 and the compensated ground 2 by rectifier tubes. Certain pieces of electrical apparatus, such as impedance coil 8, condensers 9 and ballast or tungsten filament lamp 10, constitute a low-pass filter whereby the rectified alternating current is effectively transformed into a direct current potential to raise or lower the potential of the compensated ground 2 above or below the potential of the office ground 1. The amount by which the potential of the compensated ground 2 is varied is controlled by a vacuum tube circuit in accordance with the variations of the potential of the distant control ground 3.

This control is exercised by virtue of a connection from the control ground 3 to the compensated ground 2, comprising conductor 4, potentiometer 7, conductor 5, and impedance coil 8. The conductor 4 is shown extending through certain resistances 6 and condenser connections to ground to illustrate the normal condition of a long line, which in some cases may be of the order of a hundred miles. From a point on the potentiometer 7 there is a connection to a vacuum tube 11 which acts as a simple amplifier. This feeds into another vacuum tube 12 which in turn controls a pair of vacuum tubes 13 and 14. Under normal balanced conditions, the tube 12 maintains the grids of vacuum tubes 13 and 14 both at the same potential, but when a change takes place the potential of the grid of tube 13 is raised or lowered, while the potential of the grid of tube 14 is correspondingly lowered or raised by the same amount.

The tubes 13 and 14 form variable elements

in two alternating current phase shifting bridges for controlling rectifier tubes 15 and 16, respectively. A source of alternating current 34 is connected to a transformer having a primary winding 31 and a secondary winding comprising coils 29 and 30, to a similar transformer associated with tube 14 and to a transformer having a primary winding 33 and a secondary winding 32. As will be explained more in detail hereinafter, this alternating current connection will result in the flow of rectified current from the compensated ground 2 through the anode-cathode circuit of tube 15 to the office ground 1 over a range from a maximum value to zero or, similarly, from the office ground 1 through the anode-cathode circuit of tube 16 to the compensated ground 2 from a maximum value to zero.

The action of the alternating current phase shifting bridge and the control of the rectifier tubes is well known, and is described and the theory of operation is explained, for example, in an article entitled Hot-cathode Thyratrons in the General Electric Review, vol. 32, No. 7, for July, 1929.

The tubes 11 to 16 are shown with heater filaments unconnected to any circuit, but it will be understood that appropriate connections are made to the source of power 34. Such connections are omitted here for the sake of clarity in the drawings.

The condensers 9 are shown as a pair since they are of large capacity and in practice they would be of the electrolytic type. The lamp 10 indicates a ballast lamp which under practical conditions may be a tungsten filament electric lamp having a negative coefficient of resistance. This offers a path of low impedance between the office ground 1 and the compensated ground 2 under normal conditions when the potential of the compensated ground 2 is the same as the potential of the control ground 3 but will raise this impedance as current begins to flow therethrough.

In more detail, the constants of the tube 11 and its circuit are so adjusted that, when no potential difference exists between the compensated ground 2 and the control ground 3, the tube is working at about the mid-point of its characteristic curve and at this point the constants of the other tubes and their circuits are fixed so that there is no current flow from the office ground 1 to or from the compensated ground 2 and through the anode-cathode circuits of tubes 15 and 16. The arm 17 of the potentiometer 7 is so adjusted that if a difference of potential between the compensated ground 2 and the control ground 3 is set up, the potential of the grid of tube 11 becomes more positive or more negative. Since tube 11 acts as a simple amplifier, a plate current will flow through resistance 20, part of resistance 21, conductor 5, part of resistance 19, to the cathode of tube 11. The resistance 20 is in a circuit in which current flows from positive battery through resistance 18, resistance 20, part of resistance 21, conductor 5 and thence back to compensated ground. The variation in the current flow in resistance 20, caused by the action of tube 11, causes a change in the potential of tube 12 which is a corresponding and amplified change to that on the grid of tube 11.

Tube 11 is shown as a pentode with its plate connected to plus battery through a resistance 18 and its screen connected directly to battery. It will be understood, however, that the use of a pentode is not necessary as an equal result can be obtained from other types of tubes.

Tube 12, then, is controlled in the same way as tube 11, the latter acting as a simple amplifier of the change of potential on its grid. Tube 12 functions to control the potentials of the tubes 13 and 14. Under normal conditions these two grids are maintained at the same potential but as tube 12 is affected so are the grids of tubes 13 and 14. When the potential of the one is raised the potential of the other is lowered by an equal amount.

The plate of tube 12 is connected through a resistance 23 to positive battery, while positive battery is connected directly to the screen. From positive battery a circuit may be traced through the resistance 23, the potentiometer formed by resistances 24 and 25 to negative battery. Likewise, a circuit may be traced from negative battery through the potentiometer formed of resistances 26 and 27 through the resistance 21 to compensated ground. These resistances are all so chosen that, when there is no difference of potential between the compensated ground 2 and the control ground 3, the potentials on the grids of tubes 13 and 14 are equal. Then if the potential applied to the grid of tube 12 is varied the plate current of tube 12 varies and, due to the potentiometer connections to the grids of tubes 13 and 14, these tubes are affected, equally but in opposite directions. If the potential applied to the grid of tube 12 becomes more positive the potential of the grid of tube 13 is reduced by an increased drop across the resistance 23 and the potential of the grid of tube 14 is increased by an increased drop across resistance 21. If, on the other hand, the potential applied to the grid of tube 12 becomes more negative then the potential of the grid of tube 13 is increased by the reduced drop across resistance 23 and the potential of the grid of tube 14 is reduced by the reduced drop across the resistance 21. Thus the action of the tubes 13 and 14 is equal and opposite.

The anode-cathode circuit of tube 13 forms an adjustable arm of an alternating current phase shifting bridge, the other three arms being the condenser 28, the upper half 29 and the lower half 30 of the secondary winding of a transformer having a primary winding 31. The tube 15 is connected between diagonal points of this bridge, the grid of tube 15 being connected by means of the isolation transformer 35 to the point between transformer windings 29 and 30 and the anode-cathode circuit being connected to a point between the cathode of tube 13 and condenser 28. By means of the variation of the flow of current between the anode and cathode of tube 13, the grid of tube 15 is so affected that a perfect control of average current may be obtained in the circuit between the office ground 1 and the compensated ground 2 from zero to a maximum. Since the variation of the flow of current between the anode and cathode of tube 13 varies the phase of the grid of tube 15 with respect to its anode-cathode circuit, the tube 15 is rendered ineffective in varying degree.

In like manner but in an opposed direction, tube 14 controls tube 16 with the net result that the direct current potential set up on the compensated ground 2 through the action of tubes 15 and 16 may be smoothly changed from a maximum in one direction through zero to a maximum in the other direction.

Due to the great capacity of condensers 9 and the fact that the response of the vacuum tubes is extremely quick, the potential of the compensated ground 2 may be kept practically at a level with the potential of the control ground 3. Any

change in this potential immediately results in a great flow of current to quickly charge the condensers 9 in one direction or the other to maintain the potential level of the compensated ground 2.

Figs. 2 and 3 show variations of the invention. Fig. 2 shows how the output of the tubes 15 and 16 may be applied to the field 35 of a direct current generator 36 running at a constant speed. The reaction of such a device can be made sufficiently rapid to provide reasonably satisfactory compensation though the arrangement of Fig. 1 is preferred.

Fig. 3 shows how the output of tubes 15 and 16 may separately be applied to the windings 37 and 38 of a double field for generator 36. It is believed that the action of these arrangements will be fully understood in connection with the description of Fig. 1.

What is claimed is:

1. A ground connection for electrical communication systems comprising an office ground, a compensated ground, a control ground, a source of alternating current, rectifying means and a space discharge tube amplifier under control of said control grounds for controlling the flow of alternating current from said source rectified by said rectifying means between said office ground and said compensated ground in direction and volume sufficient to maintain said compensated ground at substantially the same potential as said control ground.

2. A ground connection for electrical communication systems comprising an office ground, a compensated ground, a control ground, a source of alternating current, rectifying means, a space discharge tube circuit for feeding direct current rectified from said alternating current source from said office ground into said compensated ground and a connection from said control ground to said discharge tube circuit for adjusting the flow of said current in said discharge tube circuit over a predetermined range on either side of zero for automatically maintaining the potential of said compensated ground at the same level as said control ground.

3. A ground connection for electrical communication systems comprising an office ground, a compensated ground, a control ground, a source of alternating current, and rectifying means connected between said office ground and said compensated ground, a potentiometer connection between said compensated ground and said control ground and a space discharge tube control circuit controlled from said potentiometer circuit for controlling the flow of rectified alternating current in direction and volume sufficient to maintain said compensated ground at substantially the same level as said control ground.

4. A ground connection for electrical communication systems, comprising an office ground, a compensated ground, a control ground, a source of alternating current and a pair of rectifying tubes, one for directing current in one direction and the other for directing current in the reverse direction connected between said office ground and said compensated ground, a potentiometer connection between said compensated ground and said control ground and a space discharge tube circuit controlled from said potentiometer circuit for regulating said rectifying tubes for automatically maintaining said compensated ground at substantially the same potential as said control ground.

5. A ground connection for electrical communication systems, comprising an office ground, a compensated ground, a control ground, a source of alternating current, a discharge tube rectifier circuit for feeding direct current rectified from alternating current from said source between said office ground and said compensated ground, an alternating current phase shifting bridge circuit for controlling said rectifier circuit, and means for controlling said alternating current phase shifting bridge circuit from said control ground.

6. A ground connection for electrical communication systems comprising an office ground, a compensated ground, a control ground, a source of alternating current, a connection between said office ground and said compensated ground including a connection from said source of alternating current and the anode-cathode circuits of two space discharge tubes oppositely connected in parallel with each other, an alternating current phase shifting vacuum tube bridge circuit for controlling each of said discharge tubes, and means for controlling said alternating current phase shifting vacuum tube bridge circuits in inverse relation to each other both from said control ground.

7. A ground connection for electrical communication systems, comprising an office ground, a compensated ground, a control ground, a source of alternating current, rectifier means for feeding direct current rectified from said alternating current over a range from a predetermined plus value through zero to a predetermined minus value into said compensated ground, and a pair of alternating current phase shifting discharge tube bridge circuits, one directly and the other inversely responsive to potential changes in said control ground for controlling said rectifier means.

8. A ground connection for electrical communication systems comprising an office ground, a compensated ground, a control ground, a direct current generator having its armature connected between said office ground and said compensated ground, a source of alternating current, rectifying means for energizing the field of said generator from said source of alternating current, and a pair of alternating current phase shifting discharge tube bridge circuits, one directly and the other inversely responsive to potential changes in said control ground for controlling said rectifying means.

9. A ground connection for electrical communication systems comprising an office ground, a compensated ground, a control ground, a direct current generator having its armature connected between said office ground and said compensated ground, a source of alternating current, rectifying means for energizing the field of said generator from said source of alternating current, a pair of alternating current phase shifting space discharge tube bridge circuits, one directly and the other inversely responsive to potential changes in said control ground for controlling said rectifying means, said generator field comprising two normally opposed windings and said rectifying means comprising a space discharge tube controlled by each of said alternating current phase shifting bridges for separately exciting said field windings.

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