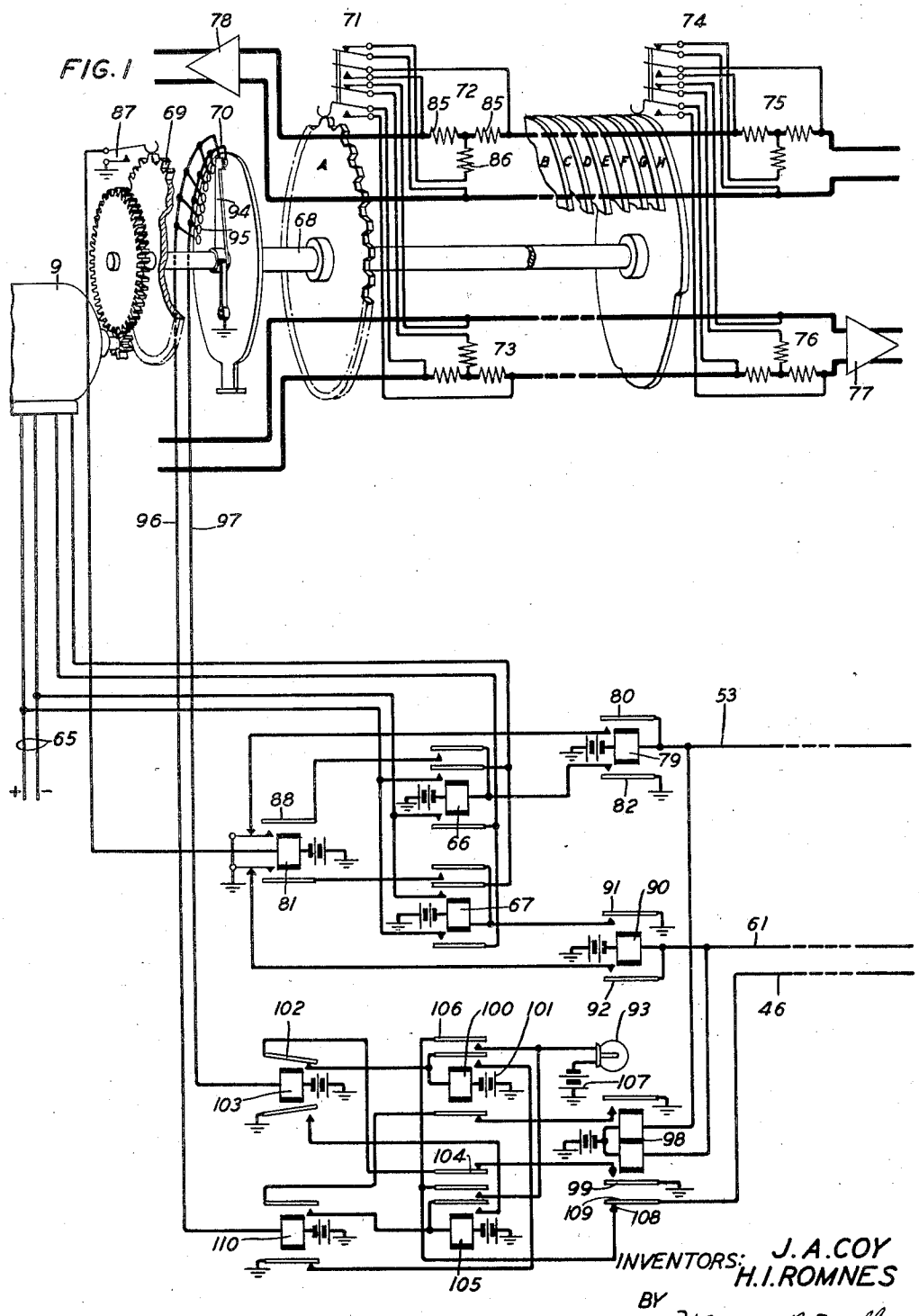
Oct. 15, 1935. J. A. COY ET AL 2,017,654

GAIN CONTROL CIRCUIT

Filed Oct. 17, 1931 3 Sheets-Sheet 1

FIG. 1



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GAIN CONTROL CIRCUIT

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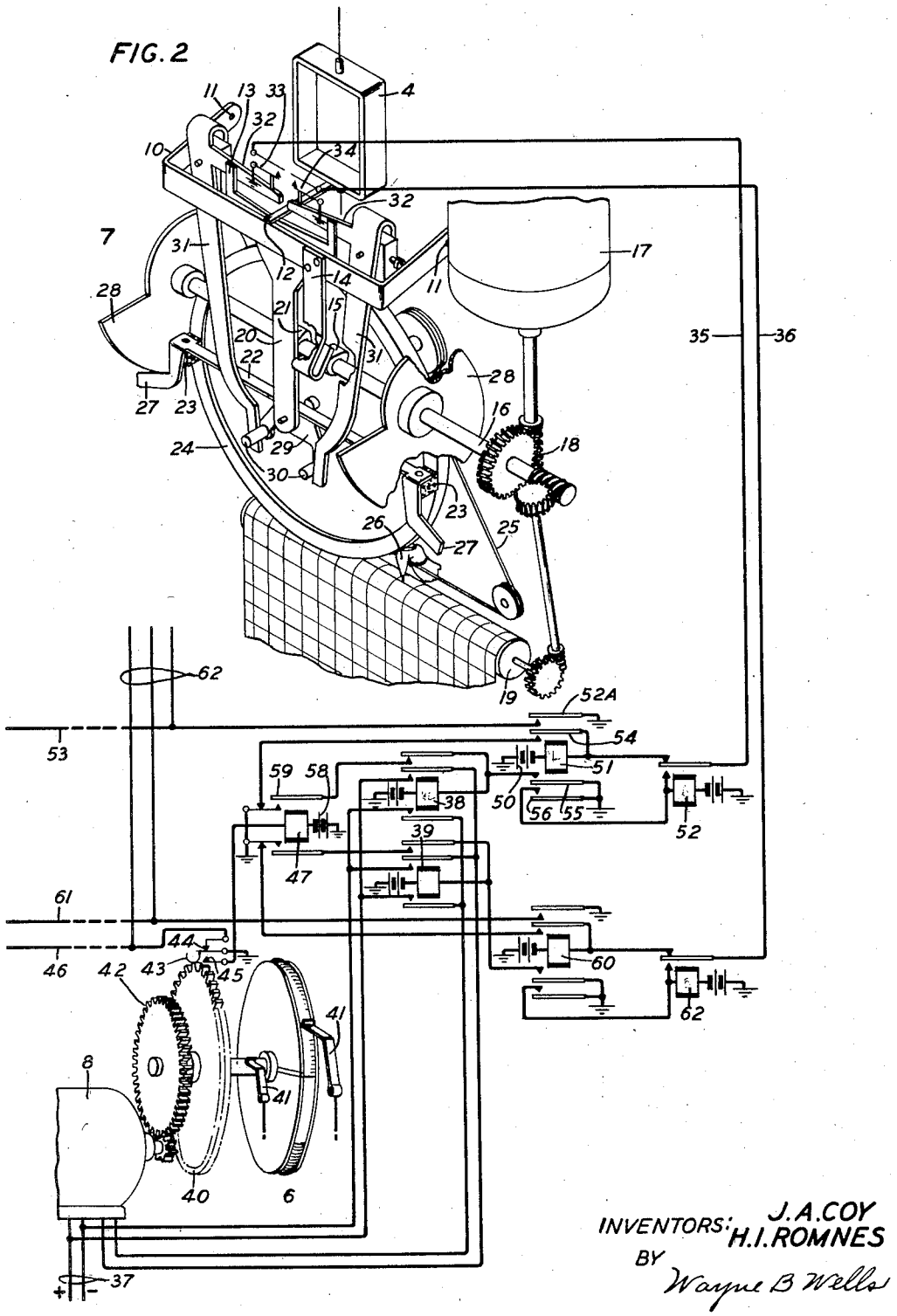
FIG. 2



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GAIN CONTROL CIRCUIT

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FIG. 3

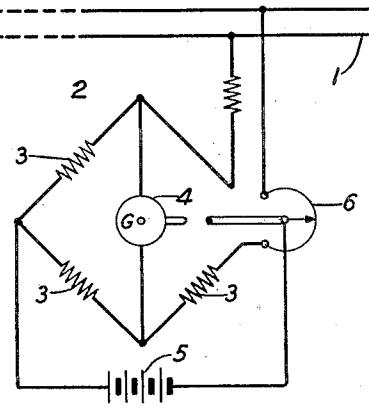
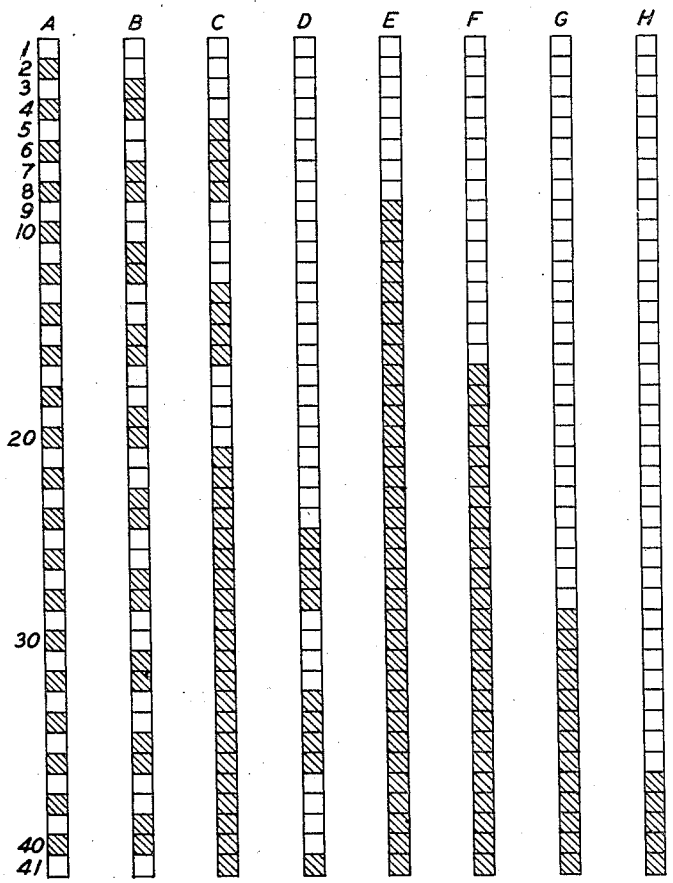


FIG. 4



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UNITED STATES PATENT OFFICE

2,017,654

GAIN CONTROL CIRCUIT

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Application October 17, 1931, Serial No. 569,360

16 Claims. (Cl. 178—44)

This invention relates to control circuits for adjusting the gain on signal transmission lines and particularly to gain control circuits at repeater stations on telephone toll lines.

One object of the invention is to provide a gain control system for controlling the gain at a repeater station on toll lines that shall compensate for changes in attenuation on the toll lines due to temperature changes in a new and improved manner.

Another object of the invention is to provide a gain control system for a repeater station on a signal transmission line that shall vary the gain on the line at the repeater station under the control of a pilot line to compensate for attenuation changes on the line in a manner to prevent objectionable clicks on the line and to insure against interference with the transmission of signals on the line in case of failure of power on the gain control system.

Another object of the invention is to provide a gain control system for a repeater station on a signal transmission line that shall govern a galvanometer according to the attenuation variations on a pilot line associated with the transmission line and control a reversible motor according to the operation of the galvanometer to control the number of impedance pads in the transmission line at the repeater station in an improved manner.

A further object of the invention is to provide a gain control system having a pilot line associated with a signal transmission line and forming one arm of a Wheatstone bridge circuit, a galvanometer connected to the bridge circuit and operated according to the attenuation variations on the pilot line, a main motor controlled by the galvanometer to restore the bridge balance and a gain control motor governed by the galvanometer that shall operate a plurality of cam members according to the operation of the gain control motor to govern a number of impedance pads at a repeater station on the signal transmission line.

The attenuation of a signal transmission line varies according to temperature changes. It is necessary to compensate for such changes of attenuation by reason of temperature changes to obtain good transmission characteristics. It is customary to vary the attenuation of a line by varying the gain at repeater stations.

In a gain control system constructed in accordance with our invention, the gain at a repeater station for one or any number of toll lines is varied to correct the attenuation of the line or lines in accordance with the changes caused by temperature variation. A pilot line which is associated with the toll lines and which is subjected to the same temperature variations as the toll lines is employed to control the gain at the repeater station. In the case of cable toll circuits, one pair of wires which is subjected to average temperature conditions is selected as the pilot line.

The pilot line which is associated with the toll lines and which is subjected to the same temperature variations as the toll lines forms one arm of an impedance Wheatstone bridge circuit. A galvanometer which is connected across opposite vertices of the Wheatstone bridge circuit is operated in accordance with the variations in attenuation on the pilot line. The galvanometer operates a mechanism of the type disclosed in the C. A. Borland et al. Patent No. 1,717,831, dated June 18, 1929, for Controlling a main motor and a gain control motor. The main motor operates a slide wire resistance element for restoring the balance of the Wheatstone bridge circuit after each operation of the galvanometer. The main motor also operates a centering cam element for insuring the operation of the main motor a fixed step or a number of fixed steps for each operation of the galvanometer.

The gain control motor which is operated in a forward and a reverse direction in accordance with the operation of the galvanometer serves to govern the operation of a plurality of cam members which in turn control a number of attenuation or impedance pads in the toll line or lines at a repeater station. The gain control cam elements directly operate switching elements which in turn control the insertion and exclusion of the pads from the toll lines. A centering cam is also associated with the gain control motor for insuring that the gain control motor operates a fixed step or a number of fixed steps for each operation of the galvanometer. The term "fixed step" when used to describe each movement of the main motor or the gain control motors is intended to mean a step of unit amount so that all steps in the operation of the motors are equal.

A dial switch which is operated by the gain control motor cooperates with switching mechanism operated by the main motor for operating an alarm in case the gain control motor does not operate in accordance with the operation of the galvanometer and the main motor.

In the disclosed gain control system eight gain control cam elements are associated with each

repeater for controlling pads on opposite sides of a toll line. The gain control motor preferably will operate five sets of gain control cams on five different toll lines. Only one main motor and one galvanometer are required for controlling the gain on all the pairs of toll lines in one toll cable. In a cable having, for example, 300 pairs of toll lines, a set of eight gain control cams and a set of eight pads will be required for each toll line. One gain control motor will be required as before set forth, for operating five sets of gain control cams and five sets of gain control pads; thus, 60 gain control motors will be required for controlling the gain at the repeaters on the 300 pairs of toll lines. The 60 gain control motors will be associated with one galvanometer and one main control motor.

The gain control cams which are formed in units of 8 each have 41 different positions to effect 41 different combinations of the impedance pads in a toll line. The gain control cams are operated in a forward and a reverse direction according to the direction of operation of the gain control motor to increase or decrease the gain in a toll line at the repeater station. Very little power is required to operate the main motor and the gain control motors and in case of failure of the power supplied to these motors, no objectionable interference with the transmission of signals over the toll line would be effected. It has been customary in some cases to control pads at the repeater station by relays. Objectionable clicks are caused by the operation and release of relays in the normal operation of the circuits. If the power fails, all relays release causing the repeater gain to be so widely changed that the circuits become commercially useless.

In the accompanying drawings, Figs. 1 and 2 taken together disclose a galvanometer controlling a gain control system constructed in accordance with the invention.

Fig. 3 is a diagrammatic view showing the connection of the pilot line to the Wheatstone bridge circuit for operating the galvanometer.

Fig. 4 is a developed view of the gain control cams.

Referring to Fig. 3 of the drawings, a pilot line 1 is assumed to be one pair of lines in a cable and to be subjected to the same conditions, as for example, temperature, as the other pairs of toll lines in the cable. The pilot line 1 forms one arm of a Wheatstone bridge circuit 2. The other arms of the Wheatstone bridge circuit 2 are preferably resistance elements 3. A galvanometer 4 is connected across two opposite vertices of the Wheatstone bridge circuit and a suitable source of current 5 is connected across the other two vertices of the bridge circuit. A slide wire resistance element 6 which is controlled by the galvanometer 4 in a manner to be described hereinafter serves to restore the balance of the bridge circuit after each operation of the galvanometer 4.

The galvanometer 4 is operated in accordance with the variations in resistance of the pilot line 1 and accordingly is operated according to the variation in attenuation of the toll lines in the cable carrying the pilot line. In Figs. 1 and 2, the galvanometer 4 is shown controlling a galvanometer mechanism 7 for governing the operation of a main motor 8 and a plurality of gain control motors 9. Only one gain control motor 9 is shown on the drawings. The other gain control motors are similar in construction and operation to the illustrated motor 9 and operate apparatus similar to the apparatus shown operated by the illustrated motor 9.

The galvanometer mechanism 7 controlled by the galvanometer 4 comprises a U-shaped rocker arm 10 which is pivotally mounted at points 11. The pointer member 12 of the galvanometer 4 rides on a U-shaped supporting member 13 which is attached to the rocker arm 10. The member 13 limits the movement of the galvanometer pointer 12. An arm 14 secured to the rocker arm 10 engages a cam member 15 on a constantly rotating shaft 16. The shaft 16 is preferably connected to a motor 17 by a suitable gearing 18. The gearing 18 also connects the motor 17 to a recording paper roll 19. The constant rotation of the cam member 15 serves to raise the rocker arm 10 at predetermined intervals. Preferably the rocker arm is operated approximately every eight seconds. A flexible arm 20 engages a second constantly rotating cam member 21 on the shaft 16. A cross arm 22 is pivotally mounted on the resilient arm 20 and carries a pair of shoes 23 which are adapted to frictionally engage a disc 24. The disc 24 by means of a flexible connecting member 25 serves to control the movement of a recording pen 26. The cross arm 22 terminates in a pair of projecting lugs 27 which are located in a position such that a pair of rotating cams 28 on the constantly rotating shaft 16 will normally not engage them. A plate 29 is fixed to the cross arm 22 and carries a pair of pins 30. Pivotally mounted arms 31 are held in engagement with the pins 30 by any suitable spring means not shown. The arms 31 are provided with projections 32 positioned above the pointer 12 of the galvanometer 4. When the galvanometer needle or pointer 12 is deflected in one direction or the other it will pass under one of the projections 32 attached to the arms 31 and upon the rising of the rocker arm 10 under control of the cam 15 on the constantly rotating shaft 16, one of the arms 31 will be given a movement of rotation to rotate the cross arm 22 on its pivotal support. The rotative movement of the cross arm 22 places one of the projections 27 in the path of movement of one of the cam members 28. The cam member 28 upon engaging the projection 27 on the cross arm 22 moves the cross arm back to its original position. At this time the cam member 21 will act to allow the shoes 23 on the cross arm 22 to frictionally engage the disc 24 and as the rocker arm is given a movement of rotation, it will give a like movement of rotation to the disc 24 for controlling the recording needle 26.

The projections 32 on the arms 31 not only control the rotation of the disc 24 for recording purposes, but also control two switches 33 and 34. The switch 33 serves to place a ground on a conductor 35 when the galvanometer 4 is operated to reduce the gain at a repeater station. The switch 34 places a ground on a conductor 36 when the galvanometer is operated to increase the gain at a repeater station.

The switches 33 and 34 controlled by the galvanometer 4 serve to operate the main motor 8 in a forward and in a reverse direction and also to control all of the gain control motors 9. The main motor 8 is preferably a shunt wound motor having the field winding thereof directly connected to suitable power conductors 37. The armature of the main motor 8 is connected to the power conductors 37 by means of relays 38 and 39, the relay 38 serving to operate the motor 8 in one direction

and the relay 39 serving to operate the motor in a reverse direction. The main motor 8 is geared to a shaft carrying a centering cam member 40 and the slide wire resistance 6. The slide wire resistance serves to restore the balance of the Wheatstone bridge circuit upon operation of the galvanometer 4. Two brushes 41 are provided for completing the circuit through the slide wire resistance element 6.

The centering cam 40 is provided with cam projections 42 equal in number to the steps or changes in the gain that can be effected at the repeater station. In the system under consideration, the cam member is assumed to have 41 cam projections corresponding to the 41 different steps of gain that can be effected at the repeater station. The centering cam 40 operates a switch member 43 which engages a contact member 44 or a contact member 45. When the switch member 43 engages the contact member 44, a ground is placed upon a conductor 46 for operating an alarm in case any one gain control motor does not follow the operation of the main motor 8 and the galvanometer 4. When the switch member 43 engages the contact member 45 a relay 47 is operated.

Assuming the switch 33 is closed by the galvanometer 4 for reducing the gain at the repeater station, a circuit is completed from a grounded battery 50 through the coil of a relay 51 and a switch arm of a relay 52. The relay 51 operates a switch arm 52A for placing a ground on a conductor 53, a switch arm 54 for establishing a locking circuit for the relay through a switch arm controlled by the relay 47, and a switch arm 55 for completing a circuit to operate the relay 38. The relay 51 also operates a fourth switch arm 56 for effecting operation of the relay 52 to break the operating circuit for the relay 51. Upon operation of the relay 38, a circuit is completed from the power conductors 37 through the armature winding of the main motor 8 to effect operation of the main motor in a direction for operating the slide wire resistance to restore the balance of the Wheatstone bridge circuit. The centering cam 40 is also operated by the motor 8. When the centering cam is moved to the position whereby the switch member 43 engages the contact member 45, a circuit is completed from the grounded battery 58 for operating the relay 47. The relay 47 operates a switch arm 59 for breaking the holding or locking circuit for the relay 51 and for establishing a locking circuit for the relay 38. The switch arm of relay 52 is released upon release of relay 51 by the operation of the relay 47 under control of the centering cam 40. As soon as the centering cam 40 has moved one step to the next cam projection, the switch member 43 disengages contact member 45 and engages the contact member 44. A ground is placed upon the conductor 46 and the relay 47 is released to release the relay 38 and stop the operation of the main control motor 8.

In case the galvanometer 4 is operated to increase the gain at the repeater station, the switch 34 is closed to place a ground on the conductor 36. The placing of a ground on the conductor 36 operates a relay 60 from a grounded battery in the same manner as the relay 51 is operated from the grounded battery 50 when ground is placed upon the conductor 35 by the switch 33. Relay 60 is similar in construction and operation to the relay 51 and upon operation serves first to establish a locking circuit for itself through a contact arm of the relay 47; second, to place a ground upon the conductor 61; third, to effect operation of the motor relay 39; and fourth, to effect operation of a relay 62 which corresponds to the relay 52 associated with conductor 35. The relay 62 breaks the energizing circuit for the relay 60 and leaves relay 60 under the control of the relay 47 governed by the centering cam 40. The operation of the motor relay 39 completes a circuit through the armature winding of the main motor 8 from the power conductor 37 for effecting operation of the motor in a reverse direction. The operation of the motor 8 serves again to govern the slide wire resistance 6 to restore the balance of the Wheatstone bridge circuit and to operate the centering cam 40. Centering cam 40 first operates the relay 47 for releasing the relays 60 and 62 and then breaks the operating circuit of the relay 47 to release the motor relay 39 and stop the operation of the motor. The centering cam 40 limits the operation of the main motor 8 to a fixed step. If the wire resistance 6 is not adjusted sufficiently by one motor step to balance the bridge circuit then the main motor is operated step by step until the bridge circuit is balanced. The conductors 53, 61 and 46 which extend from the relay mechanism controlling the main motor 8 serve to control all the gain control motors 9 which govern the gain on all the pairs of toll conductors in the toll cable in which the pilot line is located.

In Fig. 2 of the drawings, conductors 53, 61 and 46 are shown connected to mechanism for operating one gain control motor 9 shown in Fig. 1 of the drawings. Conductors 62 which are connected to the conductors 53, 61 and 46 are assumed to control the operation of another gain control motor.

The gain control motor 9 shown in Fig. 1 of the drawings is preferably a shunt wound motor having the field winding directly connected to a source of power comprising conductors 65. The armature winding of the gain control motor 9 is connected to the power conductors 65 by means of motor relays 66 and 67, the relay 66 when operated serving to effect rotation of the motor 9 in one direction and the relay 67 when operated serves to effect rotation of the motor 9 in a reverse direction. The relays 66 and 67 operate in controlling the gain control motor 9 similar to the operation of the relays 38 and 39 which control the operation of the main motor 8.

The gain control motor 9 is geared to a shaft 68 carrying a centering cam 69 similar to the centering cam 40 which is operated by the main motor 8, a dial switch 70 and a set of gain control cam members A, B, C, D, E, F, G, and H. Although only one set of eight gain control cam members is shown mounted on shaft 68, it is to be understood that a number of similar gain control cam members are operated by each gain control motor. Preferably each gain control motor operates five sets of gain control cam members.

One set of gain control cam members is shown developed in Fig. 4 of the drawings. Each cam of the set controls a switch member which in turn controls a pad in the east to west channel at the repeater station and a pad in the west to east channel at the repeater station. In Fig. 1 of the drawings the cam member A is shown controlling a gain control switch 71 which in turn controls an impedance pad 72 in the east to west channel of the repeater and an impedance pad 73 in west to east channel of the repeater. The cam member H is shown controlling a switch member 74 similar to the switch member 71. Switch member 74 controls two pads 75 and 76. The

cam members B to G inclusive between the cam members A and H operate switches similar to switches 71 and 74 which in turn control impedance pads similar to the impedance pads 72 and 73 controlled by the cam member A and impedance pads 75 and 76 controlled by the cam member H. Preferably the pads controlled by the various cam members are not of equal value in order to obtain a greater range of gain control. The impedance pads controlled by the cam member A may compensate for ½ *db*, the pads controlled by the cam member B may compensate for 1 *db*, the pads controlled by cam members C and D may compensate for 2 *dbs*, and the pads controlled by the cam members E, F, G and H may compensate for 4 *dbs*.

The pad 72 is shown comprising an impedance element 85 which is adapted to be connected in series with the east to west side of the repeater and an impedance element 86 which is adapted to be connected across the east to west side of the repeater. The switch 71 which is operated by the cam member A is shown engaging a cam projection on the cam member A and when in such position the impedance element 85 is in series with the east to west side of the repeater and the impedance element 86 is connected across the east to west side of the repeater. The switch 71 at the same time effects a like connection of impedance elements comprising the pad 73 in the west to east side of the repeater. When the cam member A is moved so that the switch member 71 does not engage the cam projection, then the impedance element 85 is shunted and the shunt connection of the impedance element 86 across the line is opened. The switches controlled by the cam members B to H inclusive are similar in construction and operation to the switch member 71 and the pads associated with the other switches are similar in construction to pads 72 and 73 except that the pads vary in size. An amplifier 77 is shown in the west to east side of the repeater included in Fig. 1 of the drawings and an amplifier 78 is shown in the east to west side of the repeater. Preferably the amplifiers 77 and 78 are of the thermionic type.

Assuming the galvanometer 4 is operated to close the switch 33 and reduce the gain at the repeater station, the mechanism associated with the main motor 8 is operated as before set forth and at the same time a ground is placed on the conductor 53 by the switch arm 52A operated by the relay 51. The ground placed on the conductor 53 completes a circuit from a grounded battery for operating a relay 79. The relay 79 operates a switch arm 80 for completing a locking circuit for itself through a switch arm controlled by a relay 81. A second switch arm 82 operated by the relay 79 completes a circuit for operating the motor relay 66. The motor relay 66 completes a circuit from the power conductors 65 for operating the motor in a direction to increase the number of resistance pads in the gain control circuits at the repeater station.

Upon operation of the gain control motor 9, a switch 87 is closed by the centering cam 69. The closure of switch 87 completes a circuit for operating relay 81. Relay 81 operates a switch member 88 for establishing a locking circuit through the relay 66 and at the same time opens the holding circuit for the relay 79. The switch 87 is held closed until the motor 9 has made a complete step. The relay 81 is then released to open the locking circuit for the motor relay 66. The relay 66 opens the circuit of the motor 9 for preventing further operation of gain control cams. The gain control motor 9 is limited in its operation to a fixed step by the centering cam 69 in the same manner as the main motor 8 is limited to a fixed step by the centering cam 40. In such manner the cam members A to H inclusive are operated fixed steps to vary the pads in the line at the repeater station fixed amounts.

If the galvanometer 4 is operated in a direction to close the switch 34 for increasing the gain at the repeater station, the relay 60 as hereinbefore set forth is operated for effecting operation of the main motor 8. At the same time relay 60 grounds the conductor 61 which controls the operation of the gain control motor 9 in a predetermined direction. The grounding of conductor 61 completes a circuit for operating a relay 90. The relay 90 operates the switch member 91 for completing a circuit for operating the motor relay 67. A second switch member 92 is operated by the relay 90 for establishing a locking or holding circuit for the relay 90 under control of relay 81. The motor relay 67 upon operation completes a circuit from the power conductors 65 through the armature of the motor 9 for operating the motor in a reverse direction to that which it had been operated by means of the relay 66. The cam members A to H inclusive will be operated in a reverse direction for controlling the switches operated thereby to reduce the number of pads included in the line at the repeater station. The centering cam 69 again closes the switch 87 for operating the relay 81. The relay 81 breaks the holding circuit for the relay 90 and completes a holding circuit for the motor relay 67. When the gain control motor is operated a fixed step, the centering cam 69 opens switch 87 for releasing the relay 81. The relay 81 releases the motor relay 67 which in turn opens the circuit of the gain control motor 9.

The dial switch 70 which is operated by the gain control motor 9 serves to operate an alarm in case the gain control motor 9 and the cam member operated thereby do not follow the operation of the main motor 8 and the galvanometer 4. In Fig. 1 of the drawings, the alarm is shown in the form of a lamp 93. The dial switch 70 comprises a grounded switch arm 94 which is mounted to rotate with the shaft 68. The switch arm 94 engages contact members 95 which are alternately connected to conductors 96 and 97. The number of contact members 95 is equal to the number of gain control steps that can be effected in the system. In the system under consideration, the number of steps is assumed to be 41.

Assuming that the switch arm 94 of the dial switch is in engagement with a contact member 95 connected to the conductor 97 when ground is placed on the conductor 53 by operation of the relay 51 when the galvanometer 4 closes the switch 33, a relay 98 is operated by the grounding of the conductor 53. The relay 98 operates a switch member 99 for completing a circuit to effect operation of a relay 100. The circuit for operating the relay 100 may be traced from grounded battery 101 through the coil of relay 100, switch member 102 of relay 103, switch member 104 of relay 105, switch member 99 of relay 98 and ground return to the battery 101. The relay 100 operates a switch member 106 for connecting a circuit from a grounded battery 107 through the lamp 93 to a contact member 108

adapted to be engaged by a switch member 109 operated by the relay 98. At this time the relay 98 is assumed to be operated by the ground on the conductor 53 which is established by the switch member 52A of the relay 51. However, when the main motor 8 has completed its operation and the relay 51 is released to release relay 98, then the switch member 109 is released to engage the contact member 108. At this time if the gain control motor 9 fails to follow the operation of the main motor 8, a circuit will be completed from the battery 107 through the lamp 93, contact member 106, contact member 108, switch member 109, and a ground return established by the switch member 43 controlled by the centering cam 40 of the main motor. If such circuit is completed, the lamp 93 will be lighted. However, such circuit will only be completed in case the gain control motor 9 fails to follow the operation of the main motor. In the case under consideration, it has been assumed that the switch arm 94 has not moved away from the contact member 95 connected to the conductor 97. If the switch arm 94 had moved one step so as to engage a contact member 95 connected to the conductor 96, then the circuit for operating relay 103 would have been opened to prevent operation of the alarm.

If the switch arm 94 of the dialing switch is in engagement with a contact member 95 connected to the conductor 96, then a relay 110 will be operated in place of the relay 103 when the gain control motor 9 fails to follow the operation of the main motor. The relay 98 is operated by ground on the conductor 61 in the same manner as it is operated by a ground on the conductor 53. When the relay 110 is operated by the dialing switch, a relay 105 is operated in the same manner as relay 100 for establishing a circuit through the lamp 93. The relays 103 and 110 prevent operation of the alarm except when the gain control motor fails to complete its operation.

The developed view of the cam members A to H inclusive shown in Fig. 4 of the drawings indicates the 41 steps of the gain control system. The squares which are in cross-section on the various cam members indicate cam projections for operating switches to insert the pads in the line. For example, in position 1 no pads are inserted in the line; in position 2 the pad controlled by the cam member A is inserted in the line; in position 3 the pad controlled by the cam member B is inserted in the line; and in position 4 the pads controlled by the cam members A and B are inserted in the line.

It is to be understood that although only one set of cam members is shown connected for operation by the gain control motor 9, that at least four other sets of cam members are operated by the gain control motor. Furthermore, it is to be understood that any desired number of gain control motors 9 may be governed and controlled according to the operation of the main motor 8 and the galvanometer 4.

Modifications in the system and in the arrangement and location of parts may be made within the spirit and scope of the invention and such modifications are intended to be covered by the appended claims.

What is claimed is:

1. In a gain control system for a transmission line, a Wheatstone bridge circuit having one arm thereof in the form of a pilot line associated with said transmission line, a galvanometer connected to said bridge circuit and operated according to the variations of a characteristic of said pilot line, means comprising a main motor of a continuously operable type controlled by said galvanometer for restoring the bridge circuit balance upon operation of the galvanometer, means operated by the main motor for limiting each movement of said motor to a fixed step so that the motor steps are equal, and means comprising a control motor governed by said galvanometer for governing the gain on the transmission line.

2. In a gain control system for a transmission line, a pilot line, a Wheatstone bridge circuit having three impedance arms and one arm formed by said pilot line, a galvanometer connected across opposite vertices of said bridge and operated according to a characteristic of said pilot line, means comprising a main motor of a continuously operable type controlled by said galvanometer for restoring the balance of the bridge upon operation of the galvanometer, means operated by said main motor for insuring operation of the main motor by equal steps when governed by the galvanometer to balance the bridge circuit, and means comprising a control motor governed by the galvanometer for governing the gain on said transmission line.

3. In a gain control system for a transmission line having a repeater station therein, a pilot line associated with said transmission line, a Wheatstone bridge circuit having three fixed impedance arms and a fourth arm comprising said pilot line, a galvanometer connected across two opposite vertices of said bridge circuit, means comprising a main motor controlled by said galvanometer for restoring the balance of said bridge circuit upon operation of the galvanometer, means operated by the main motor for effecting step-by-step operation of said motor by equal steps when balancing said bridge circuit, means comprising a second motor controlled directly by said galvanometer and independently of the operation of said main motor for adjusting the gain at the repeater station in said transmission line and means for effecting step by step operation of said second motor by equal steps when controlled by the galvanometer.

4. In a gain control system for a transmission line having a repeater station therein, a pilot line associated with said transmission line, a motor, a plurality of cam members operated by said motor, a plurality of impedance pads, switch members operated by said cam members for inserting said pads in the transmission line, means operated in accordance with a characteristic of said pilot line for governing the operation of said motor, a centering cam operated by said motor, and means operated by the centering cam for limiting each operation of said motor to a fixed step.

5. In a gain control system for a transmission line having a repeater station therein, a pilot line associated with said transmission line, means comprising a gain control motor of a continuously operable type and a plurality of cam members operated thereby for controlling the gain on the transmission line at said repeater station, control means operated in accordance with a characteristic of said pilot line for operating said motor and means operated by said motor for limiting the operations of said motor to fixed equal steps.

6. In a gain control system for a transmission line having a repeater station therein, a Wheatstone bridge circuit having one arm thereof in

the form of a pilot line associated with said transmission line, a galvanometer connected to opposite vertices of said bridge circuit and operated according to the variations in a characteristic of said pilot line, a control motor of a continuously operable type operated in a forward and in a reverse direction according to the operation of said galvanometer, means comprising a plurality of gain control cams operated by said control motor for controlling the gain at the repeater station, and means governed by the control motor for limiting each rotative movement of said motor under control of the galvanometer so that each motor movement is a fixed step and all steps are equal.

7. In a gain control system for a transmission line having a repeater station therein, a Wheatstone bridge circuit having an arm thereof in the form of a pilot line associated with said transmission line, a galvanometer connected to opposite vertices of said bridge circuit and operated according to the variations in a characteristic of said pilot line, means comprising a main motor of a continuously rotatable type operated in a forward and in a reverse direction by said galvanometer for restoring the bridge circuit balance upon operation of the galvanometer, means controlled by the main motor for effecting operation thereof in a step-by-step manner, each step of the main motor being fixed and all steps being equal, a control motor operated in a forward and in a reverse direction by said galvanometer, means for operating the control motor in a step-by-step manner, each control motor step being fixed and all steps being equal, and means comprising a plurality of gain control cams operated by said control motor for controlling the gain at the repeater station.

8. In a gain control system for a transmission line having a repeater station therein, a Wheatstone bridge circuit having one arm thereof in the form of a pilot line associated with said transmission line, a galvanometer connected to opposite vertices of said bridge circuit and operated according to the variations in a characteristic of said pilot line, a plurality of gain control cams, means comprising a motor of the continuously operable type operated in a forward and a reverse direction according to the operation of said galvanometer for operating said cams to control the gain at the repeater station on the transmission line and means operated by the motor for controlling said motor to insure operation of the gain control cams in a step-by-step manner, each step being fixed and all steps being equal.

9. In a gain control system for a transmission line, a Wheatstone bridge circuit having one arm thereof in the form of a pilot line associated with said transmission line, a galvanometer connected to said bridge circuit and operated in accordance with variations in a characteristic of said pilot line, main control means governed by said galvanometer for restoring the bridge circuit balance upon operation of the galvanometer, gain control means mechanically independent of said main control means and controlled by said galvanometer for governing the gain on the transmission line, and means jointly controlled by the gain control means and the main control means for operating an alarm in case the gain control means fails to operate in accordance with the operation of the main control means.

10. In a gain control system for a transmission line having a repeater station therein, a Wheatstone bridge circuit having one arm thereof in the form of a pilot line associated with said transmission line, a galvanometer connected to said bridge circuit and operated in accordance with variations in a characteristic of said pilot line, main control means governed by said galvanometer for restoring the bridge circuit balance upon operation of the galvanometer, gain control means operated according to the operation of said galvanometer for controlling the gain at the repeater station on the transmission line, a dial switch operated with said gain control means, and means jointly controlled by said main control means and the dial switch for operating an alarm in case the gain control means fails to operate in accordance with the operation of the main control means.

11. In a gain control system for a transmission line, a Wheatstone bridge circuit having one arm thereof in the form of a pilot line associated with said transmission line, a galvanometer connected to said bridge circuit and operated in accordance with variations in a characteristic of said pilot line, means comprising a main motor controlled by said galvanometer for restoring the bridge circuit balance upon operation of the galvanometer, means comprising a control motor operated according to the operation of said galvanometer for controlling the gain at a repeater station on said transmission line, a dial switch operated by said control motor, and means controlled by said main motor and the dial switch for operating an alarm in case the control motor fails to operate in accordance with the operation of the main motor.

12. In a gain control system for a transmission line, a pilot line associated with said transmission line, a Wheatstone bridge circuit having one arm thereof formed by said pilot line, a galvanometer connected across opposite vertices of said bridge circuit and operated according to variations in a characteristic of said pilot line, a main motor, means for operating said main motor in a forward and a reverse direction according to the operation of said galvanometer, means operated by said main motor for restoring the balance of the bridge circuit upon operation of the galvanometer, a centering cam operated by said motor, and means operated by said centering cam for limiting each operation of the motor to a fixed step.

13. In a gain control system for a transmission line having a repeater station therein, a pilot line associated with said transmission line, a Wheatstone bridge circuit having one arm thereof formed by said pilot line, a galvanometer connected across opposite vertices of said bridge circuit and operated according to variations in a characteristic of said pilot line, a control rotative member, control means governed by said galvanometer for operating the control member in a forward and a reverse direction, means operated by said rotative member for governing said control means to limit each operation thereof to a fixed step, and means comprising a plurality of gain control cams operated by said rotative member for controlling the gain on the transmission line at said repeater station.

14. In a gain control system for a transmission line having a repeater station therein, a pilot line associated with said transmission line, a Wheatstone bridge circuit having one arm thereof formed by said pilot line, a galvanometer connected across opposite vertices of said bridge circuit and operated according to variations in a characteristic of said pilot line, a control motor,

means governed by said galvanometer for operating the control motor in a forward and a reverse direction, a plurality of gain control cams and a centering cam operated by said control motor, a plurality of impedance pads at said repeater stations, means operated by said gain control cams for controlling the number of said pads in the transmission line at the repeater station to govern the gain at the repeater station, and means operated by said centering cam for limiting each operation of the motor to a fixed step.

15. In a gain control system for a transmission line having a repeater station therein, a pilot line associated with said transmission line, a Wheatstone bridge circuit having one arm thereof formed by said pilot line, a galvanometer connected across opposite vertices of said bridge circuit and operated according to variations in a characteristic of said pilot line, a main motor, means for operating said main motor in a forward and a reverse direction according to the operation of said galvanometer, means operated by said main motor for restoring the balance of the bridge circuit upon operation of the galvanometer, a centering cam operated by said motor, means operated by said centering cam for limiting each operation of the main motor to a fixed step, a control motor, means operated by the galvanometer for operating the control motor in a forward and a reverse direction, a plurality of gain control cams and a centering cam operated by said control motor, means operated by said last mentioned centering cam for limiting each operation of the control motor to a fixed step, and means operated by said gain control cams for governing the gain at the repeater station and the transmission line.

16. In a gain control system for a transmission line, a galvanometer, means for operating said galvanometer according to a characteristic of said line, a main motor of a continuously operable type controlled by said galvanometer, means operated by said main motor for returning the galvanometer to initial position, means operated by the main motor for insuring operation of the main motor by equal steps, a gain control motor of a continuously operable type directly controlled by said galvanometer, and means operated by the gain control motor for insuring the operation of the gain control motor by fixed equal steps.

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