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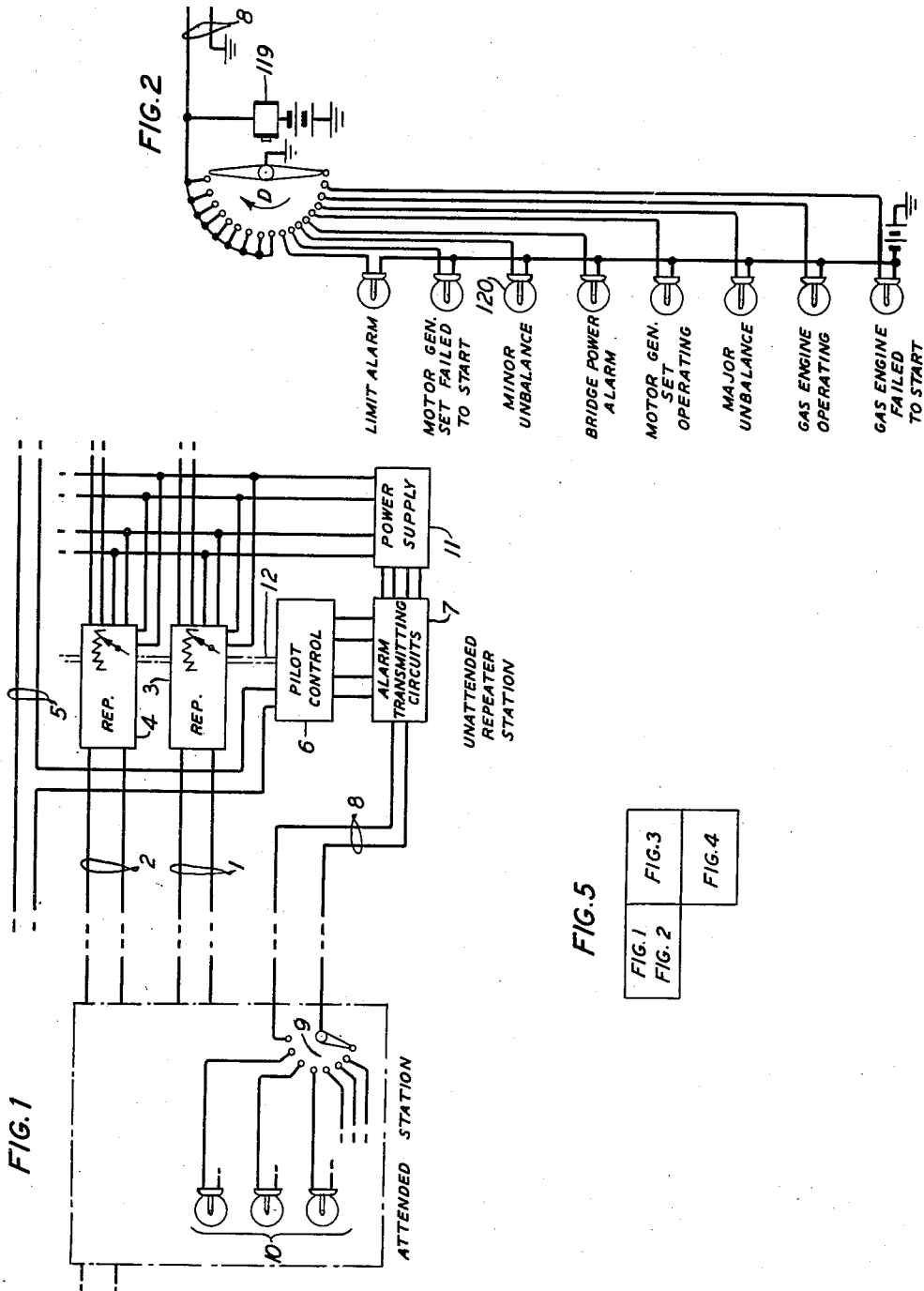
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2,003,964

REPEATERED LINE SYSTEM

Filed Aug. 31, 1932

3 Sheets-Sheet 1



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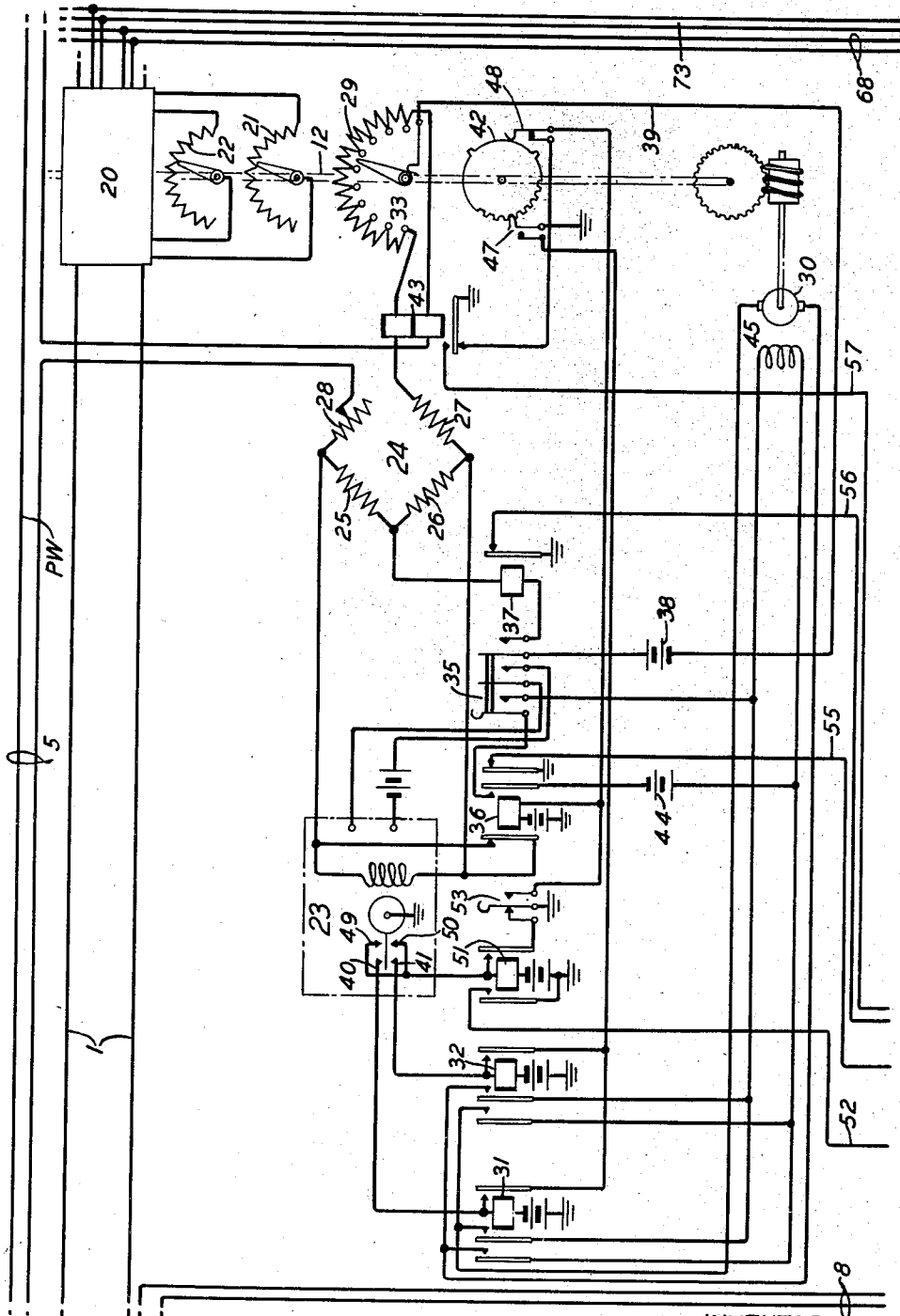
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3 Sheets-Sheet 2

FIG. 3



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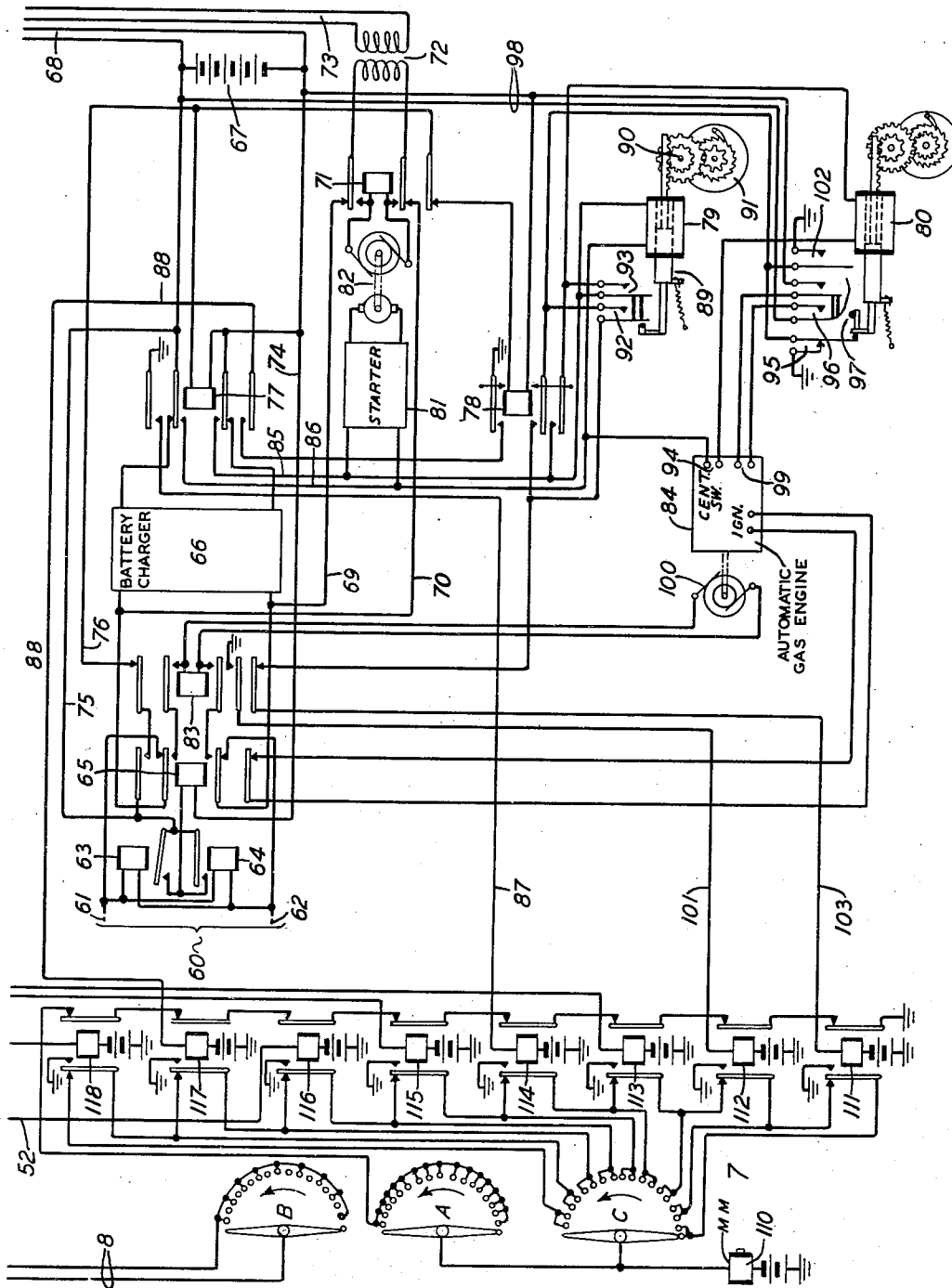
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**2,003,964**

## REPEATERED LINE SYSTEM

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3 Sheets-Sheet 3



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## UNITED STATES PATENT OFFICE

2,003,964

## REPEATERED LINE SYSTEM

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Application August 31, 1932, Serial No. 631,159

4 Claims. (Cl. 179—170)

The present invention relates to a telephone or other type of transmission system in which repeaters are included in tandem at intervals along the system.

In such a system using frequencies extending up to the order of 100 kilocycles or higher, it is necessary or advantageous to place the line repeaters at much shorter intervals than in the case of ordinary voice repeaters. While the maintenance of continuous high grade service in such a system could be achieved by having a sufficient number of attendants to exercise immediate and constant supervision over all of these repeaters, this would be prohibitive from the cost standpoint in many situations.

It is an object of the present invention to provide maintenance of service at repeater points by means which are to a large extent automatic in operation and do not require constant and personal supervision.

A further object of the invention is to enable indications to be made at an attended station to show some abnormal conditions of operation at an unattended repeater station.

A feature of the invention comprises a type of unattended repeater station with normal and emergency sources of power supply whereby the station is maintained in operation without attention, both normally and in case of power failure.

The invention includes various other and related features which will appear more fully from the following detailed description of a typical system in accordance with the invention, reference being had to the accompanying drawings in which:

Fig. 1 is a diagram showing the manner of association of an attended station with an unattended repeater station; and

Figs. 2, 3 and 4, when placed together with Fig. 3 above Fig. 4 and Fig. 2 to the left of Fig. 3, (as indicated in Fig. 5) show in greater detail the circuit for the automatic gain control, the power supply and the signals for notifying an attendant at the attended station of the condition at the unattended repeater station.

While the invention is capable of various modifications and forms of embodiment, it is illustrated and described as embodied in a multiplex carrier telephone cable system in which one or several unattended repeater stations are included between each two attended stations.

In Fig. 1 the attended station is indicated at the left of the drawings and is connected by a large number of pairs within the same cable

sheath with the unattended repeater station shown at the right. Only two talking pairs, 1 and 2, are shown in this figure for simplicity. It will be assumed that each of the conductors in the cable is multiplexed to transmit a plurality of voice modulated carrier waves which may extend, for example, in the frequency range from 8 kilocycles to 100 kilocycles providing 24 speech channels. Each line pair, 1, 2, etc. includes at the unattended repeater station a repeater 3, 4, etc. for simultaneously amplifying all of the voice modulated waves on the corresponding line. The attended station may contain similar repeaters or terminal apparatus for the line. The repeaters 3, 4, etc. may be of any suitable type such, for example, as the repeater disclosed in Fig. 65 of my prior application, Serial No. 606,871 filed April 22, 1932, or that disclosed in my application Serial No. 628,400 filed August 11, 1932, which is now Patent No. 1,956,547, of May 1, 1934.

Included in the same cable with the telephone pairs 1, 2, etc. is a special pair 5 which is used as a pilot conductor subject to the same temperature variations as the signaling pairs 1, 2, etc. An automatic pilot control 6 is connected to the pilot wire 5 and is arranged to control the gain of each of the repeaters 3, 4, etc. as, for instance, by a rotatable shaft 12 leading to variable resistances associated with the repeaters. These resistances may, for example, correspond to resistance 390 of Fig. 65 of my prior application referred to.

Filament heating current and plate voltage for the repeaters 3, 4, etc. are furnished by a power supply system 11, which is local to the unattended repeater station. This power supply, as will be described more in detail hereinafter, contains both normal and standby sources of power so that the repeaters 3, 4, etc. are maintained in operation in case of failure of the local power supply.

It is desirable that an attendant at the attended station be kept informed at all times as to the condition of the apparatus at the unattended repeater station. It is contemplated that there may be several unattended stations between each two attended stations and it is necessary or desirable that the condition of each of these repeater stations be made known at the attended station.

In accordance with the invention, the pilot control 6 and the power supply 11 are associated with alarm transmitting circuits 7 which are connected to a special pair 8 in the cable leading to the

attended station. Instead of using a special pair in the cable exclusively for transmitting these signals, the circuit indicated as 8 in the drawings may, of course, be a derived circuit formed by compositing one of the lines 1, 2, etc. Circuit 8 controls a step-by-step switch 9 or other suitable selector at the attended station and causes signals 10 to be selectively operated at that station to indicate the condition of the apparatus at the unattended repeater station or stations.

Referring to more detailed disclosure of the various circuits in Figs. 2, 3 and 4, one cable pair 1 and the pilot wire 5 are shown leading into the unattended repeater station. The repeater itself is not shown in this figure but the means for changing its gain to compensate for variations in temperature of the cable are shown in the form of two variable resistances 21 and 22 for controlling the characteristics of an attenuation network 20 assumed to be placed in the input to the repeater. Instead of this method of control, it would be obvious, in view of what is said above, to use a single resistance, such as 21, and insert this in the circuit of the repeater in place of the variable resistance 390 of Fig. 65 of my prior application above referred to. The present description will assume, however, that the changes in gain at the repeater circuit as a whole are made by changing the loss in the attenuating network 20. This network may, for example, be a constant resistance type of network such as is disclosed in U. S. patent to Stevenson 1,606,817, November 16, 1926, or Zobel 1,603,305, October 9, 1926, certain of the resistances of which are made variable as are indicated in the drawings by the two resistances 21 and 22. These resistances are varied by the rotation of the shaft 12 which also extends to the other repeaters in the same repeater station so that all of the repeaters are controlled in unison. A greater number of resistances than two may be used to control the characteristics of each attenuating network 20 by properly associating them with shaft 12.

The shaft 12 leading to the gain control mechanism of the several repeaters is rotated under control of motor 30 through suitable reduction gearing, motor 30 in turn being controlled through the medium of either relay 31 or relay 32 from contacts of galvanometer 23. Galvanometer 23 is connected across the diagonals of a Wheatstone bridge 24 comprising fixed resistance arms 25, 26 and two other arms 27 and 28. Arm 28 is made up of a variable resistance 28 in series with the pilot conductor 5 and a variable portion of resistance 29, the portion which is included in the bridge arm depending upon the position of contact arm 33. Arm 27 is made up of a fixed resistance and the remainder of resistance 29 that is not included in arm 28. The battery diagonal for bridge 24 includes the windings of relay 37, contacts of key 35, battery 38 and lead 39 to movable arm of resistance 29, key 35 being closed when the regulator is in condition for operation.

The bridge is normally set to be balanced when the pilot wire 5 has its lowest operating temperature and the loss in attenuating network 20 is a maximum due to the setting of resistances 21 and 22. An increase in the temperature of pilot conductor 5 unbalances the bridge and causes galvanometer 23 to make contact with one or the other of its two normal contacts 40 or 41. At this time, relay 36 is assumed to be operated by a circuit from ground at the lower armature of relay 43 and normally closed spring contacts

of centering cam 42 so that the shunt across the galvanometer 23 is opened at the left armature and back contact of relay 36 while the right-hand armature of relay 36 connects battery 44 across the field winding 45 of motor 30 and prepares a circuit for the armature of this motor to be completed through contacts of relay 31 or 32 when the galvanometer is deflected. If the galvanometer is deflected in the direction to close contact 40, relay 31 is energized causing motor 30 to rotate in the proper direction to restore bridge 24 to a balanced condition by movement of arm 33 on resistance 29. As soon as cam 42 starts to move in response to the starting up of motor 30, the centering spring contacts 47 are closed, holding relay 31 locked so that motor 30 continues to rotate until the arm 33 is moved off from one contact and on to the center of its next contact, at which time springs 47 are opened and relay 31 is allowed to fall back, opening the circuit of the armature of motor 30 if at this time galvanometer 23 has opened contact 40, so that no further movement of the motor results. The movement of shaft 12 controlling arm 33 of course also moves the arms that change resistances 21 and 22 thereby decreasing the attenuation of network 20 a suitable amount to correct for the increase in temperature assumed to have taken place in pilot wire 5 and line 1. For successive increases in temperature, the pilot control mechanism operates in a similar manner to decrease the attenuation in network 20. For a decrease in temperature, the galvanometer 23 is caused by the bridge unbalance to close contacts 41, energizing relay 32 which operates in a manner entirely analogous to that described for relay 31 to cause motor 30 to rotate in the opposite direction such as to restore the balance of bridge 24 and adjust resistances 21 and 22 in a direction to increase the attenuation of network 20.

Various alarms are associated with the automatic gain control mechanism to indicate the proper or improper functioning of the mechanism. If a minor unbalance of the bridge occurs such as to cause the galvanometer 23 to contact with either contacts 49 or 50, relay 51 is energized, placing a ground on lead 52, the effect of which is to send a signal from the alarm transmitting circuit 7 over circuit 8 to the attended station. These alarm circuits and their manner of operation will be described more in detail hereinafter. If the arms which control resistances 21, 22 and 29 have moved to either limit of their adjustment, cam 42 causes springs 48 to open and release normally energized relay 36 which places a protective shunt at its left armature and back contact across the galvanometer 23 and at its right contact opens the circuit for motor 30 from battery 44. A third armature on relay 36 places a ground on conductor 55 leading to the alarm circuits. If battery 38 fails to apply suitable operating voltage to the battery diagonal of bridge 24, relay 37 releases placing a ground on lead 56 leading to the alarm circuits. If the unbalance of the bridge becomes still greater than sufficient to operate relay 51, for example, twice as great, relay 43 which is a differential relay is caused to operate and place ground on conductor 57 leading to the alarm circuits. This relay also breaks the normal circuit for relay 36 at its lower armature and back contact which operates as already described.

Referring to Fig. 4, the local supply is assumed to be in the form of 60 cycle alternating current connected across the leads 61 and 62. This power

may be derived from a local power company's mains. A battery charging outfit 66 comprising preferably a suitable type of rectifier and filter is used to charge storage battery 67 from the local power circuit. Conductors 69 and 70 are connected to conductors 61 and 62 and lead through the back contacts of relay 71 to transformer 72 which steps the voltage down to the proper value for supplying the cathode heating circuits of the various repeaters over leads 73. Plate voltage for the various repeaters is supplied over conductor 68 from storage battery 67.

Bridged across conductors 61 and 62 are two marginal relays 63 and 64 with normally open contacts arranged to be closed in case of over-voltage or under-voltage or interruption of the local supply. Relay 63, for example, releases its armature in case of interruption in the local supply or of reduction in voltage below the prescribed value. Relay 64 is an over-voltage relay arranged to close its contacts when the voltage exceeds the prescribed value. When the contact of either relays 63 or 64 closes, a circuit is closed for relay 65 from battery 67, lower conductor 74, winding of relay 65, contact of relay 63 or 64, conductor 75 to upper terminal of battery 67. Relay 65, in energizing, closes at its inner armatures and front contacts the two leads extending from the armatures of relay 83, this circuit closure having no effect at this time, however. At the back contact of these two armatures the leads 61 and 62 are disconnected from the input terminals of the battery charging outfit 66. The lower armature of relay 65 removes a normal short-circuit around the ignition terminals of the gas engine 84. The upper armature and contact of relay 65 closes a circuit through back contact of relay 83 from battery lead 75 to conductor 76 and winding of relay 77 causing this relay to energize. A circuit in parallel with relay 77 is closed through back contact of relay 71 and winding of relay 78. Relay 78 is provided with a dash-pot or other delay mechanism to make it slow to operate so that its contacts are not immediately closed.

Relay 77, in energizing, disconnects the normal output leads from the battery charging set 66 from the battery 67 and connects the battery across the two leads 85 and 86. Battery voltage from source 67 is thus applied to the motor generator set 82 through the automatic starter 81 causing the motor generator set to start up and generate suitable current for heating the cathodes of the repeaters. The output current from the motor generator 82 is at first applied only to the winding of relay 71 which is arranged to operate when the generator voltage reaches its normal operating value. Relay 71, in operating, connects the motor generator set directly to transformer 72 leading to the cathode heating circuit 73.

When relay 77 first energized, ground was applied over its upper armature and front contact to conductor 87 leading to the alarm transmitting circuits 7 to give an indication that reserve power supply No. 1, that is, the motor generator set, was being put into service.

The operation of relay 78 is so timed that if the motor generator set operates in its normal and expected fashion, the armatures of relay 78 are not fully attracted since its energizing circuit is broken at the lower armature and back contact of relay 71 when that relay is energized. If, however, the motor generator set fails to start and cause relay 71 to break this circuit, re-

lay 78 will attract its armatures. At its upper armature it closes a circuit from ground through the lower armature and front contact of relay 77 and over conductor 88 to the alarm transmitting circuits to give an indication that the motor generator has failed to operate. It will be assumed for present purposes, however, that the motor generator set has started and has prevented relay 78 from attracting its armatures.

When leads 85 and 86 were connected to battery 67 by energization of relay 77 battery voltage was applied to the winding of relay 79. This relay is a slow operate relay requiring the order of 15 minutes to fully attract its armature. It may, for example, comprise a solenoidal winding with a core which is gradually drawn in against the action of a dash-pot, the core being indicated at 89 having a rack which engages pinion 90 so that as the core is drawn into the solenoid, pinion 90 winds up a spiral spring in the casing 91 which may also enclose suitable vanes in an oil or suitable medium to provide a dash-pot action. If the circuit of the solenoid is broken before the core 89 is fully attracted, the spring 91 quickly returns the core to its normal position.

In the event that the power does not come on the circuits 61, 62 from the local supply main and release the motor generator set within a predetermined time, for example, fifteen minutes, relay 79 will become fully operated and close its contacts 92 and 93. Contact 93 closes an operating circuit for relay 80 in series with the centrifugal switch 94 on the shaft of the gas engine 84. The solenoidal winding 80 quickly attracts its core and cam 97 on the core cooperates with switch spring contact 96 to close a circuit from battery 67, leads 98, contacts 96 to the starting terminals 99 of gas engine 84. It is assumed that the gas engine has any suitable type of starting motor operated from battery 67 and magneto ignition. After the gas engine has started, centrifugal switch 94 opens the circuit of relay 80.

Assuming that the gas engine 84 starts in normal manner, it drives the alternating current machine 100, to the terminals of which relay 83 is connected. When the machine 100 develops normal voltage, relay 83 attracts its armatures thus extending the leads from generator 100 through the front contacts and inner armatures of relay 65, which is now energized, to the input leads to battery charging set 66.

The energization of relay 83 opens at its upper armature and back contact the circuit through lead 76 for relay 77 so that the latter is caused to release and connect the output leads from battery charging set 66 to the battery 67. Relay 77, in releasing, disconnects leads 85 and 86 from battery 67 thus shutting down the motor generator 82 and releasing relay 79. The shutting down of the motor generator set 82 releases relay 71 which reconnects transformer 72 across the input leads to the battery charging set 66 so that some of the alternating current power from generator 100 is supplied to the filament heating circuit 73.

When relay 83 attracted its armatures, ground was applied through the lower middle armature and front contact to lead 101 extending to the alarm circuit so that an alarm is transmitted to the attended station indicating that the second reserve power is now operating.

By suitable construction the gas engine 84 may be arranged to bridge over any desired period of power failure. If the motor generator set 82 75

failed to operate after the operation of relay 77, as above described, relay 71 fails to open the energizing circuit of relay 78 in time to prevent the latter relay from fully attracting its armatures. In this situation, as has already been explained, relay 78 at its upper armature and front contact supplies ground over a circuit extending through the lower armature and front contact of relay 77 and lead 88 to the alarm transmitting circuit to give an indication at the attended station that the motor generator set has failed to operate.

Relay 78 at its lower armature and front contact closes an energizing circuit for relay 80 from conductor 85, contact of relay 78, winding of solenoid 80, centrifugal switch 94, normally closed, and lead 86. Relay 80 then attracts its armature, closing its contact 96 as above described and causing the gas engine 84 to start. It is assumed that the repeaters are provided with cathodes having sufficient heat capacity to bridge over a period of interruption in the filament heating current of a few seconds, thus giving time for relay 78 to operate and for solenoidal relay 80 to operate and start the gas engine 84 and alternator 100 to supply filament heating current before the cathode emission of the repeater tube has fallen to an inoperative level. The motor generator set 82 can, of course, be started in much less time than is required to start the gas engine so that there is less likelihood of interruption of service from the starting of the motor generator set 82 than from the starting of the automatic gas engine. Moreover, it is likely that most of the power failures may be of only momentary duration such as can be bridged over by the motor generator set 82 in which case it will only be necessary to start the automatic gas engine 84 on rare occasions.

By providing all of the repeaters with heater type tubes as disclosed in my application, Serial No. 628,400, filed August 11, 1932, the repeaters may be kept in operative condition for about fifteen seconds with the filament heating current shut off. Allowing two seconds as the normal time for the motor generator set 82 to start and develop full load current, the relay 78 may be timed to attract its armatures in three to four seconds, giving one or two seconds to indicate failure of motor generator set 82 to operate properly. This would leave a margin of ten seconds or more for the gas engine 84 to be started up and to begin furnishing cathode heating current in time to prevent an interruption of service of the repeater.

If, after relay 79 has operated, relay 80 does not operate to break contact 96, a circuit is closed from ground over contacts 92 of relay 79 and lower back contact of relay 83 and conductor 103 to the alarm transmitting circuits to indicate that the gas engine has failed to start. In the normal operation of relay 80, as the plunger is drawn into the solenoid, cam member 97 closes springs 95 and maintains them closed for a sufficient length of time for the gas engine to start under normal conditions of operation. If, after continuous cranking for the normal period of time, the gas engine should fail to operate, cam member 97 passes beyond the lower end of contact springs 96 and allows these contacts to open so that continuous cranking of the engine with consequent heavy drain on battery 67 is avoided. After contacts 96 are closed, the motion of the core is damped so that considerable time is required to complete the stroke. When the plunger

of relay 80 is drawn in to the completion of its stroke, cam 97 closes contact springs 102. The timing of the relay is such, however, that these springs are not closed until sufficient time has been allowed for relay 83 to have been energized if the gas engine started and operated in normal manner so that the closing of contact springs 102 is without effect under normal conditions of operation. If the gas engine fails to start after cranking for the prescribed time under control of relay 80, relay 83 is not energized and the closure of contact springs 102 places ground on conductor 103 leading to the alarm transmitting circuit to indicate that the gas engine has not started.

When the power comes back on to leads 61 and 62 or when the abnormal conditions which actuated either relay 63 or 64 have ended, the relay which was operated opens its contact allowing relay 65 to release thus extending leads 61, 62 through to the battery charging set 66 by way of the inner armatures and back contacts of relay 65. If the motor generator set 82 is operating at this time, relay 77 is operated and upon the release of relay 65 its operating circuit is broken at the upper armature and front contact of relay 65 so that relay 77 releases and extends the output leads of the battery charging set 66 to the terminals of battery 67, at the same time cutting off leads 85 and 86 from battery 67 so that the motor generator set 82 is stopped. At the upper contact and armature of relay 77 ground is removed from conductor 87 leading to the alarm transmitting circuit and causing the corresponding lamp to be extinguished to give an indication that power reserve No. 1 that is, the motor generator set, has been shut down and that the normal power supply has come on.

If, instead of the motor generator set, the gas engine is operating at the time the normal power is restored, the release of relay 65 places a short circuit across the ignition terminals of the gas engine 84 by closure of the lower armature and back contact of relay 65. The gas engine is thus shut down and restored to its normal condition.

The alarm transmitting circuits comprise a group of eight relays, 111 to 118, inclusive, and a stepping switch mechanism comprising motor magnet 110 and three banks of segments indicated at A, B and C. Further description of this apparatus can, it is thought, best be given by following its operation.

Consider, for example, that minor unbalance relay 51 has operated in the manner already described to place a ground on conductor 52 which leads to relay 116 causing this relay to operate. By its operation, ground is placed on the armatures and back contacts of relays 111 to 115, inclusive, from the armature of relay 116. A circuit is thus closed for the motor magnet 110 from battery through the motor magnet, switch arm of segment C, normal or resting contact, and conductor leading to the armature of relay 111, thence through the back contacts and armatures of the other relays to the ground at the front contact of relay 116. A similar ground exists on the next succeeding five contacts of segment C so that the switch arm is caused to take six steps, the motor magnet 110 releasing in the usual manner after each step as the circuit is broken between contacts.

The other brushes of segments A and B are also caused to take six steps and as brush of segment B moves it closes and opens the circuit 8 leading to the motor magnet 110 of the selector 75

D at the attended station. Selector D is thus caused to take six steps and stop on the terminals of minor unbalance lamp 120 thus closing the circuit of that lamp and causing it to light.

5 The selector D may be constructed in a manner well known in the art so that no contact is made between the brush arm and the segment while the brush arm is being stepped around, but the contact is made only when the brush comes to rest. Lamp 120 continues to remain lighted as long as the relay 116 remains operated at the unattended station and the alarm transmitting station remains otherwise the same. If the minor unbalance condition ceases to exist and relay 116 releases its armatures, ground is removed from all of the contacts of segment C but ground is now applied to the contacts of segment A by way of the right-hand armatures and back contacts of relays 111 to 118. The motor magnet 110 is thus caused to step the mechanism around to its zero position again. This causes segment B to transmit a series of impulses over circuit 8 to selector switch D at the attended station restoring that switch to its normal position and causing the lamp 120 to be extinguished.

10 In similar manner, a ground on any one of the other conductors 55, 56, 57, 88, 101, 87 or 103 causes its corresponding relay 111 to 118 to operate and send a corresponding number of impulses over circuit 8 to the selector D at the attended station and to give an indication thereof of the abnormal condition at the unattended station represented by the grounding of such conductor as has already been described.

15 It is contemplated that a number of selectors similar to D will be located at the attended station with banks of indicators such as the lamps 10 thereat, and that they will be connected by circuits similar to 8 with different outlying unattended repeater stations on line 1 and also on other similar lines so that the condition of the apparatus at these unattended stations is continuously indicated at the attended station.

What is claimed is:

45 1. A repeater station for a transmission line, comprising a space discharge type repeater employing devices having cathodes and anodes, a local source of cathode heating current, an operating and a reserve source of anode voltage supply derived from said local source, means operable in response to failure of said local source to utilize said reserve source to supply both anode voltage and cathode heating current to said repeater, a prime mover local to said repeater, and means operative to utilize the energy of said prime mover in substitution for said local cathode heating current source in response to continued failure of the latter.

2. A repeater station for a line, including space discharge devices having cathodes and anodes, a local source of alternating current supply, a circuit supplying from said source heating current for said cathodes and a rectifier supplying rectified anode voltage from said source for said anodes, a storage battery floated across said rectifier, an inverter, a prime mover, a generator driven by said prime mover, means operating in response to failure of said alternating current supply, to connect said inverter to said storage battery to supply heating current of proper kind to said cathodes, and other means operating in response to continued failure of said alternating current supply to derive energy from said prime mover to charge said battery and supply cathode heating current.

3. In a repeated line system, an attended repeater station and an unattended repeater station on the same line, a repeater requiring power located at the unattended station, a local source of power supply for said repeater, a local stand-by source of power also at said repeater, a signal at said attended repeater station, means operating in response to failure in said local source of power for substituting said stand-by source of power to energize said repeater and means controlled by said last mentioned means for actuating said signal at said attended repeater station.

4. In a signalling system a long line adapted to transmit message waves, an attended and an unattended station on said line distantly separated from each other, a message wave amplifying repeater at the unattended station requiring energizing current for its operation, normal and stand-by sources of current for said repeater local to said unattended station, means operable in response to an abnormal condition in the normal source of current for substituting for said normal source said stand-by source to supply energizing current to said repeater, regulator means locally controlled in response to a condition of said line for regulating the action of said repeater, a group of circuits associated with each of said means and adapted to be individually controlled in response to the operation of said means, a code sending apparatus at said unattended station common to and operating under control of said groups of circuits to send characteristic impulses to said distant station in accordance with the control of said individual circuits and indicating means at said latter station selectively actuated in accordance with said impulses.

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