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AUTOMATIC LINE TESTING AND SWITCHING CIRCUITS

Filed Dec. 9, 1943 2 Sheets-Sheet 1

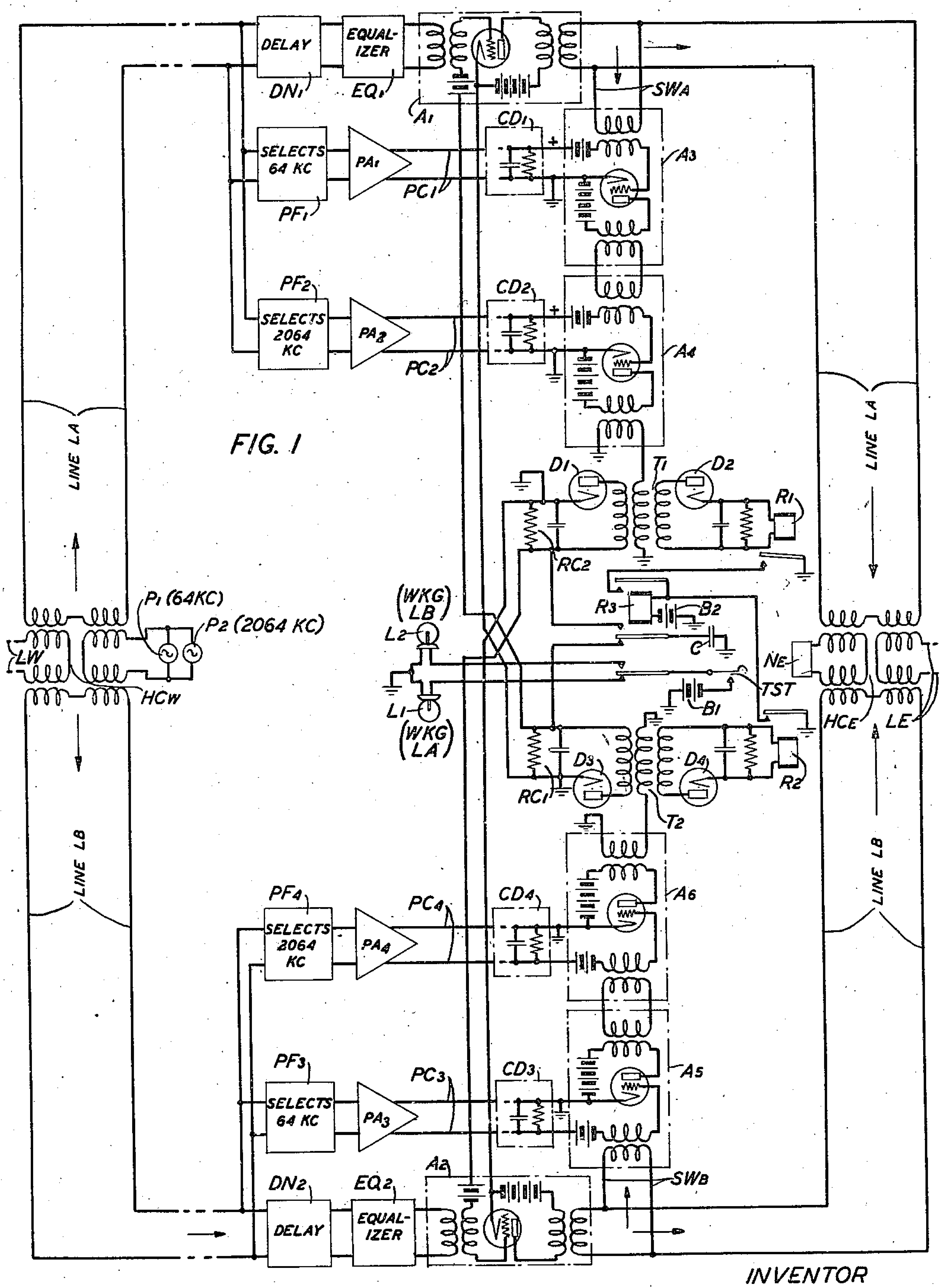

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FIG. 2

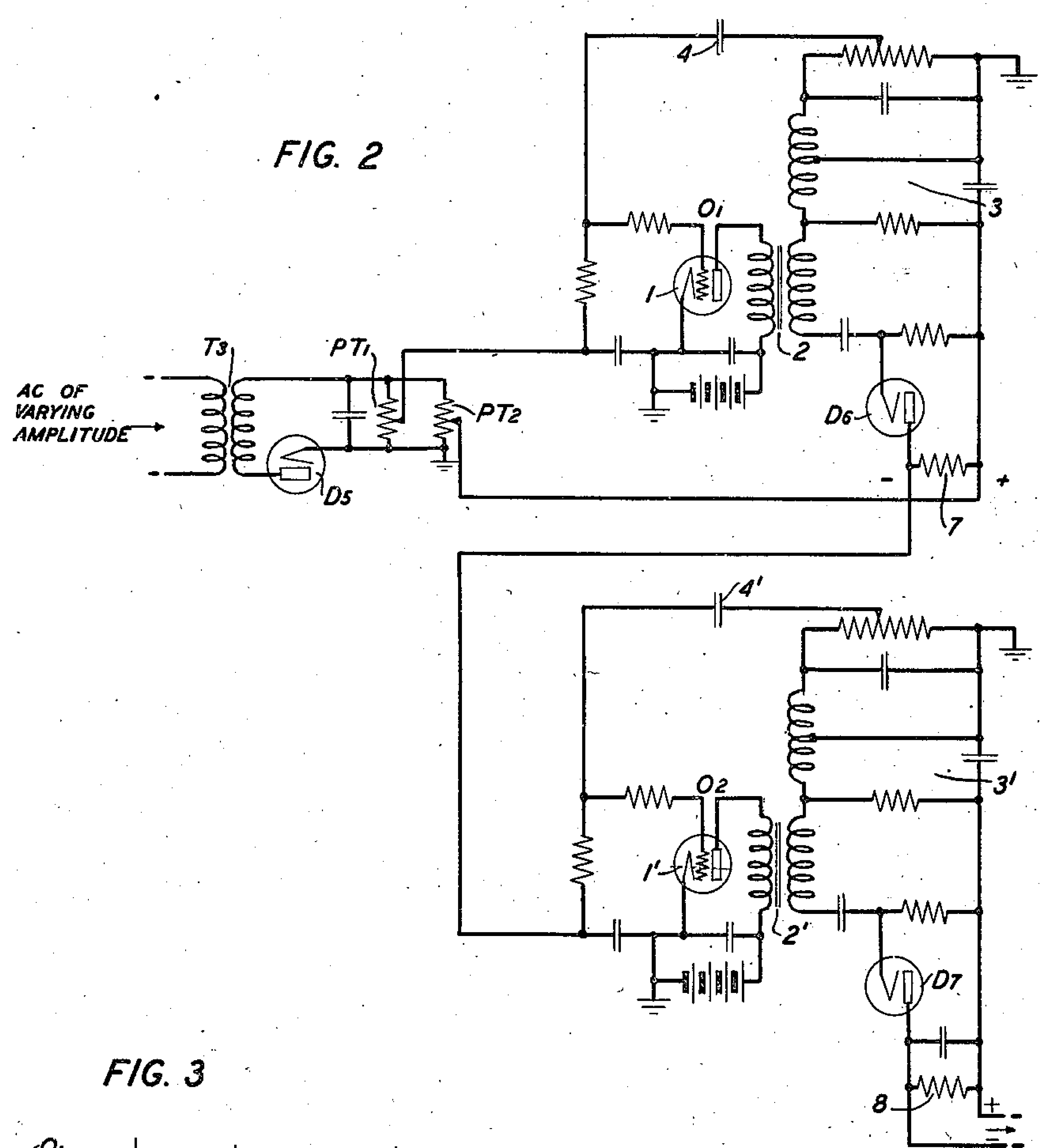
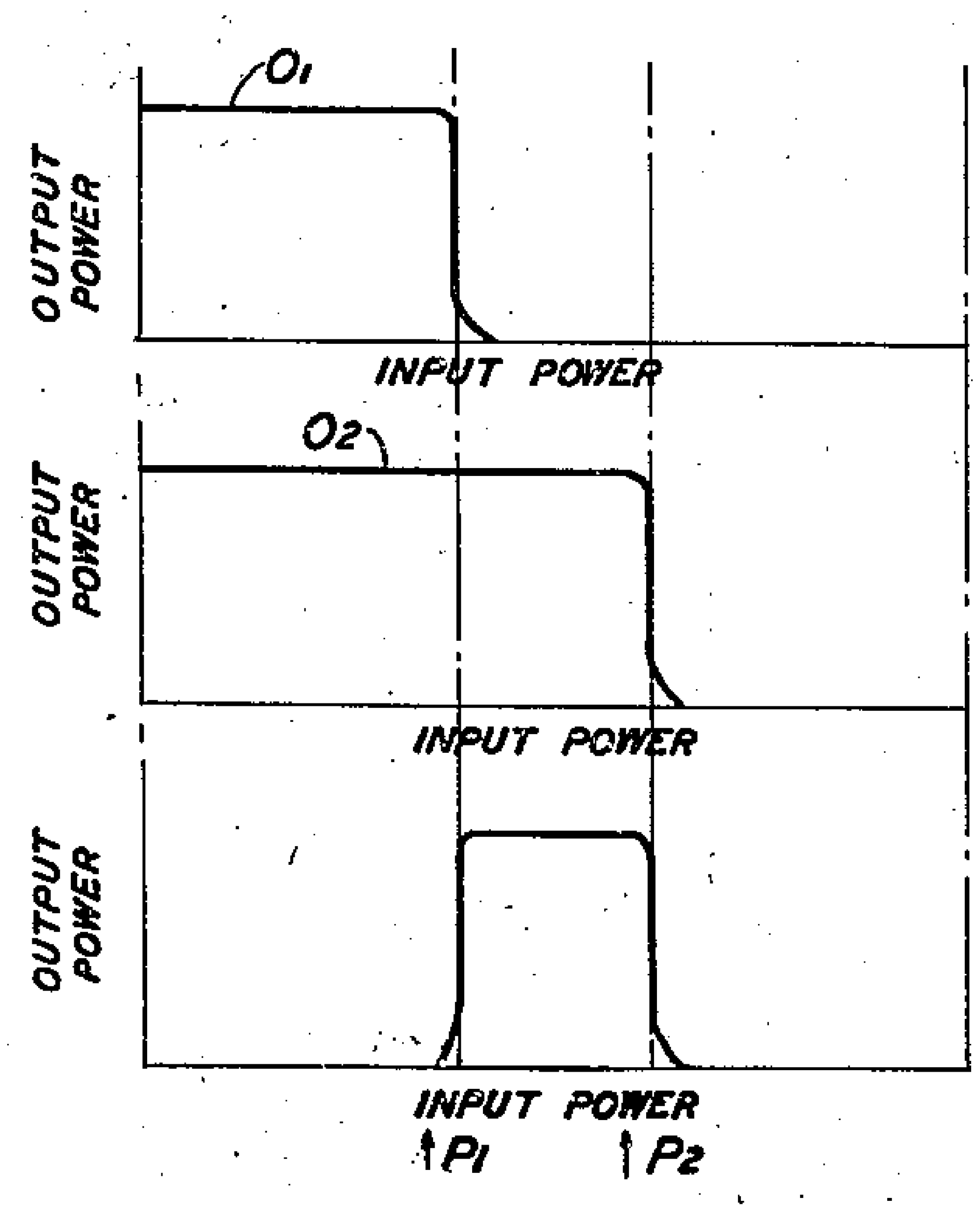


FIG. 3



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AUTOMATIC LINE TESTING AND SWITCHING CIRCUITS

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13 Claims. (Cl. 178—44)

The invention relates to broad frequency band transmission systems, such as multichannel carrier wave signaling systems, and particularly to automatic line testing and switching circuits for use with such systems.

In such systems employed for transmitting signal waves over a long distance, it is customary to use a large number of repeaters in tandem, some of which may be attended and others unattended. The failure or substantial impairment in transmission efficiency of a single transmission element, for example, an amplifying vacuum tube or a line conductor, in a line section between repeaters may result in complete failure or intolerable degradation of transmission over that line section. In certain carrier wave signaling systems, such as multichannel coaxial cable carrier signaling systems, in which a single line pair or coaxial conductor is employed for transmitting several hundred signaling channels, such partial or complete failure may interrupt or seriously degrade transmission in a large number of signaling circuits, resulting in much inconvenience and substantial loss of time and revenue before the condition causing the failure is found and remedied. For that reason, it is customary to employ in such systems, two or more completely equipped parallel lines in each repeater section, only one of which is normally in working relation to provide through signal transmission, with suitable switching circuits for substituting a spare line section in place of a working line section in which a transmission failure occurs.

My copending patent application, Serial No. 495,989, filed July 24, 1943, which issued as Patent No. 2,379,069 on June 26, 1945, discloses automatic switching arrangements for use with such a system, employing special relay circuits adapted for control by any one of a number of pilot waves of different frequencies outside the signal frequency range continuously transmitted over the working and spare lines in a switching repeater section, when its transmission level deviates a given amount from normal level in either direction indicating serious line impairment, to continuously monitor each of the lines to determine if an impaired condition exists; to indicate the transmission condition of each line to an attendant; and to automatically shift signal transmission from an impaired working line to a spare line only if the latter is in tolerable working condition.

An object of the invention is to improve automatic arrangements of the above-described general type particularly from the standpoint of simplification and speed of operation.

More specific objects are to continuously monitor the working and spare lines in the repeater sections of a broad frequency band signal transmission system; to operate suitable signaling apparatus indicating which of the lines are working and which are spare, and the condition of each line; and to shift through signal transmission quickly from a working line found to be substantially impaired to a spare line only if the latter is in tolerable working condition.

Another object is to provide regulating control of a switching device associated with a line transmitting wave energy only when the amplitude level of that wave energy is outside tolerable limits.

These objects are attained in accordance with the invention by simple pilot-controlled automatic circuit arrangements employing particular arrangements of electronic switching devices to provide the required line switching and alarm indications within a relatively short time interval after a line trouble condition occurs.

A feature of the invention is a control device which produces an appreciable output for applied alternating wave inputs within a given range of amplitude levels and substantially no output for alternating wave inputs of amplitude levels above and below that range.

The various objects and features of the invention may be better understood from the following detailed description when read in conjunction with the accompanying drawings in which:

Fig. 1 shows schematically a switching repeater section for one direction of transmission in a wide band signal transmission system, such as a multichannel carrier telephone system, equipped with automatic line testing, switching and indicating arrangements embodying the invention;

Fig. 2 shows schematically a control device of novel type such as are used in the arrangements of the invention shown in Fig. 1; and

Fig. 3 shows curves illustrating the operation of the control device shown in Fig. 2.

Fig. 1 shows one switching repeater section for the west-to-east direction of transmission in a wide band signal transmission system, such as a multichannel repeatered cable carrier wave signaling system, comprising the two one-way lines LA and LB extending between a west repeater station and an east repeater station at the terminals of the section. It is understood that the line may include any number of tandem-connected repeater spans containing any number of repeater offices which may be attended or unattended, each line being completely equipped with the amplifiers, associated gain regulating apparatus, equalizers and other equipment (only a portion of which is shown) required to provide a desired volume and quality of signal transmission over the switching section. The lines LA and LB are permanently connected through the balanced windings of the hybrid repeating coil HC_W in energy transmitting relation with the output line LW of the preceding repeater switching section or carrier terminal station so as to be supplied in common from the latter line with equal energy portions of the carrier signal frequency band containing the carrier signals of all signal channels to be transmitted.

If the switching repeater section shown in Fig. 1 is the first one in the system for transmission in the west-to-east direction, so that the hybrid coil HC_W is located at a terminal repeater station, pilot waves of frequencies, say 64 kilocycles and 2,064 kilocycles, on either side of the carrier signal band to be transmitted and of equal, initially constant amplitude levels, are continuously supplied in common to the input of the lines LA and LB through the hybrid coil HC_W from the combined output of the pilot wave sources P_1 and P_2 generating those respective frequencies, connected to the net side of the hybrid coil. In that case, the combined output impedance of the two pilot wave sources P_1 and P_2 would be made such that it operates as an equivalent line balancing network to balance the characteristic impedance of the incoming line LW which it faces, through the hybrid coil HC_W. If the switching repeater section illustrated in Fig. 1 is not the first switching repeater section for that direction in the system, the pilot waves may be supplied in a similar manner at the preceding terminal station or at the input of any preceding switching repeater section so that the pilot waves will be received over the line LW and applied through the hybrid coil HC_W in equal energy portions to the inputs of the lines LA and LB. In that case, the usual line balancing network would be substituted for the pilot wave sources P_1 and P_2 connected to the net side of the hybrid coil HC_W.

The outputs of the lines LA, LB are coupled at the output of the switching repeater section shown in Fig. 1 in conjugate relation with each other and in energy transmitting relation with the line LE leading to the next succeeding switching repeater section or to a terminal repeater station, by the hybrid repeating coil HC_E and associated line balancing network N_E.

The line LA includes near its output the delay network DN_1 followed by the line equalizer EQ_1 and the line amplifier A_1, shown as consisting of only one three-electrode amplifying vacuum tube stage having a parallel resistance-condenser grid biasing arrangement RC_1 in its control grid circuit, but which may include any number of vacuum tube stages required to provide the desired signal amplification. Similarly, the line LB includes near its output a delay network DN_2 followed by an equalizer EQ_2 and a line amplifier A_2, similar to the amplifier A_1, including a three-electrode amplifying vacuum tube stage having a parallel resistance-condenser grid biasing arrangement RC_2 in its control grid circuit.

Connected across the line LA at a point in the output of the amplifier A_1 is the input of a signal controlled switching circuit SW_A including two tandem-connected amplifiers A_3 and A_4, which may be of the vacuum tube type similar to the amplifiers A_1 and A_2 in the lines LA and LB, and which, when both are operative, pass the portion of the signal and pilot wave output of line amplifier A_1 diverted from the path LA into that switching circuit, in amplified form to the two diode rectifiers D_1 and D_2 having their inputs coupled to the output of the second amplifier A_4 in the switching circuit by the common transformer T_1. Similarly, the input of a switching circuit SW_B is connected across the output of the line LB in the output of the line amplifier A_2, that switching circuit including the tandem-connected amplifiers A_5 and A_6, which, when both are operative, pass the portion of the signal and pilot wave output of amplifier A_2 diverted into the switching circuit from line LB, in amplified form to the diode rectifiers D_3 and D_4 having their inputs coupled to the output of the second amplifier A_6 in the switching circuit, by the common transformer T_2.

The rectified voltage output of the diode rectifier D_1 in switching circuit SW_A applies a negative voltage across the parallel resistance-condenser biasing arrangement RC_2 to the control grid circuit of the amplifier A_2 in the line LB, which voltage, when completely built up, is sufficient to bias the latter amplifier to cut-off so as to block the line LB in its output. Similarly, the rectified voltage output of the diode rectifier D_3 in switching circuit SW_B applies across the resistance-condenser biasing arrangement RC_1 a negative voltage to the control grid circuit of amplifier A_1 in line LA, which, when completely built up, is sufficient to bias the latter amplifier to cut-off so as to block line LA in its output.

The rectified voltage output of the diode rectifier D_2 in switching circuit SW_A controls the operation of a relay R_1, and the rectified voltage output of the diode rectifier D_4 in switching circuit SW_B controls the operation of a relay R_2 which in turn controls the operation of a relay R_3. The circuits controlled by the operation of the relays R_1 and R_3 in accomplishing the purposes of the invention will be described later in connection with a complete description of operation of the system of Fig. 1.

Connected across the line LA at a point near its output in front of the delay network DN_1 is the common input of the pilot-controlled control circuits PC_1 and PC_2, and connected across the line LB at a point near its output in front of delay network DN_2 is the common input of the pilot-controlled control circuits PC_3 and PC_4.

The control circuit PC_1 includes in its input a filter PF_1 for selecting from the portion of the wave energy applied to its input, that of the frequency 64 kilocycles received over the line LA from the pilot wave source P_1 at the input of the switching section, and for suppressing applied wave energy of other frequencies; an amplifier PA_1 for amplifying the selected pilot wave energy; and a control device CD_1 responsive to the amplified 64-kilocycle pilot wave energy, only when its amplitude level rises above or falls below the range of pilot amplitude levels considered tolerable, due to serious line trouble conditions in the line LA over which the 64-kilocycle pilot wave passes, to bias the amplifier A_3 in switching circuit SW_A to cut-off. The control circuit PC_2 includes in its input a filter PF_2 for selecting from the wave energy applied to its input, that of the frequency 2,064 kilocycles received over the line LA from the pilot wave source P_2 at the input of the switching section, and for suppressing the applied wave energy of other frequencies; an amplifier PA_2 for amplifying the selected pilot wave energy; and a control device CD_2, similar to the control device CD_1, responsive to the amplified 2,064-kilocycle pilot wave energy only when its level rises above or falls below the tolerable range of pilot amplitude levels, due to serious trouble conditions in the line LA, to bias the amplifier A_4 in switching circuit SW_A to cut-off.

Similarly, the circuit PC_3 includes in its input a filter PF_3 for selecting from the energy applied to its input that of the frequency 64 kilocycles received over the line LB from the pilot wave source P_1; an amplifier PA_3 for amplifying the selected pilot wave energy; and a control device CD_3, similar to the devices CD_1 and CD_2, responsive to the amplified 64-kilocycle pilot wave energy, only when its amplitude rises above or falls below the tolerable range of pilot amplitude levels, due to line trouble conditions in line LB, to bias the amplifier A_5 in switching circuit SW_B to cut-off. The circuit PC_4 includes in its input a filter PF_4 for selecting from the wave energy applied to its input that of the frequency 2,064 kilocycles received over the line LB from the pilot wave source P_2; an amplifier PA_4 for amplifying the selected pilot wave energy; and a control device CD_4, similar to the devices CD_1 to CD_3, responsive to the amplified 2,064-kilocycle pilot wave energy only when its level rises above or falls below the tolerable range of pilot amplitude levels, due to serious trouble conditions in line LB, to bias the amplifier A_6 in the switching circuit SW_B to cut-off.

The control devices CD_1 to CD_4 in the system of Fig. 1 may be of the type shown in detail in Fig. 2.

The control device of Fig. 2 includes two similar oscillators O_1 and O_2 for generating alternating waves of substantially the same frequency and of substantially the same constant power, which oscillators may be of any suitable type, for example, as illustrated, respectively comprising a single three-electrode electron discharge device 1, 1′ with a feedback connection including a phase reversing transformer 2, 2′, a tuned circuit 3, 3′ for determining the frequency of oscillation, and a series condenser 4, 4′, between the plate-cathode circuit and the high impedance control grid-cathode circuit. Each oscillator is adapted to cut off in response to a different amount of input power, supplied by the voltage drop in a different potentiometer PT_1, PT_2 with different settings, each having its adjustable resistance portion connected in series with the control grid-cathode circuit of a different one of oscillator tubes 1, 1′. The current flowing through the two potentiometers PT_1 and PT_2, which determines the amount of applied negative bias to the control grids of oscillator tubes 1 and 1′, respectively, is supplied from the output of the common diode rectifier D_5, the input of which is connected through the input transformer T_3 to a source of alternating waves of a wide range of amplitudes, which in the case of the corresponding control devices in the system of Fig. 1 would be the varying amplitude alternating pilot wave of the frequency 64 kilocycles or 2,064 kilocycles supplied to each device from the associated pilot amplifier and pilot filter. The alternating output waves of the oscillators O_1 and O_2 are respectively rectified by the diode rectifiers D_6, D_7 fed from the tuned circuit 3, 3′, to produce a constant direct current output voltage across the terminals of the output resistances 7 and 8, respectively.

The output resistance 7 of oscillator O_1 is connected in series with the adjustable resistance portion of potentiometer PT_2 in the control grid-cathode circuit of the tube 1′ of oscillator O_2, with the proper poling, so that, while the oscillator O_1 is producing an input, the net negative potential produced on the grid of the oscillator tube 1′ is such as to bias oscillator O_2 to cut-off.

With proper relative adjustments of the settings of the potentiometers PT_1 and PT_2, the oscillator O_1 may be made to produce across output resistance 7 a direct current output of substantially constant power for all values of alternating wave input power supplied to input transformer T_3 up to a value P_1, determined by the setting of potentiometer PT_1, where that oscillator (O_1) cuts off, and to produce substantially zero output power for all higher values of input power, as indicated by the upper curve of Fig. 3; and the oscillator O_2, without the connection between its control grid circuit and the output of oscillator O_1 shown, may be made to produce an equivalent constant direct current output power for all values of alternating input power applied to the input transformer T_3 up to the value P_2, higher than P_1, determined by the setting of potentiometer PT_2, as indicated by the middle curve of Fig. 3. With the output resistance 7 of oscillator O_1 connected effectively in series with the control grid-cathode circuit of tube 1′ of oscillator O_2 and properly poled as shown in Fig. 2, the oscillator O_2 may be made to give a constant direct current output across the terminals of its output resistance 8 for the range of input power applied to input transformer T_3 between the values P_1 and P_2, and substantially zero output power for all values of input power above and below that range, as indicated by the lower curve of Fig. 3.

In the corresponding control devices CD_1 to CD_4 in the control circuits PC_1 to PC_4, respectively, in the system of Fig. 1, the cut-off points of the two oscillators in each are made, by proper adjustment of the associated potentiometers, to coincide with the minimum amplitude level and the maximum amplitude level, respectively, of the tolerable range of levels of the pilot waves supplied over the associated line LA or LB, and the output resistance 8 of the oscillator having the higher cut-off point in the control device in each control circuit PC_1 to PC_4, as indicated in Fig. 2, is arranged in the direct current biasing circuit for either amplifier A_3 or A_4 in the switching circuit SW_A, and in the direct current biasing circuit for either amplifier A_5 or A_6 in the switching circuit SW_B, respectively, so that each amplifier is held operative by the constant direct current output of the associated control devices CD_1 to CD_4, when the amplitude levels of the controlling pilot waves supplied from the associated line LA or LB are within the tolerable range, and is biased to cut-off by the substantially zero output of that control device when the amplitude level of the controlling pilot wave supplied from the associated line LA or LB rises above or falls below that range, due to a partial or complete transmission failure in that line.

The operation of the complete system of Fig. 1 will now be described.

It will be assumed that line LA is the working line normally used for transmitting carrier signals over the switching section between the lines LW and LE, the line LB then being the spare line.

Half of the energy of the carrier signals received over the line section LW and half of the energy of the two pilot waves of frequencies 64 kilocycles and 2,064 kilocycles generated by the pilot wave sources P_1 and P_2, respectively, will pass through the hybrid coil HC_W to each of the lines LA and LB, and will pass thereover respectively through delay network DN_1, equalizer EQ_1 and line amplifier A_1, and delay network DN_2 and the equalizer EQ_2, toward the line section LE at the output of the switching section. A portion of the signal and pilot wave energy will be diverted from the line LA into the input of switching circuit SW_A, and, if the amplifiers A_3 and A_4 therein are both operative, as will be the case if the pilot energy diverted into pilot control circuits PC_1 and PC_2 is within tolerable amplitude level limits, with no appreciable impairment of transmission over the associated line LA, will pass in amplified form through these amplifiers to the diode rectifiers D_1 and D_2 and will be rectified by them. The rectified output of detector D_1 maintains a "blocking" (cut-off) bias on the line amplifier A_2 in line LB and the rectified output of diode rectifier D_2 holds operated relay R_1, which in turn holds open the locking circuit for relay R_3.

Since amplifier A_2 in line LB is biased to cut-off, the other half of the signal and pilot wave energy diverted into line LB will be prevented from passing over the output of that line to line LE or into the switching circuit SW_B. Therefore, no cut-off bias voltage will be supplied by rectifier D_3 in switching circuit SW_B to the amplifier A_1 in line LA, and the relays R_2 and R_3 in the output of rectifier D_4 will be released, causing the bias delay condenser C to be maintained connected in the biasing circuit for amplifier A_1 in line LA. The line LA then will operate as the working line to transmit signals and pilot wave energy from line section LW to line section LE, and line LB will be the spare line disabled in its output. If the manual key TST is operated and relay R_3 is released, an energizing circuit from battery B_1 will be provided for lamp L_1, and that lamp will light up to indicate that line LA is the working line and is in tolerable working condition, whereas lamp L_2 not supplied with battery will be extinguished, indicating to an attendant that line LB is operating as the spare line.

Now, if the amplitude level of either or both of the 64 kilocycles and 2,064 kilocycles pilots continuously transmitted over the line LA and passing through the pilot filter PF_1 and amplifier PA_1 to control device CD_1 in control circuit PC_1, and through the pilot filter PF_2 and amplifier PA_2 to control device CD_2 in control circuit PC_2, respectively, rises above or falls below the prescribed tolerable amplitude limits, in response to a complete or paritial failure of a conductor or other transmission element in that line, the resultant reduction in the direct current output of the control device or devices will cause amplifier A_3 or amplifier A_4, or both, to be biased to cut-off, thereby cutting off the input to rectifiers D_1 and D_2 in switching circuit SW_A. This will cause the blocking (cut-off) bias to be removed from the amplifier A_2 in line LB, and the relay R_1 to release to close the break through its contacts in the locking circuit for relay R_3.

The unblocking of amplifier A_2 in line LB will allow the signals and pilot waves received over that line from the west line section LW, and the pilot wave sources P_1 and P_2, respectively, to be transmitted to the input of the switching circuit SW_B and over the output of line LB through the hybrid coil HC_E to the east line section LE.

If line LB is then in tolerable operating condition, as indicated by the pilot wave outputs of the 64-kilocycle and 2,064-kilocycle pilot control circuits PC_3 and PC_4 producing constant outputs such as to bias both amplifiers A_5 and A_6 in the switching circuit SW_B to the operative condition, the portion of the signal and pilot wave energy in the output of amplifier A_2 diverted from line LB into that switching circuit, will pass in amplified form through the former amplifiers to the diode rectifiers D_3 and D_4 and will be rectified by them. The rectified output of rectifier D_3 will build up a blocking bias on amplifier A_1 in line LA, and the rectified output of rectifier D_4 will cause the operation of relay R_2 and thus of relay R_3.

The operation of relay R_3 through its operated upper contacts will close a normal break in the locking circuit for that relay enabling it to be locked operated when relay R_1 releases to close the other break in that locking circuit, from battery B_2. The operation of relay R_3, through its lower sets of contacts will disconnect the bias delay condenser C from across the biasing circuit of amplifier A_1 in line LA and will connect it across the biasing circuit of amplifier A_2 in line LB. Thus, the output of line LB will be enabled and the output of line LA disabled so that line LB will then operate as the working line to transmit signals and pilot wave energy from line section LW to line section LE, and line LA will be conditioned as the spare line disabled in its output.

The operation of relay R_3 in response to the rectified output of rectifier D_4, if test key TST is operated, will cause energizing current to be supplied from battery B_1 to the lamp L_2 causing it to light up to indicate that line LB is now the working line and is in tolerable operating condition, and energizing current to be cut off from the lamp L_1 causing it to be extinguished, indicating that LA is now the spare line.

If, as previously described, line LA is operating as the working line and line LB as the spare line, and line LB fails causing operation of one or both of its associated pilot-controlled circuits PC_3 and PC_4 to disable one or both of the amplifiers A_5 and A_6 in the switching circuit SW_B associated with line LB, nothing happens as regards line switching. However, when the spare line LB fails, the resultant reduction substantially to zero of the output of the control device CD_3 in control circuit PC_3, or of the output of the control device CD_4 in control circuit CD_4, or of the outputs of both of these control devices, causing the disabling of amplifier A_5, amplifier A_6 or both of those amplifiers in the switching circuit SW_B, indicate the spare line failure to an attendant.

If, on the other hand, both lines LA and LB fail simultaneously causing both switching circuits SW_B and SW_A to be disabled under control of the pilot-operated control circuits connected to the associated lines, the cut-off bias will be removed from the amplifier A_2 in line LB, and the relay R_1 will be released. Since relay R_3 is in its normal released conditions, the release of relay R_1 has no effect on the line switching control circuits. The operation of at least one pilot-controlled control circuit associated with one of the lines LA and LB, simultaneously with the operation of at least one pilot-controlled circuit associated with the other line, in consequence of the simultaneous failure of both lines, to disable one or more amplifiers in both switching circuits SW_A and SW_B will indicate total failure.

A simultaneous restoration of both lines LA and LB to a tolerable operating condition after a failure in both will cause all four diode rectifiers D_1 to D_4 to start producing direct current power. Then, since relay R_3 is in the released condition, the bias delay condenser C will be connected across the biasing circuit for the amplifier A_1 in line LA and disconnected from the biasing circuit for the amplifier A_2 in line LB, causing the development of a cut-off bias for amplifier A_1 to be slower than that for amplifier A_2. Therefore, amplifier A_2 in line LB will become biased to cut-off, permitting amplifier A_1 in line LA to remain at normal gain. This action is too rapid to allow relay R_2 to become operated. Therefore, if a total failure occurs, that is both lines LA and LB become impaired at the same time, when line LA is operating as the working line, restoration of through transmission to the same line (line LA) will be made.

If, while line LB is operating as the working line, line LA, operating as the spare line, fails, nothing happens as regards line switching, since amplifier A_1 in line LA is already biased to cut-off. If a total failure occurs under those conditions, the relay R_3 will remain locked operated through released contacts on relay R_1. Therefore, under those conditions, a simultaneous restoration of both lines LA and LB to the tolerable operating condition will cause the disabling of amplifier A_1 in line LA, since the bias delay condenser C is connected at the time across the biasing circuit for amplifier A_2 in line LB by the continued operation of relay R_3. Therefore, if a total failure occurs when line LB is the working line, and line LA the spare line, restoration of through transmission is made to the same line (line LB).

Since relay R_3 is released when line LA is the working line and is operated when line LB is the working line, the operated or non-operated condition of the contacts in that relay as indicated will cause the lighting or extinguishing of the lamps L_1 and L_2 to indicate which is the working line and which is the spare line when the TST key is operated manually.

So far no mention has been made of the functions of the delay networks DN_1 and DN_2 in lines LA and LB, respectively. If voice frequency telegraph signals are being transmitted over the coaxial system, the line cannot fail for more than a few milliseconds without causing an error. Such a condition is termed a "hit." If "T" represents the maximum safe time permitted to open a voice frequency telegraph circuit, which will not cause a "hit" disturbance; "S" represents the total elapsed time required for the switching circuit of Fig. 1 to enable a disabled spare line amplifier and to disable the previously working line amplifier, when a working line failure occurs; and "D" represents the time delay required to be supplied by the delay networks DN_1 and DN_2, then

$$D=S-T \quad (1)$$

Therefore, suitable selection of the circuit elements in the arrangement of Fig. 1 should produce a fast enough switch operating time, "S," to permit a practical value of delay time "D" for the networks DN_1 and DN_2 to be used in the lines LA and LB to prevent hits being caused by switches.

The speed of operation of the electronic arrangement which has been described, to switch from one line to another, should be in the order of a millisecond or less, as compared with a switching time of about 200 milliseconds required with the automatic switching arrangements which have been used previously in commercial systems.

Since the complexity of a delay network depends upon the frequency band width to be delayed, it might be permissible to reduce or limit the complexity of the delay networks by assigning the voice frequency telegraph circuits to a limited frequency range in the system with which the circuits of the invention would be used. The delay would then only have to be provided over this limited range, and at the control pilot frequencies of the sources P_1 and P_2 used. It is assumed that no delay is required by other types of circuits due to the inherent rapidity of this type of switching.

The arrangements of the invention have been described as applied to systems employing one working line in each direction of transmission and a single line operating as a spare for the working line, and to the use of only two pilot waves of different frequencies continuously transmitted over each line to control the switching between the working and a good spare line when transmission failure in the working line occurs. It is apparent, however, that by using in connection with additional lines other control circuits, similar to those illustrated and described and operating in similar manner, the arrangements of the invention may be readily adapted for use in connection with systems employing more than one working line and two or more spare lines if that becomes desirable. Also, it is apparent that by employing a greater number of pilot waves of different frequencies within the signal frequency range, but not interfering with any signal frequencies (located within bands of the signal frequency range which are devoid of signal frequencies), continuously transmitted over the working and spare lines, a corresponding number of pilot-controlled switching circuits similar to those which have been described, respectively selective to a different one of the pilot frequencies, connected to the working and spare lines, and a corresponding number of tandem-connected amplifiers in the signal-controlled switching circuits connected to the several lines, respectively controlled by a different one of the control circuits, suitable line switching and alarm indications may be attained for line trouble conditions affecting different portions of the signal frequency range, thus providing better operation under all service conditions.

Other modifications of the circuits illustrated and described which are within the spirit and scope of the invention will occur to persons skilled in the art.

What is claimed is:

1. In combination, a source of signals, an output circuit, two transmission circuits connecting said source to said output circuit, a signal-operated switching device connected to each of said transmsission circuits near its output, which when completely operated in response to the signals applied thereto from that circuit disables the other transmission circuit and the switching device connected thereto, means for making one of said switching devices connected to one of said transmission circuits effectively faster in operation than the other switching device connected to the

other transmission circuit so that for normal signal transmission conditions in said one circuit it is operative to transmit signals from said source to said output circuit and the other transmission circuit is prevented from doing so, and means responsive to the occurrence of abnormal signal transmission conditions in said one circuit, only if normal signal transmission conditions exist in said other circuit, for so controlling the operation of the two switching devices that said other circuit becomes operative to transmit signals from said source to said output circuit and said one circuit is prevented from doing so.

2. In combination, a source of signals, two transmission circuits supplied in common from said source, a common output circuit for said transmission circuits, a signal-operated switching device connected to each transmission circuit, which when completely operated by signals in that circuit disables the other transmission circuit and the switching device connected thereto, means for making the switching device connected to one of said transmission circuits effectively faster in operation than the switching device connected to the other circuit so that for normal signal transmission conditions in said one circuit it is operative as a working circuit to transmit signals from said source to said common output circuit and the other transmission circuit is prevented from doing so and means responsive to the occurrence of abnormal transmission conditions in the transmission circuit operating as the working circuit to disable the switching device connected thereto so that said other transmission circuit is rendered operative as the working circuit to transmit signals between said source and said common output circuit and the switching device connected to said other circuit holds the first transmission circuit and the switching device connected thereto disabled while said abnormal signal transmission conditions in said first circuit continues.

3. The combination of claim 1, in which the last-mentioned means comprises means for continuously transmitting a plurality of pilot waves of different frequencies outside the signal frequency range over each of said transmission circuits and means responsive to abnormal variation of the level of any one of the transmitted pilot waves at a given point in the circuit over which they are transmitted to cause the switching device connected thereto to be disabled.

4. In combination, a source of signals, two transmission circuits supplied from said source, a common output circuit for the two transmission circuits, a signal-operated switching device connected to each transmission circuit near its output, which when completely operated by the applied signals from the connected circuit disables the other transmission circuit and the switching device connected thereto, delay means normally connected in the switching device connected to one transmission circuit, rendering its operation slower than the switching device connected to the other transmission circuit so that for normal signal transmission conditions in said other transmission circuit it is operative as a working circuit to transmit to said output circuit and said one transmission circuit is prevented from doing so, means responsive to the occurrence of abnormal signal transmission conditions in each signal transmission circuit for rendering the switching device connected thereto inoperative so that the occurrence of abnormal signal transmission conditions only in the transmission circuit operating as a working circuit will result in that circuit being rendered inoperative and the other transmission circuit being rendered operative to transmit signals between said source and said common output circuit while said abnormal signal transmission continues and means responsive to the complete operation of the switching device connected to said one circuit for causing said delay means to be switched from that switching device to the switching device connected to said other transmission circuit so as to render the latter switching device slower in operation than the former switching device.

5. In combination, two transmission circuits fed from a common source of signals and feeding a common output circuit, each including a normally operative transmission device near its output, a switching circuit including one or more normally operative transmission devices, connected to each of said transmission circuits in the output of the transmission device therein, and operatively responsive to applied signals, when that transmission device is operative, to disable the output transmission device in the other transmission circuit and thus to prevent transmission therefrom to said common output circuit, the two switching circuits normally having respectively different time constants making one effectively faster in operation than the other so that for normal signal transmission conditions in the transmission circuit to which said one switching circuit is connected, that transmission circuit is conditioned as an operative working circuit to transmit signals from said source to said output circuit and the other transmission circuit as a spare circuit disabled in its output, and other means responsive to abnormal signal transmission conditions in either of said two transmission circuits for causing the switching circuit controlled therefrom to be disabled, whereby the occurrence of abnormal signal transmission conditions in the transmission circuit which at the time is conditioned as a working circuit to transmit to said output circuit, will result in that transmission circuit being disabled in its output and the other transmission circuit which at the time is conditioned as a spare circuit, being rendered operative as the working circuit to transmit to said output circuit, but only if signal transmission conditions in said other transmission circuit are normal at that time.

6. The system of claim 5 in which said other means comprises means for continuously transmitting at least one pilot wave of a frequency outside the signal frequency range over each of said transmission circuits, and control means connected to each of said transmission circuits at an output point in front of the disabling point therein, controlled by the applied pilot wave of that frequency and operatively responsive, only when its amplitude level is outside prescribed tolerable limits, such as would be caused by complete or partial transmission failure in that transmission circuit, to apply a blocking bias to a transmission device in the switching circuit connected to that transmission circuit.

7. The combination of claim 5 in which each of said transmission devices in said two transmission circuits and in said switching circuits is an electronic device having a control element, which is disabled by the application of a blocking bias to that control element in response to operation of the controlling switching circuit or said other means, respectively.

8. The combination of claim 5 in which the

transmission device in the output of each of said transmission circuits is an electron discharge device having a control grid circuit, which is disabled by the application of a cut-off bias to its control grid circuit in response to operation of the switching circuit controlled from the other transmission circuit, and the switching circuit controlled from the transmission circuit normally conditioned as a working circuit being rendered faster in operation than that switching circuit controlled from the transmission circuit normally conditioned as a spare circuit, by the inclusion in the latter switching circuit of means for delaying the application of cut-off bias to the control grid circuit of the electron discharge device which it controls.

9. The combination of claim 5 in which the output transmission device in each of said transmission circuits includes an electron discharge device having a control grid circuit which is disabled by the application of a cut-off bias to the control grid circuit of that electron discharge device, and said one switching circuit connected to the transmission circuit normally operating as the working circuit being effectively rendered faster in operation than that switching circuit connected to the transmission circuit normally operating as a disabled spare circuit, by the normal inclusion in the latter switching circuit only of means for delaying the building up of a cut-off bias on the control grid circuit of the electron discharge device in the working circuit, which said cut-off bias delaying means is transferred to said one switching circuit on operation of the other switching circuit to render the latter effectively faster in operation, after said one switching circuit has been disabled in response to abnormal signal transmission conditions in the transmission circuit to which it is connected, so as to condition the other transmission circuit thereafter during normal signal transmission conditions therein, as the working circuit transmitting to said output circuit and the first transmission circuit as the disabled spare circuit during that time interval.

10. In combination, two line sections each including an output amplifier fed from a common source of signals of wide frequency range and feeding a common output line, a signal-controlled switching device connected across each line section in the output of its output amplifier and responsive to the signal output thereof, when that amplifier is operative, to disable the output amplifier in the other line section, the relative time constants of the two switching devices being selected so that under normal signaling conditions in one line section only the one switching device connected thereto is completely operated, thus normally conditioning said one line section as the working line transmitting to said output line and the other line section as a spare line disabled in its output, means to continuously transmit a plurality of pilot waves of different frequencies outside or within the signal frequency range, but not interfering with the signal frequencies, over each of said line sections, a plurality of control devices respectively selective to a different one of said pilot waves connected across the output of each line section in front of its output amplifier, each operatively responsive only to deviations in the amplitude level of the selected pilot wave beyond tolerable level limits, such as would be caused by partial or complete failure of the associated line section, to effectively disable the switching device controlled from that line section, whereby operation of any of the control devices connected to a working line will cause signal transmission to be effectively transferred to the spare line but only if the latter is in tolerable operating condition.

11. The combination of claim 10 in which each of said control devices connected to each line section includes two oscillators adapted for control by the pilot wave selected thereby, in such manner that one oscillator produces an output only for pilot wave inputs to the control device of levels up to the lower of said tolerable level limits, which output holds the second oscillator inoperative to produce an output for such pilot wave inputs, and said second oscillator produces a constant output for higher level pilot wave inputs up to the higher of said tolerable level limits, and no output for still higher level pilot wave inputs, the output of said second oscillator being so connected to the switching device controlled from the associated line section that the constant output of that oscillator for pilot wave inputs of levels between said tolerable limits will have no effect on the operation of that switching device, whereas during periods of pilot wave inputs of levels outside said tolerable limits when said second oscillator produces no output, that switching device will be disabled.

12. In combination with a source of waves of a wide range of amplitudes, one oscillator having a control input controlled by the waves from said source in such manner as to tend to make said oscillator produce an output of appreciable power for wave inputs of all amplitudes up to a given limiting value within said range, and substantially no output for wave inputs of higher amplitudes, a second oscillator having a control input controlled by the waves from said source in such manner as to make said second oscillator produce an output of appreciable power for wave inputs of all amplitudes up to a second limiting value lower than that of said given value, and substantially no output for wave inputs of higher amplitudes, means to apply the output of said second oscillator to the control input of said one oscillator in such manner as to bias the latter oscillator to cut-off while wave inputs of amplitudes up to said lower limiting value are being applied thereto from said source, thus providing a wave output for said one oscillator of appreciable power for wave inputs applied to said control device from said source over the amplitude range between said lower and higher limiting values, and substantially no output for wave inputs of amplitudes above and below said range.

13. A control device comprising an output circuit, an input circuit supplied with alternating current of a wide range of amplitude levels, a rectifier for rectifying said current, two oscillators each having a biasing input circuit, the output of one of said oscillators being coupled to said output circuit, a pair of potentiometers, the output of said rectifier being applied to the biasing input circuit of each of said oscillators through a different one of said potentiometers so as to bias the oscillator in accordance with the voltage drop produced in the associated potentiometer by the rectifier output current, the resistance values of said potentiometers and their settings being selected so that said one oscillator tends to produce an output of substantially constant power for all amplitude level values of the current supplied to said input circuit up to a given higher limiting value, and then cuts off so as to produce substantially no output for higher

amplitude level values of the input current, and the other oscillator produces an output of appreciable power for all amplitude level values of the current supplied to said input circuit up to a limiting value lower than said higher value, and then cuts off so as to produce substantially no output for higher amplitude level values of input current and means to apply the output of said other oscillator to the biasing input of said one oscillator in such manner that the latter oscillator is biased to cut-off during periods in which the amplitude level of the current supplied to said input circuit is below said lower limiting value, thus producing in said output circuit an appreciable output for current inputs to said input circuit of amplitude levels ranging between said lower and said higher limiting values, and substantially no output for current inputs of amplitude levels below and above said range.

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