April 7, 1942. L. V. LEWIS 2,279,123

REMOTE CONTROL SYSTEM

Original Filed April 17, 1937

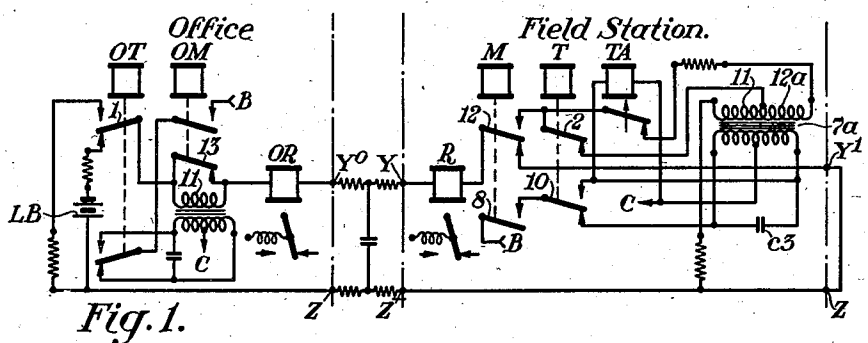


Fig. 1.

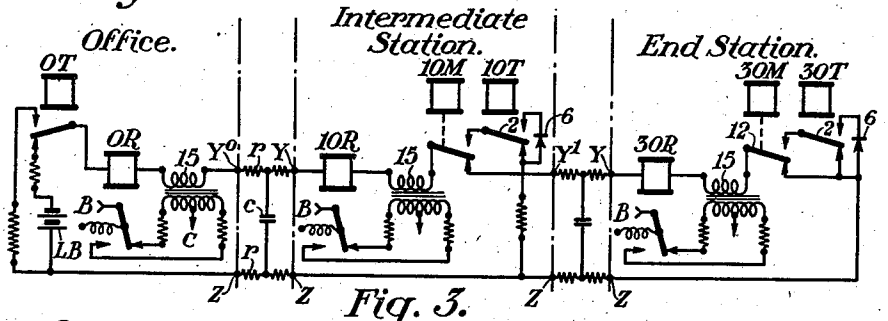


Fig. 3.

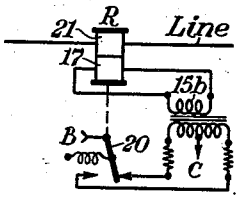


Fig. 4.

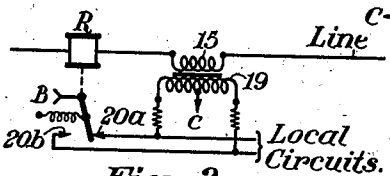


Fig. 2.

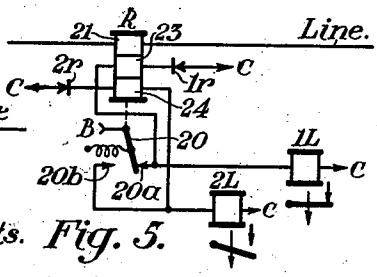


Fig. 5.

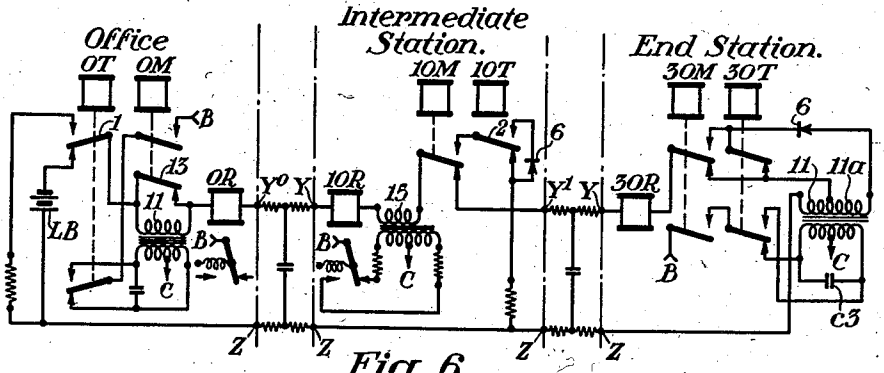


Fig. 6.

INVENTOR
Lloyd V. Lewis
BY
HIS ATTORNEY

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UNITED STATES PATENT OFFICE

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REMOTE CONTROL SYSTEM

Lloyd V. Lewis, Pittsburgh, Pa., assignor to The Union Switch & Signal Company, Swissvale, Pa., a corporation of Pennsylvania

Original application April 17, 1937, Serial No. 137,500. Divided and this application September 21, 1940, Serial No. 357,717

7 Claims. (Cl. 177—353)

My invention relates generally to remote control systems, and more particularly to systems of the above character in which code signals are transmitted over a line which is relatively long electrically, such, for example, as a long distance cable line having considerable distributed capacity as well as resistance. More specifically, the invention relates to the method, as well as apparatus, for increasing the maximum length of such cable or other line over which code signals may be effectively transmitted and accurately reproduced.

My invention is particularly adapted for, though in no manner limited to, centralized traffic controlling systems for railroads employing a normally closed line circuit connecting a dispatcher's office with a plurality of field stations located at spaced points along the line. The code signals employed for transmission from the office to the stations and from the stations back to the office may be of any suitable character, but in the illustrative embodiments which I have chosen, these signals are formed by interrupting or varying the flow of current from a line battery which will usually be located at the dispatcher's office.

My present invention may advantageously be applied, for example, to centralized traffic controlling systems such as disclosed in my copending application, Serial No. 600,786, which matured into Letters Patent of the United States No. 2,229,249, issued January 21, 1941, and one object of my invention is to extend the effective length of the territory controlled by such systems. It will be understood, however, that the method and apparatus embodying my invention, though explained with reference to a railway traffic controlling system of the above type for a clearer understanding of the invention, are of general utility in signal transmission systems and may be employed wherever suitable current impulses must be effectively transmitted over an electrically long transmission line.

Other objects and features of my invention will become apparent as the description progresses.

The present application is a division of my co-pending application Serial No. 137,500, filed April 17, 1937, for Remote control system, now Patent No. 2,216,820, issued October 8, 1940.

I shall describe several methods and forms of apparatus embodying my invention, and shall then point out the novel features thereof in claims:

In the accompanying drawing, Fig. 1 is a diagrammatic view showing apparatus embodying my invention by means of which impulses of alternately opposite polarity may be impressed upon the line either at a distant field station or at the office, or both, to improve the transmission characteristics of the line by correcting the distortion in the line current.

Fig. 2 is a diagrammatic view embodying my invention, showing other means for correcting distortion in the line current, whereas Fig. 3 is a diagrammatic view showing the apparatus of Fig. 2 applied to a centralized traffic control system.

Figs. 4 and 5 are diagrammatic views, both embodying my invention, showing additional means for overcoming the effect of distortion in the line current upon the line relays.

Fig. 6 is a diagrammatic view embodying my invention and showing a complete line circuit in which an office and an intermediate station, similar to the office and station of Figs. 1 and 3, respectively, are combined with an end station similar to that of Fig. 1 but of somewhat simplified form.

Similar reference characters refer to similar parts in each of the several views.

The designations for the various relays disclosed herein are the same as for the corresponding relays shown in my copending application, Serial No. 600,786, hereinbefore referred to, which matured into Letters Patent of the United States No. 2,229,249, issued January 21, 1941, as these relays are provided for the same purpose and perform similar functions to those described in said copending application and said patent. That is, the reference R designates the receiving line relay, and is identified by the prefix O when located at the control office or by a numerical prefix corresponding to the station number when located at a particular field station. The reference T, with corresponding prefix, similarly designates the corresponding transmitter relay for delivering code impulses to the line circuit, while M designates the master relay which controls the transmission and which is energized only when a code is being transmitted from the corresponding station.

In systems of this character, the code signals are formed by opening and closing the line circuit at time spaced intervals, and the line current variations in a short line due to the operation of any of the transmitting relays T correspond in form to the variations of the impressed voltage. Actually one or more relatively long impulses and/or intervals are interposed in the series of impulses to characterize the code, but these being

of a lower fundamental frequency are transmitted more readily. In a long cable line, considering particularly the operation of the office transmitter, a transient current flows into the cable to charge the distributed capacity of the cable each time the line is closed, and this charge leaks off at the remote end in whole or in part when the line is opened. Considering now the voltage conditions, when a steady current is flowing, the voltage across the closed line will decrease uniformly from a given value E at the office end and will become zero at the distant end, since the distant end of the line is closed. This is shown diagrammatically in Fig. 3 of the parent case referred to hereinbefore. The charge at any point along the line is proportional to the voltage at that point, and it will be clear that the total charge is ½CE where C is the total cable capacity and E is the voltage applied to the sending end. The effect is substantially as if the entire charge were located at the center of gravity of a voltage triangle drawn between the sending and receiving ends, that is, at a point which is one-third of the distance between the two ends.

That distortion of signals results from the presence of distributed capacity, due to the opening and closing of the line circuit at the battery end, will be at once apparent because, when the line becomes closed, the capacity is charged through a resistance proportional to a given distance, and when the line becomes opened, it discharges through a resistance proportional to a distance which is twice as great so that the rates of charge and discharge are not the same. The current received at the distant end of the line will therefore be non-symmetrical in wave form. Moreover, the current delivered to the line at the transmitting end will also be non-symmetrical in form.

Considering the transmission from a field station to the office, and more particularly from an end station, it will be found that the opening and closing of the line by the transmitting relay will also produce a line current variation at that end which is similar to the variation produced by the office transmitter. In this case, when the line is opened, current continues to flow to charge the entire line to a given uniform potential and a large part of the charge leaks off when the line becomes closed. In this case, the charge on the line is ½CE when the line is closed and equals twice that value or CE when the line is open, and the effect is substantially as if the entire distributed capacity were concentrated at a point one-third of the distance from the end station to the office. A transmitter at the distant end, therefore, delivers non-symmetrical signals at the office, which signals are of the same form as those delivered at the end station when the office transmitter is operating and a corrective circuit is not used. The apparatus disclosed and claimed in my parent case above referred to corrects for this type of distortion.

The impulses of current which are received over a short line will usually be quite sharp and well defined, the rate of change being high at the start and at the end of the impulse. Even if the rate of change of current delivered to the line relays is relatively low, the line relay contacts will deliver undistorted code signals provided that the A. C. component of the line current is symmetrical and provided further that the neutral axis of this current (which equals the D. C. component or average value of the line current) corresponds to the mean value of the pick-up and release values of current for the receiving relays, as determined by their bias adjustment. It is also apparent that a change in the timing of the signals delivered by the contacts of the time relays will occur when the average value of the line current becomes either greater or less than the particular value mentioned. This effect may be decreased and improved transmission may be obtained by increasing the current delivered to the line by impressing impulses of alternately opposite polarity upon the line so that the total voltage impressed on the line will have well defined positive and negative peaks, the positive peak coming at the start of the impulse and the negative peak at the end thereof. In such case, the rate of change of the current received at the distant end will be increased and the received signals will correspondingly be improved so as to approximate those which are received over a relatively short line.

Referring now to Fig. 1 of the drawing and particularly to the apparatus at the right-hand or field station portion of this figure, this apparatus performs the corrective function just referred to. This apparatus comprises an impulse transformer 7*a* having a periodically reversed E. M. F. impressed on its primary by a contact finger 10 of the transmitting relay T when a field station is transmitting. As pointed out in my parent application hereinbefore referred to, suitable code transmitting apparatus which forms no part of my present invention and which is not necessary for an understanding of the invention causes operation of relay M and relay T whereby an "off" impulse is transmitted when relay T picks up and an "on" impulse when this relay releases. As a result, when relay T picks up, a reverse E. M. F. is impressed on the line circuit by the full secondary winding comprising winding portions 11 and 12*a*. Portion 11 of the winding is included in the line circuit both when relay T picks up and when it releases, as is apparent from the drawing, and so delivers symmetrical impulses of alternately opposite polarity. The current delivered to the line will therefore be of the symmetrical form, and will have the necessary peak at the start of each impulse. The condenser *c*3 is connected across the input winding of transformer 7*a* for the purpose of storing the impulse energy so as to avoid the necessity for perfect timing of the opening of back contacts 10 and 2 of relay T, and to prevent sparking at these contacts.

In the left-hand or office portion of Fig. 1, an alternating impulse voltage is also applied to the line when the office transmitter OT is operating, by apparatus similar to that at the field station of Fig. 1, except that the additional secondary portion 12*a* is not required. Back contact 13 of relay OM at the office and back contact 12 of relay M at the station operate in an obvious manner to cut the impulse transformer secondary out of the line circuit, except during the transmission of a code, so that the added apparatus is without effect upon reception of a code from a distant point.

The apparatus so far described is concerned chiefly with the correction of the distortion of signals in a long cable line due to the characteristics of the line circuit itself. In addition to such distortion, there is also a distortion resulting from the operation of the line relays, as will become apparent from the following discussion. Each receiving relay in the line circuit is

an energy consuming device, or motor, and also possesses reactance. Each relay, therefore, generates a counter-electromotive force in the line circuit when the relay operates, in such a direction as to oppose the change in the line current which is the cause of the relay operation. In other words, each line relay upon picking up tends to prevent the other relays from picking up, and each line relay upon releasing tends, likewise, to prevent the other relays from releasing.

To decrease this effect in practice, it is customary, even in the case of a short line, to use relays of relatively low resistance so that the total relay resistance included in the line circuit is not more than one-half of the total resistance of the circuit. This measure is, however, insufficient when the line is so long that the rate of change of the line current is relatively low, in which case a slight decrease or increase in the rate of change causes a relatively large change in the time of operation. If the received current at the end of a long line having no relays included therein may be assumed to have a smooth wave form, then the counter-electromotive force due to the inclusion of several line relays in the line circuit may change the wave form by introducing irregularities which are due to the pick-up and release operations of the line relays.

To overcome this difficulty, I propose to cause each line relay, when it operates, to introduce a voltage impulse into the line circuit in a direction such as to oppose and overcome the effect of its own counter-electromotive force upon the line circuit. One form of apparatus for accomplishing this result is that shown in Fig. 2. The apparatus of this figure includes an impulse transformer having a secondary 15 in series with the line and a primary 19 supplied with impulses which are periodically reversed in direction by connection alternately to the contact 20*a* or 20*b* of the line relay R. The apparatus of Fig. 2 functions in a manner generally similar to that of the office portion of Fig. 1 already described, since relay R of Fig. 2 is controlled by and is therefore a repeater of the transmitting relay OT which provides the impulses in Fig. 1.

The apparatus of Fig. 2 may be used not only to compensate for the effect of the operation of the relays but may also be used to provide an additional corrective voltage to improve the received signals. The effect of the additional voltage provided by the apparatus of Fig. 2 will be to increase the rate of change of the line current, as in the case of Fig. 1.

The effect which the apparatus of Fig. 2 has upon the line current differs in one respect from that of the office apparatus of Fig. 1 in that the added voltage impulse is delayed slightly with respect to the transmitter and so follows rather than precedes the operation of the adjacent line relay. Accordingly, with a plurality of line relays, a corresponding plurality of overlapping impulses will be produced differing slightly in time phase. It follows that the energy of the individual impulses may, therefore, be relatively small as compared with the energy of the impulses delivered by the transmitting relay at the office or at the field station of Fig. 1. The apparatus of Fig. 2 possesses the advantage, therefore, that the distortion correcting means is distributed along the line, whereby the total effect may be made as great as desired even though the effect of each individual impulse transformer may be relatively small. The cumulative effect of the impulses, such as are produced by the apparatus of Fig. 2, is obviously to accelerate the charge and discharge of the line capacity as in the apparatus previously described.

Fig. 3 illustrates a line circuit arranged to include apparatus in accordance with Fig. 2. A rectifier 6 is included in the branch circuit passing over front contact 2 of each station transmitting relay T to provide a low resistance path for charging the capacity of the line from the end remote from the battery LB. Thus, in Fig. 3, when back contact 2 of relay 30T opens (front contact 12 of relay 30M having previously become closed in the normal operation of the system), the total voltage impressed on the line by the secondaries 15 of the impulse transformers will be of the desired value for satisfactory signal transmission from the station, while the total voltage which is impressed on the line by the line battery LB and the impulse transformers when back contact 2 of relay 30T subsequently closes will similarly have the desired value for satisfactory transmission from the office.

Fig. 4 illustrates a modified form of the invention of Fig. 2 in which the line relay R is provided with an auxiliary winding 17 across which the transformer secondary 15*b* is connected. The connections are so arranged with respect to polarity that when contact 20 moves to the left an impulse is produced in winding 15*b* tending to accelerate the motion of the contact to the left, and when contact 20 moves to the right, an impulse is produced to accelerate the movement to the right. The effect upon relay R is, therefore, the same as if the impulse traversed its line winding 21, as in Fig. 2, and since the two relay windings are coupled together magnetically and so constitute a transformer, a voltage is impressed upon the line in a similar manner to that occurring in the apparatus of Fig. 2.

In Fig. 5 I have shown a further modification of the apparatus of Fig. 2. In apparatus of this character, contacts such as 20 of the line relays R will usually be employed to control various relays such, for example, as 1L and 2L shown in the drawing, and in order to prevent sparking when either contact 20*a* or 20*b* opens, a rectifier such as 1*r* or 2*r* is usually connected across the terminals of the respective relays 1L and 2L to provide a discharge path for their stored inductive energy when the respective energizing circuits are opened. In Fig. 5, the line relay R is provided with two auxiliary windings 23 and 24 which are connected in series in the discharge paths of the respective relays 1L and 2L, whereby the stored inductive energy of these relays is rendered available to provide impulses for accelerating the motion of contact 20. Since windings 23 and 24 are inductively coupled with the line winding 21, it will be obvious that these impulses are impressed upon the line circuit as in the other forms of the invention.

Fig. 6 illustrates another manner in which apparatus embodying my invention may be advantageously employed. In this view, the control office apparatus includes an impulse transmitter similar to that shown in Fig. 1, and this transmitter delivers control codes to the line circuit branch which includes back contacts of the various relays M and the windings of all the line relays R. The impulses which are delivered by this office transmitter are reenforced by apparatus similar to that shown in Fig. 2. Further-

more, the impulses which are delivered by transmitting relays, such as relay 10T, located at relatively short distances from the office are also reenforced by apparatus such as that shown in Fig. 1, which apparatus may be located at one or more of the intermediate stations. However, the impulses which are delivered from the more remote stations such as the end station 30 and which are subject to greater distortion are further reenforced by impulse transmitting apparatus which may take the form shown in Fig. 1. This apparatus is shown at the end station of Fig. 6.

From the foregoing description of the apparatus embodying my invention it will be apparent that I have provided novel and improved apparatus for materially extending the maximum distance over which satisfactory transmission of code signals over line circuits having relatively large distributed capacity may be effected. Moreover, by decreasing undesirable distortion of the received impulses, the apparatus embodying my invention renders the operation of the receiving equipment more positive, decreases the amount of power which must be transmitted over the line, and materially increases the speed of transmission.

It will be apparent, of course, that the apparatus and method herein described of reducing the distortion effect, although applied specifically to a centralized traffic control system in railway signaling for purposes of illustration and to provide a better understanding of my invention, are not limited to this particular use but may be used for improving transmission of code impulses in long cable circuits generally.

Although I have herein shown and described only a few forms of remote control systems embodying my invention, it is understood that various changes and modifications may be made therein within the scope of the appended claims without departing from the spirit and scope of my invention.

Having thus described my invention, what I claim is:

1. In a remote control system, two stations connected by a line circuit, a source of unidirectional current, a receiving relay at one of said stations receiving energy from said source over said line circuit, a transformer having its output winding connected to said line circuit at the other station, and transmitting means operable at time spaced intervals corresponding to a code for alternately deenergizing and energizing said receiving relay from said source and for alternately energizing the input winding of said transformer with direct current of one or the other relative polarity to deliver impulses of alternately opposite polarity to said line circuit in step with the operation of said relay, the polarity of said impulses being so chosen with respect to the polarity of unidirectional energization of said relay from said source that the impulse occurring upon deenergization of said relay opposes said unidirectional energization so as to accelerate release of the relay whereas the impulse occurring upon energization of the relay aids said unidirectional energization so as to accelerate pickup of said relay.

2. In a remote control system, two stations connected by a line circuit, a source of unidirectional current, a receiving relay at one of said stations receiving energy from said source over said line circuit, a transformer having its output winding connected to said line circuit at the other station, and means operable at time spaced intervals corresponding to a code for alternately deenergizing and energizing said receiving relay from said source and for alternately energizing the core of said transformer with unidirectional magnetization of one or the other relative polarity to deliver impulses of alternately opposite polarity to said line circuit in step with the operation of said relay, the polarity of said impulses being so chosen with respect to the polarity of unidirectional energization of said relay from said source that the impulse occurring upon deenergization of said relay opposes said unidirectional energization so as to accelerate release of the relay whereas the impulse occurring upon energization of the relay aids said unidirectional energization so as to accelerate pickup of said relay.

3. In a remote control system, two stations connected by a line circuit, a source of unidirectional current, a receiving relay at one of said stations receiving energy from said source over said line circuit, and means at the other station including transmitting contacts operable at time spaced intervals corresponding to a code for alternately deenergizing and energizing said receiving relay from said source and for causing impulses of alternately opposite polarity to be delivered to said line circuit in step with the operation of said relay, the polarity of said impulses being so chosen with respect to the polarity of unidirectional energization of said relay from said source that the impulse occurring upon deenergization of said relay opposes said unidirectional energization so as to accelerate release of the relay whereas the impulse occurring upon energization of the relay aids said unidirectional energization so as to accelerate pickup of said relay.

4. In a remote control system, two stations connected by a line circuit, a source of unidirectional current, a receiving relay at one of said stations receiving energy from said source over said line circuit, transmitting means operable at time spaced intervals corresponding to a code for alternately deenergizing and energizing said receiving relay from said source, and inductive impulse means at the other station operating in step with said transmitting means for causing impulses of alternately opposite polarity to be delivered to said line circuit, the polarity of said impulses being so chosen with respect to the polarity of unidirectional energization of said relay from said source that the impulse occurring upon deenergization of said relay opposes said unidirectional energization so as to accelerate release of the relay whereas the impulse occurring upon energization of the relay aids said unidirectional energization so as to accelerate pickup of said relay.

5. In a remote control system, a transmitting and a receiving location connected by a line circuit, a source of unidirectional current for energizing said line circuit, a transmitter at the transmitting location operable at time spaced intervals corresponding to a code for alternately interrupting the flow of current and supplying current from said source to said line circuit, and inductive impulse means also at the transmitting location controlled by said transmitter and operable at said time spaced intervals for causing impulses of alternately opposite polarity to be delivered to said line circuit, the polarity of said impulses being so chosen with respect to the polarity of unidirectional energization of said

line circuit from said source that the impulse occurring upon said interruption of current flow opposes said unidirectional energization whereas the impulse occurring upon the supply of current aids said unidirectional energization so as to facilitate transmission of the code to said receiving location.

6. In a remote control system, a transmitting and a receiving location connected by a line circuit, a source of unidirectional current for energizing said line circuit, a transformer having its output winding connected to said line circuit at said transmitting location, and transmitting means also at said transmitting location operable at time spaced intervals corresponding to a code for alternately interrupting the flow of current and supplying current from said source to said line circuit and for alternately energizing the input winding of said transformer with direct current of one or the other relative polarity to deliver impulses of alternately opposite polarity to said line circuit in step with the interruption and the supply of current to the line circuit, the polarity of said impulses being so chosen with respect to the polarity of unidirectional energization of said line circuit from said source that the impulse occurring upon said interruption of current flow opposes said unidirectional energization whereas the impulse occurring upon the supply of current aids said unidirectional energization so as to facilitate transmission of the code to said receiving location.

7. In a remote control system, a line circuit, a source of unidirectional current for energizing said line circuit, a transformer having its output winding connected to said line circuit, and transmitting means operable at time spaced intervals corresponding to a code for alternately interrupting the flow of current and supplying current from said source to said line circuit and for alternately energizing the input winding of said transformer with direct current of one or the other relative polarity to deliver impulses of alternately opposite polarity to said line circuit in step with the interruption and the supply of current to the line circuit, the polarity of said impulses being so chosen with respect to the polarity of unidirectional energization of said line circuit from said source that the impulse occurring upon said interruption of current flow opposes said unidirectional energization whereas the impulse occurring upon the supply of current aids said unidirectional energization so as to facilitate transmission of the code to said receiving location.

LLOYD V. LEWIS.