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H. NYQUIST

2,206,423

TELEGRAPH SYSTEM

Filed Sept. 24, 1938

FIG. 1

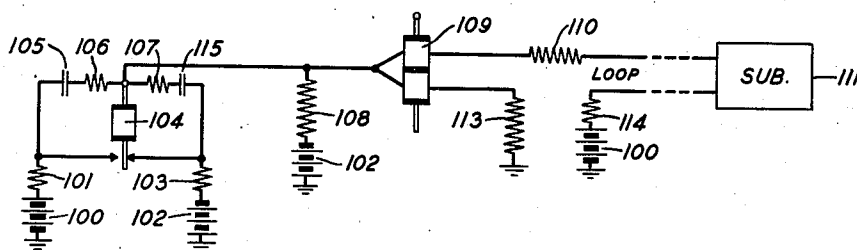


FIG. 2

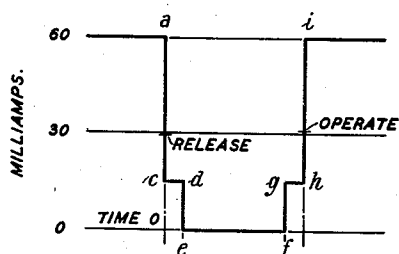


FIG. 3

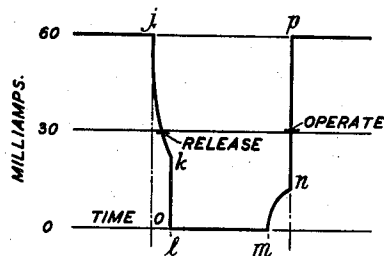


FIG. 4

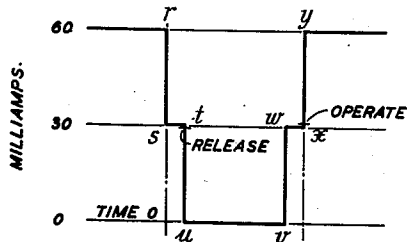
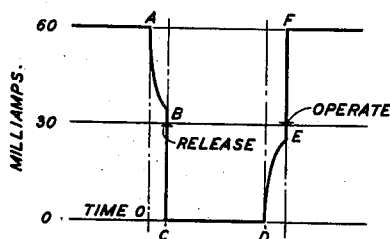


FIG. 5



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TELEGRAPH SYSTEM

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8 Claims. (Cl. 178—59)

This invention relates to telegraph systems and more particularly to a means of improving the transmission over telegraph loop circuits by reducing the bias inherent in the operation of certain well-known loop circuits now widely used in the art.

In these well-known loop circuits, the current flowing between the telegraph relay armature and one of its associated contacts differs widely in value from the current flowing through said armature and its opposing contact. The effect of this invention is to equalize said current for the two conditions. Since the design of contact protection networks is affected by the variations of said current, this problem is simplified by this invention. The bias of the receiving relay in said loop circuits, further, is affected, as now employed in the art, by the present contact protection networks. As a result of this invention the effect of the contact protection networks on said bias is eliminated. It is possible, therefore, as a result of this invention to design contact protection networks without regard to their effect upon bias.

An object of this invention is to reduce bias in a telegraph circuit.

A further object of this invention is to eliminate bias in a telegraph circuit caused by relay travel time.

A further object of this invention is to facilitate the design of telegraph relay contact protection networks.

A further object of this invention is to equalize the current flowing between the armature and the marking and spacing contacts of a telegraph relay transmitting into a balanced subscriber's telegraph loop circuit.

A feature of this invention is the connection of one terminal of a resistance to the apex of a balanced telegraph loop circuit, said resistance being equal in value to the resistance of said loop, the second terminal of said resistance being connected to marking battery, with the loop being terminated in spacing battery of equal value but opposite polarity from said marking battery.

A further feature of this invention is that the amount of current flowing in the subscriber's loop during the armature travel time of the relay transmitting into the loop, both from its marking to spacing and spacing to marking contacts, is just slightly less than is necessary to balance the biasing current or spring tension on the subscriber's receiving relay, so that said relay does not release nor operate until said travel is ended in each instance, but does operate and release

in each instance the instant the travel is ended, thus insuring signals equal in length to the transmitted signals.

These and other features will be apparent from the description of the operation of the invention hereinafter following read with reference to the various associated figures:

Fig. 1 is a well-known telegraph subscriber's loop circuit to which the bias correction feature of this invention has been added. This feature is incorporated in resistance 108 and its connection to the battery 102 and the apex of relay 109;

Figs. 2 to 5 are current-time curves for the subscriber's loop per Fig. 1 by means of which the effectiveness of the invention herein will be demonstrated.

Referring now to Fig. 1, a telegraph subscriber's line circuit widely used in teletypewriter switching systems is shown. Resistances 101, 103 and 114 are used to protect batteries 100 and 102 from short circuit. The magnitude of their resistance values is negligible as compared with the loop resistance and their effect may be disregarded.

Fig. 1 will first be described as arranged generally at present, disregarding resistance 108 and its connections. The effect of the usual condenser and resistance contact protection devices 105, 106, 107 and 115 will not at present be considered.

The armature of sending relay 104 is actuated, by the effect of a circuit (not shown) with which we are not concerned, to engage its right- and left-hand contacts alternately. When said armature is in engagement with its right-hand contact, a circuit may be traced, from the negative terminal of battery 102, through resistance 103, and the right-hand contact and armature of relay 104 to the apex of relay 109. The circuit continues from the apex of relay 109 over parallel paths. One path continues through the bottom or biasing winding of relay 109 and resistance 113 to ground. The other path extends through the top or line winding of relay 109, through resistance 110, the subscriber's station apparatus 111 and resistance 114, to positive battery 100. For this condition, it may be observed, that the batteries 102 and 100 are in series-aiding relationship. Resistance 110 simulates the total resistance of the loop. The resistance from the apex of relay 109 around the loop is balanced by the resistance from the apex through the bottom winding of relay 109 and resistance 113 to ground.

When the armature of relay 104 is in engagement with its left-hand contact a circuit may be

traced from positive battery 100 through resistance 101, the left-hand contact and armature of relay 104 to the apex of relay 109. Here, in the case of the circuit around the loop, positive battery opposes positive battery. For the circuit through the biasing winding of relay 109 positive battery is connected to ground.

When the armature of relay 104 is disengaged from its contacts, a circuit may be traced from positive battery 100, through resistance 114, the subscriber's station equipment 111, resistance 110, the top winding of relay 109, the bottom winding of relay 109 and resistance 113 to ground.

The values of the electromotive forces of batteries 100 and 102 are equal. Their values relative to the various resistances are such that when the armature of relay 104 is in engagement with its right-hand contact, 60 milliamperes flows around the loop. When said armature is in engagement with its left-hand contact the current in the loop is zero. And when said armature is disengaged from its contacts, the current flowing around the loop is 15 milliamperes.

Refer now to Fig. 2. This shows the subscriber's loop current for the above-described condition. The vertical ordinate represents current in milliamperes. The abscissa represents time.

While the armature is in engagement with its right-hand contact, 60 milliamperes is flowing around the subscriber's loop. This is represented by the left-hand, horizontal line marked 60 on the vertical ordinate. The armature leaves its right-hand contact at the beginning of the armature travel time. This is indicated at *a* which projects to zero on the horizontal time axis. The instant the armature leaves its right-hand contact, the loop current drops to 15 milliamperes. This occurs without any change in time. This is indicated by the line *a-c*. During the travel time of the armature from the right-hand to left-hand contact, the loop current is maintained at 15 milliamperes. This is indicated by the line *c-d*. The instant that the armature engages with its left-hand contact the current drops from 15 milliamperes to 0. This is indicated by line *d-e*. The armature is in engagement with its left-hand contact for an interval of time represented by the line *e-f*. Then the armature separates from its left-hand contact. The current rises instantly again to 15 milliamperes represented by the line *f-g*. During the travel time of the armature from its left-hand to its right-hand contact, the loop current remains at 15 amperes. This is indicated by the line *g-h*. At the end of the travel time represented by *h*, when the armature engages again with its right-hand contact, the loop current rises again instantly, during zero change in time to the original 60 milliamperes. This is represented by the line *h-i*.

Let us now consider the effect of this train of events on the receiving relay in the subscriber's station equipment 111. It will be assumed, for the present, that there is no delay between the transmission of a signal by relay 104 and its reception at the subscriber's station due to the electrical characteristics of the circuit. We will assume, also, that the receiving relay at the subscriber's station releases at 29.9 milliamperes and operates at 30.1 milliamperes.

The instant that relay 104 releases at the central station, the receiving relay in the subscriber's station will release as the line *a-b* passes through 29.9 milliamperes. This is indicated by

the point marked "Release" on line *a-c*. The time line *a-c*, therefore, defines the beginning of the spacing interval for both relays. For relay 104, the spacing interval lasts during the travel period *c-d* and the time that its armature is in engagement with its left-hand contact *e-f*. The total duration of the spacing interval is, therefore, measured by the time *a-f*. When the armature of relay 104 breaks from its left-hand contact, at the end of its spacing interval, the loop current does not rise sufficiently to operate relay 111, which requires 30.1 milliamperes. It rises instead only to 15 milliamperes, where it remains until the end of the travel time of relay 104 armature back to its right-hand contact, during the time measured by *g-h*. The receiving relay in 111 does not operate to end its spacing interval until the loop current rises through 30.1 amperes as indicated in line *h-i* by the point marked "Operate." The spacing interval for the receiving relay is, therefore, measured by the time *a-i*. It is greater than the spacing interval of the sending relay by the travel time *g-h*. This is called in the art a spacing bias and it is inherent in circuits per Fig. 1 which are widely used without the benefit of this invention.

We will now consider the effect of the connection of resistance 108 between battery 102 and the apex of relay 109. Resistance 108 is equal in value to the total resistance from the apex of relay 109 around the subscriber's loop through battery 100 to ground. It is also equal, therefore, in value to the resistance from the apex of relay 109 to ground through resistance 113. The values of resistances 101, 103 and 114, which are used as an aid in protecting batteries 100 and 102 against short circuit, are negligible as compared with the value of resistance 108. When the armature of relay 104 is in engagement with contact 103, approximately 60 milliamperes flows around the subscriber's loop. When the armature of relay 104 breaks from its right-hand contact a circuit is available from negative battery 102, through resistance 108 and extending around the loop to positive battery 100. The resistance in this circuit is approximately twice as much as when the armature was on its right-hand contact. The current around the loop for the travel time of the armature from its right to its left-hand contact is, therefore, 30 milliamperes. When the armature of relay 104 engages its left-hand contact, the batteries are opposed and the current in the loop drops from 30 milliamperes to 0. At the end of the spacing interval the loop current rises again to 30 milliamperes where it remains during the travel time of the armature from its left-hand to its right-hand contact. Then it rises instantly to the original condition, from 30 to 60 milliamperes.

Reference to Fig. 4 will disclose how this corrects the spacing bias.

Current in the loop during the interval until the armature of relay 104 breaks from its right-hand contact is indicated by the left-hand, top, horizontal line indicating 60 milliamperes. The armature breaks at *r*, which we may consider zero time. This defines the start of the spacing interval for relay 104. The current drops, still on the zero time line to 30 milliamperes, indicated by line *r-s*, which is not quite low enough to release the receiving relay in 111. The current in the loop continues at 30 milliamperes during the travel time of relay 104 armature from its right-hand, to its left-hand contact, in-

indicated by line $s-t$. Then the loop current drops from 30 milliamperes to 0 amperes. It is not till this time that the subscriber's loop current passes through 29.9 milliamperes, indicated by the point marked "Release," where it is small enough to allow the receiving relay in 111 to release. This defines the start of the spacing interval of the receiving relay. When the armature of relay 104 breaks from its left-hand contact at the beginning of its marking interval indicated at v , the current in the loop rises instantly to 30 mils., indicated by line $v-w$. This current is not great enough to operate the receiving relay. The loop current remains at 30 mils. during the travel time indicated by $w-x$. Then the loop current rises instantly to the original condition indicated by $x-y$. During this rise the receiving relay operates as the current reaches 30.1 milliamperes at a point marked "Operate" on line $h-i$. The spacing interval for relay 104 is thus measured by the time $r-v$. The spacing interval for the receiving relay is measured by the time $u-x$. Since the travel times of the armature of relay 104 in each direction are equal, the spacing bias inherent in Fig. 1 without branch 108-102 is eliminated.

The effect of the spark protection apparatus upon bias will now be considered.

Fig. 3 is a time-current curve representing the pattern of the current in the receiving relay at the subscriber's station for the marking-to-spacing and spacing-to-marking transition of relays 104 and the receiving relay when the contact protection apparatus, resistances 106 and 107 and condensers 105 and 115 are employed without resistance 108 and its connections.

The current flowing in the loop while the armature of relay 104 is in engagement with its right-hand contact is, as indicated in Fig. 3, 60 milliamperes. When said armature breaks from said contact, at point j , which defines the start of the spacing interval for relay 104, the current does not drop instantly to 15 milliamperes, as in the case for Fig. 2, but dies more slowly, during the travel time, along the curve $j-k$, due to the discharge of the condenser. The receiving relay, instead of releasing instantly, releases when the current has decreased to 29.9 milliamperes. This is indicated by the point marked "Release" on curve $j-k$, which point defines the start of the spacing interval for the receiving relay. At the end of the travel time indicated at k , the current drops instantly to zero along line $k-l$. The loop current remains at zero while the armature of relay 104 is in engagement with its left-hand contact, during the interval $l-n$. At this point, which is the end of the spacing interval of relay 104, the current rises, not instantly, but more slowly, due to the action of the condenser, to point n along the curve $m-n$. Then it rises instantly along the line $n-p$ to 60 milliamperes. During this rise it passes through 30.1 milliamperes at the point marked "Operate" which denotes the end of the spacing interval for the receiving relay.

It should be apparent, therefore, that the spacing interval for relay 104, when the contact protection devices are used, and the invention herein is not used, is equal to time $j-m$. The spacing interval for the receiving relay is that between the points "Release" and "Operate". These two time intervals are more nearly equal than for the condition per Fig. 2. In other words, the contact protection devices alone, without the invention herein, afford some improve-

ment for the spacing bias inherent in Fig. 1, over circuits in which neither the protection devices nor the invention herein is applied. Furthermore, contact protection networks affect bias in circuits per Fig. 1 not including this invention.

The loop current pattern per Fig. 5, which is obtained when the invention herein and contact protection devices, as indicated, are both applied to a circuit per Fig. 1, will now be described.

The spacing interval for relay 104 starts at the point A, when the armature breaks from its right-hand contact. The loop current, due to the action of the condenser instead of dropping instantly on the break, declines along the curve A-B as the armature travels. At B when the armature engages its left-hand contact the current drops instantly to zero, passing through 29.9 milliamperes at the point on line B-C marked "Release" which defines the start of the spacing interval of the receiving relay. The current remains at zero while the armature and left-hand contact of relay 104 are in engagement. Then said armature breaks from its contact at D. This denotes the end of the spacing interval for relay 104. The loop current rises to E instead of to 15 milliamperes along curve D-E. After the armature makes with its right-hand contact, at the point E, the loop current rises instantly to 60 milliamperes along line E-F passing through 30.1 milliamperes at the point marked "Operate" which marks the end of the spacing interval for the receiving relay.

The spacing interval for relay 104, measured by time A-D is equal to the spacing interval for the receiving relay, measured by the horizontal distance between the "Release" and "Operate" points for this relay as shown in Fig. 5. The spacing bias inherent in circuits per Fig. 1, when the invention is not included in the circuit, is eliminated by means of the invention and the bias is not affected by the contact protection networks.

This invention makes possible another improvement in the circuit per Fig. 1 in addition to the elimination of spacing bias.

When the invention is not applied to Fig. 1, and the armature of relay 104 is on its right-hand contact, the current flowing around the subscriber's loop is 60 milliamperes. The current through the bottom winding of relay 109 and resistance 113 is 30 milliamperes. All of this current totaling 90 milliamperes flows between the armature and right-hand contact of relay 104. When the armature of relay 104 is on its left-hand contact, there is no current in the loop and 30 milliamperes flow through the bottom winding of relay 109. This 30 milliamperes is the total current flowing through the armature and left-hand contact of relay 104 when the two are engaged. Under these circumstances the transient voltages and current surges developed as the armature makes and breaks with its two contacts vary. In designing contact protection networks, it is necessary to take this into consideration.

When the invention herein is employed, and the armature of relay 104 is in engagement with its right-hand contact, the current flowing through the armature and right-hand contact is the same as heretofore, approximately 90 milliamperes. This is on the basis that resistance 103 is practically negligible as compared with resistance 108 which is the case. When the armature of relay 104 is on its left-hand contact,

again assuming resistance 101 negligible, the current through the armature and left-hand contact is approximately 90 milliamperes. This follows as the current through the bottom winding of relay 109 is unchanged and although there is no current in the loop as the batteries at each end are opposed, a current equal in values to the loop current for the condition when the armature of relay 104 is on its right-hand contact now flows from positive battery 100 through resistance 101, the left-hand contact and armature of relay 104 and resistance 108 to negative battery 102. Thus approximately 90 milliamperes pass through the contact and armature of relay 104 for each condition. The transient voltage and current surges are the same for each condition. Identical contact protection networks may be used effectively for the protection of each pair of contacts.

20 What is claimed is:

1. In a telegraph system, a telegraph relay comprising an armature alternately engaging a first contact and a second contact, a first battery and a second battery of voltage equal to the voltage and of polarity opposite from that of said first battery, connected each from ground to said first and said second contacts respectively, a subscriber's loop circuit of a first resistance value connected at one end to said armature and at the other end to said first battery, an artificial line circuit of a resistance value equal to said first resistance value connected at one end to ground and at the other end to said armature and a resistance element of a value equal to the resistance value of said loop, connected at one end to said second battery and at the other end to said armature.

2. In a telegraph system, a first telegraph station, a second telegraph station, a sending and a receiving relay at said first station, a receiving relay at said second station, an armature on said sending relay, a telegraph loop extending from said armature through the windings of said receiving relays, a balancing circuit of resistance equal to said loop resistance, extending from said armature through a second winding on said receiving relay at said first station to ground, and a lumped resistance equal to the resistance of said loop circuit or said balancing circuit connected from the junction between said armature, said loop and said balancing circuit through battery to ground.

3. A balanced polar telegraph loop circuit comprising a loop and a balancing circuit connected in parallel to the fixed end of the armature of a telegraph sending relay, said circuit being characterized in that a lumped resistance equal to the resistance of the loop is also connected from said armature end to ground through one of the polar batteries.

4. A balanced polar telegraph loop circuit, a sending relay in said circuit having an armature, connected to one end of said loop, operating between opposing contacts connected to equal

batteries of opposite polarities, the opposite end of said loop being connected to one of said batteries and a lumped resistance equal to the resistance of said loop connected between said armature and the other of said batteries.

5. In a balanced polar telegraph loop circuit, a telegraph sending relay, an armature on said relay operating alternately between opposing contacts connected to equal batteries of opposite polarities, resistance and battery means in said circuit for transmitting full current around said loop when said armature is in engagement with one of said contacts, battery means for transmitting zero current around said loop when said armature is in engagement with the other of said contacts, and battery and resistance means connected to said circuit for transmitting half current around said loop when said armature is traveling between contacts.

6. In a balanced polar telegraph loop circuit, a telegraph sending relay, an armature on said relay, a first and a second contact also on said relay, a first battery of a first polarity connected to said first contact, a second battery of electromotive force equal to and of polarity opposite from said first battery connected to said second contact, means for transmitting current of a first value around said loop when said armature is in engagement with said first contact, means for transmitting current smaller in value than said first value around said loop when said armature is in engagement with said second contact and means for transmitting currents through said armature and said contacts equal in value each to each when said armature is in engagement with said contacts.

7. In a balanced polar telegraph loop circuit, a transmitting relay at a first station, an armature on said relay, a marking and a spacing contact also on said relay, a receiving relay at a second station, means for delaying the release of said receiving relay until said armature has traveled from its marking to its spacing contact, and means for delaying the operation of said receiving relay until said armature has returned to its marking contact.

8. In a balanced polar telegraph loop circuit, a polar transmitting relay at a first station, an armature on said relay operating between a marking and a spacing contact also on said relay, a receiving relay in a second station, both of said relays connected to said circuit, means also connected to said circuit for equalizing the current flowing around said loop through said receiving relay during the travel of said armature between said contacts in each direction, means connected to said circuit for maintaining said loop current above the release current value of said receiving relay for said armature travel in one direction and below the operate current value of said receiving relay for said armature travel in the opposite direction.

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