Feb. 19, 1924.

K. S. JOHNSON

SUBSTATION CIRCUITS

Filed Jan. 10, 1921

1,484,397

Fig. 1.

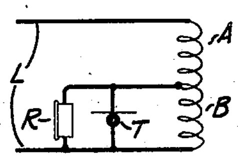


Fig. 2.

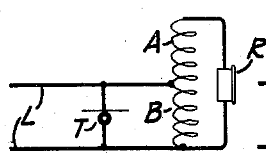


Fig. 3.

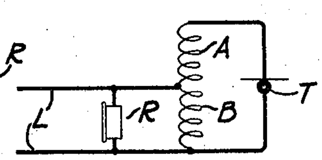


Fig. 4.

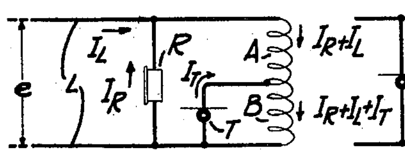


Fig. 5

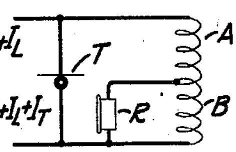


Fig. 6

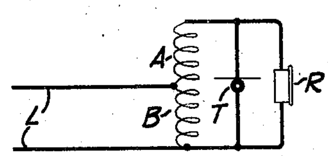


Fig. 7

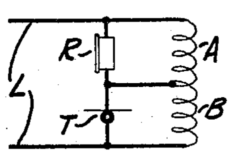


Fig. 8.

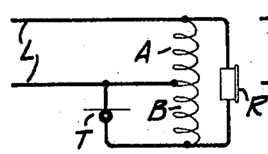


Fig. 9.

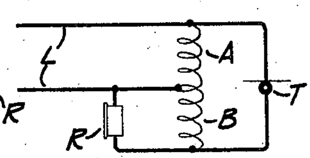


Fig. 10.

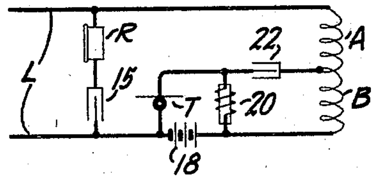
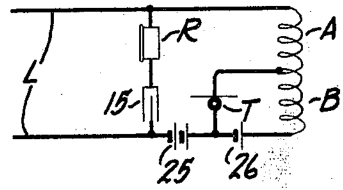


Fig. 11.



Inventor:

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by W. C. Beatty. Att'y.

Patented Feb. 19, 1924. **1,484,397**

UNITED STATES PATENT OFFICE.

KENNETH S. JOHNSON, OF JERSEY CITY, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

SUBSTATION CIRCUITS.

Application filed January 10, 1921. Serial No. 436,304.

To all whom it may concern:

Be it known that I, KENNETH S. JOHNSON, a citizen of the United States, residing at Jersey City, in the county of Hudson, State of New Jersey, have invented certain new and useful Improvements in Substation Circuits, of which the following is a full, clear, concise, and exact description.

This invention relates to substation circuits and more particularly to substation circuits in which the telephone instruments are directly connected to the line and in which these connections comprise an auto transformer between one or more of the instruments and the line.

In designing a substation circuit for a particular type of line, the impedance of the line and of the available telephone instruments is frequently such that it is not desirable to use a substation circuit in which the instruments are actually or effectively in series with each other. It is an object of this invention to connect the telephone instruments effectively in parallel with respect to a line and to arrange the connections so that maximum efficiency may be had.

In the preferred form of the invention the receiver is connected across the line without the intervention of inductive means. The transmitter, however, is connected to the line by means of a two-winding auto-transformer for the purpose of properly adjusting the impedance of the transmitter to that of the line.

The invention will be more fully understood from the following detailed description and claims taken in connection with the accompanying drawing, in which each of Figs. 1 to 9 inclusive, represents diagrammatically an arrangement in which the instruments are connected effectively in parallel with respect to the line and one or both of the instruments are connected to the line through a two-winding auto-transformer; Figs. 10 and 11 represent respectively, two ways of supplying current to a system employing the circuit of Fig. 4.

Referring to the drawings by reference characters, each of the circuits shown comprises an auto-transformer having windings A and B. In Fig. 1, a transmitter T and a receiver R are connected in parallel across the winding B, while line L is connected across both windings A and B. In Fig. 2, the line and the transmitter are connected across winding B, while the receiver is connected across both windings. In Fig. 3, the line and the receiver are connected across winding B, and the transmitter is connected across both windings. In Fig. 4, the line and the receiver are connected across both windings while the transmitter is connected across winding B. In Fig. 5, the line and the transmitter are connected across both windings and the receiver is connected across winding B. In Fig. 6, the line is connected across winding B, and the transmitter and receiver are connected in parallel across both windings. In Fig. 7, the line is connected across both windings, the receiver is connected across winding A and the transmitter is connected across winding B. In Fig. 8, the line is connected across winding A, the transmitter across winding B, and the receiver across both windings. In Fig. 9, the line is connected across winding A, the receiver across winding B and the transmitter across both windings.

In designing a substation of the types shown herein, the impedance of the set should equal that of the line to which it is to be connected, and under good line conditions when receiving, the received energy should be dissipated equally in the receiver and the transmitter. A discussion of the principles involved in two-way signalling in telephone substations will be found in Campbell Patent No. 1,254,474, dated January 22, 1918, and a more complete discussion including the circuits herein disclosed will be found in a paper entitled "Maximum output networks for telephone substation and repeater circuits," by George A. Campbell and Ronald M. Foster, read before the American Institute of Electrical Engineers, in New York, February 19, 1920, published in the transactions of that organization for 1920, vol. 39, Part I, page 231. Figs. 1 to

9 herein are shown in the above paper in Fig. 9, in the following order, circuits with elements effectively in parallel, Nos. 32, 34, 33, 39, 40, 38, 35, 36 and 37.

Taking the circuit shown in Fig. 4 as an example, the design formulæ for the set impedance and the energy ratio may be obtained as follows:

Assume an electromotive force e acting in the line L, and currents having their directions and values indicated in the drawing.

Let L, T, R, A, B and M represent the values of the impedances of the line, transmitter, receiver, and the self impedances windings A and B, and their mutual impedance respectively.

Let

$$y=\frac{I_T^2T}{I_R^2R}=\text{energy ratio},$$

and

$$Z_s=\text{the set impedance}.$$

By Kirchhoff's laws we obtain by going around the mesh containing L and R

$$e=I_LL-I_RR \quad (1)$$

by going around the mesh containing A, B and R

$$(I_R+I_L)A+(I_R+I_L+I_T)M+(I_R+I_L+I_T)B+(I_R+I_L)M+I_RR=O \quad (2)$$

by going around the mesh containing B and T

$$I_TT+(I_R+I_L+I_T)B+(I_R+I_L)M=O \quad (3)$$

Rearranging equations (1), (2) and (3):

$$I_LL+I_R(-R)+I_T(O)=e \quad (4)$$

$$I_L(A+B+2M)+I_R(A+B+2M+R)+I_T(B+M)=O \quad (5)$$

$$I_L(B+M)+I_R(B+M)+I_T(B+T)=O \quad (6)$$

Solving these equations simultaneously, we get:

$$I_L=\frac{-e[(B+M)^2-(A+B+2M+R)(B+T)]}{H} \quad (7)$$

$$I_R=\frac{-e[(A+B+2M)(B+T)-(B+M)^2]}{H} \quad (8)$$

$$I_T=\frac{-e[R(B+M)]}{H} \quad (9)$$

in all of which

$$H=L[(A+B+2M+R)(B+T)-(B+M)^2]+[A+B+2M][R(B+T)]+[B+M][-R(B+M)]$$

By the definition of Z_s and from the value of I_L as given in the equation (7)

$$Z_s=\frac{e}{I_L}-L=\frac{[B+M][R(B+M)]+[A+B+2M][-R(B+T)]}{(B+M)^2-(A+B+2M+R)(B+T)} \quad (10)$$

Assuming an ideal transformer, we have $M=\sqrt{AB}$ and we get:

$$Z_s=\frac{-RT(A+B+2M)}{-R(B+T)-T(A+B+2M)} \quad (11)$$

or

$$=\frac{RT(A+B+2M)}{R(B+T)+T(A+B+2M)} \quad (12)$$

Since also in an ideal transformer, B is infinitely large as compared with T, we get:

$$Z_s=\frac{RT(A+B+2M)}{R(B)+T(A+B+2M)} \quad (13)$$

It will be noted that the impedance of the substation as given in equation 13 is in the form of a fraction, the numerator of which involves the product of the receiver and the transmitter impedances and the denominator involves their sum, thus indicating that the telephone instruments are effectively in parallel for received currents. While in actual practice the value of B is not infinite, still if properly designed, its value is large as compared with the impedance of the transmitter and very little current flows serially through the receiver and transmitter.

From equations (8) and (9) and the definition of y, we obtain:

$$y=\frac{I_T^2T}{I_R^2R}=\frac{[R(B+M)]^2T}{[(A+B+2M)(B+T)-(B+M)^2]^2R} \quad (14)$$

If $M=\sqrt{AB}$. this resolves to

$$y=\frac{R}{T}\left[\frac{B+M}{A+B+2M}\right] \quad (15)$$

As above stated, the value of y should be unity for maximum efficiency. Conditions such as line noise may make it preferable to give this ratio a value somewhat greater than 1. This invention, accordingly, is not limited to cases where y has precisely the value of 1.

The design formulæ for the other circuits shown herein may be obtained by methods similar to the above. In every case it will be found that the impedance formula is of a form similar to equation 13 showing that the instruments are effectively in parallel.

In Fig. 10, is shown an adaptation of the circuit of Fig. 4 which has been found useful as an operator's circuit in fire alarm systems in which the operator's circuit is connected to a large number of substation circuits simultaneously. Since the substation circuits are connected in parallel, the impedance of the line as seen is considerably lower than that of the average telephone line. The impedance of the operator's circuit however, can easily be designed to be correspondingly low, since the instruments are effectively in parallel. The receiver R is connected in series with a condenser 15 across the line. With respect to alternating currents, the transmitter T is connected across winding 8 just as in Fig. 4. 18 represents a common battery which is employed for energizing the transmitter of the substation circuits (not shown), which may, for example, be the residence telephone circuits of the individuals belonging to a local fire company. This battery is also employed to energize the transmitter T of the operator's circuit. The direct current circuit comprises the transmitter T, the battery 18 and the retardation coil 20, which is designed to have a sufficiently high direct current resistance to cut down the voltage to the proper value for the transmitter. In one installation where a twenty-four volt common battery was employed, the winding of coil 20 had a direct current resistance of 165 ohms. The condenser 22 is provided to prevent the direct current from being short-circuited around the retardation coil. The inductance 20 is substantially an open circuit for talking currents and the condenser 22 is of negligible impedance for such currents, so that from the alternating current standpoint the circuit resolved to that of Fig. 4.

In Fig. 11 is shown the operator's circuit, disclosed in the application of W. P. Andrick and J. H. Dahl, Serial No. 419,413, filed October 25, 1920, when in the condition in which the switches have been operated to connect the operator's circuit to a plurality of substation circuits. This circuit is similar to that of Fig. 10, except that the retardation coil 20 and condenser 22 are omitted and the common battery is divided into two parts 25 and 26, so arranged that the two parts are in series with respect to the line, but that a fraction only of the total voltage applied across the line is effective in producing current in the transmitter T.

The circuits shown herein are similar to the three winding auto-transformer circuits shown in my copending application Serial No. 195,364, filed October 8, 1917, for "Telephone substation sets," in that the telephone instruments are effectively in parallel.

What is claimed is:

1. A substation circuit comprising a transmitter and a receiver, connections from said instruments to a line, said instruments being connected effectively in parallel with each other with respect to signaling currents from said line, said connections comprising a two-winding auto-transformer between at least one of said instruments and said line, and a battery connected to send current through said line, said last mentioned instrument being energized by direct current from said battery.

2. A substation circuit comprising a transmitter and a receiver, connections from said instruments to the line, said instruments being connected effectively in parallel with each other with respect to signaling currents from said line, said connections comprising a two-winding auto-transformer between said transmitter and said line, and a battery connected to send current through said line, said transmitter being energized by direct current from said battery.

3. A substation circuit comprising a transmitter and a receiver, connections from said instruments to a line, said instruments being connected effectively in parallel with each other with respect to signaling currents from said line said connections comprising a two-winding auto-transformer said line and said receiver being connected across both windings of said transformer, and said transmitter being connected across one of said windings.

4. A substation circuit comprising a two-winding auto-transformer, a receiver and a line connected across both windings of said transformer, the transmitter being connected across one of said windings, a common battery adapted to send current out on said line, and connections for energizing said transmitter through said battery.

5. A substation circuit comprising a two-winding auto-transformer, a transmitter, and a receiver, said transformer serving to couple at least one of said instruments to a line, said instruments being connected effectively in parallel to said line, the effective impedances of said instruments as viewed from said line being such that the energy of received signals divides approximately equally between said receiver and said transmitter.

In witness whereof, I hereunto subscribe my name this 3rd day of January A. D., 1921.

KENNETH S. JOHNSON.