Oct. 29, 1929. J. W. DEHN 1,733,585

METHOD OF TESTING AND TEST SET

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FIG. 1.

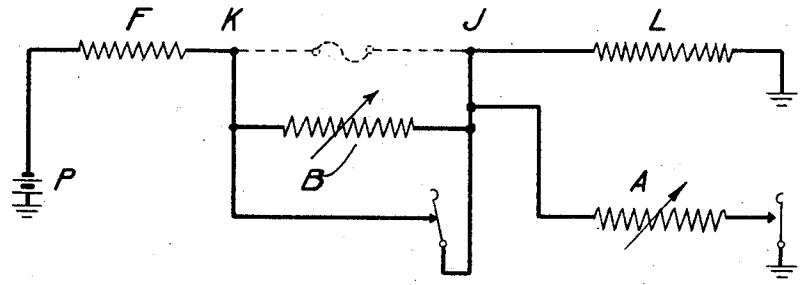
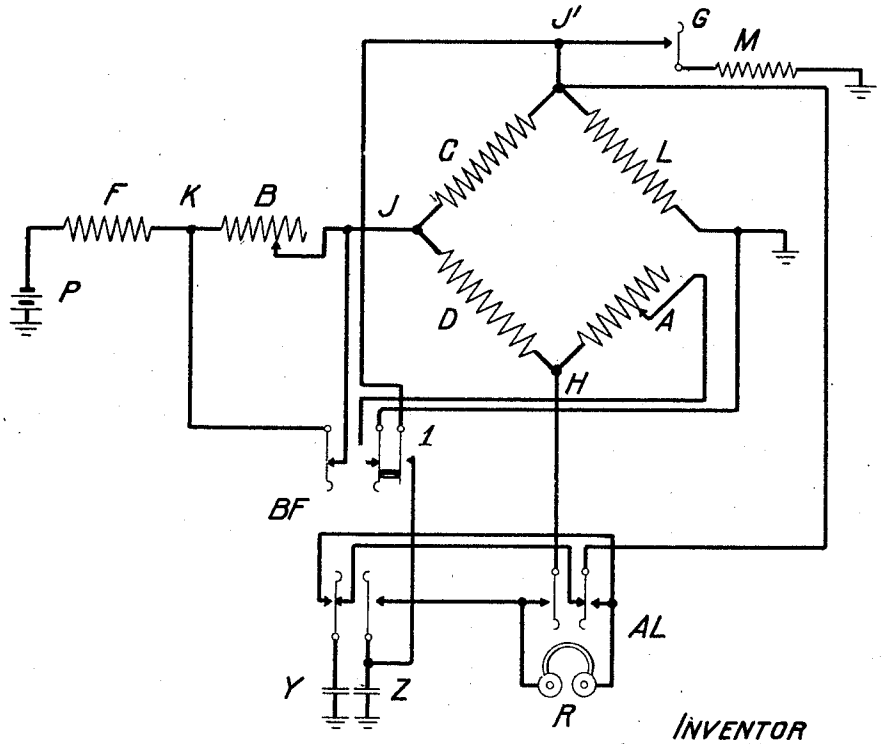


FIG. 2.



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METHOD OF TESTING AND TEST SET

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This invention relates to a method and to apparatus for measuring an electrical constant of a transmission line without materially disturbing the normal functions of such line. More specifically, it relates to the measuring of the electrical impedance of a battery feeding transmission line extending from a main exchange to a private branch exchange in a telephone system and without interrupting the operation of the private branch exchange.

It is necessary in the maintenance of telephone service where a large number of private branch exchanges are worked from a central office to check up periodically on the resistance of the battery feeding transmission lines extending from the main exchange to the private branch exchanges. Heretofore, a number of methods of measuring such resistances have been employed but in so far as the applicant is aware all of the relatively accurate methods have involved disconnecting the feeder from the private branch exchange. Disconnecting the feeder has necessitated taking the measurement at some time when the private branch exchange was not in operation. It was therefore not always convenient to take the measurement, particularly as some of the private branch exchanges are in operation during the major portion of the twenty four hours of the day.

The present invention provides a method involving two steps in which known methods of resistance measurement are applied in a particular manner and sequence to obtain the desired measurement.

In accordance with the invention, the first step consists in connecting in parallel with the load at the private branch exchange an impedance which is equal to or bears a definite ratio to the load of the private branch exchange. This step may be conveniently performed using a Wheatstone bridge arrangement. The only precaution necessary to observe is for the tester to make sure that the load on the private branch exchange has not changed during the measuring interval by some act of the operator such as the changing of a cord.

Having connected such impedance in parallel with the private branch exchange load, the potential at the point of connection of the load and parallel impedance to the line may be noted. The parallel impedance is then disconnected and an impedance is connected in series with the load and is adjusted until the potential at the point of connection of the load with the feeder is the same as in the previous step. It can be shown that under the conditions outlined for the measurement, the resistance necessary to bring this point to the same potential as before, is a direct measure of the impedance of the feeder.

In accordance with the invention, apparatus for performing the method as above outlined is provided in the convenient and compact form of a single instrument. The tester can make the entire measurement by merely manipulating the keys of the instrument in sequence or alternately, noting the effect in a telephone receiver. This embodiment of the invention, comprises adjustable resistance, two condensers and a telephone receiver connected into keyed circuits and arranged to compare the potentials at a point between the line and the load under different circuit conditions. The apparatus may conveniently be arranged in the form of a portable test set, but it is thought the invention will be better understood from diagrammatic drawings. In the drawings, Fig. 1 is a simple circuit diagram illustrative of the method of this invention and Fig. 2 is a schematic diagram of the circuits in a proposed test set or instrument.

The general features of the method will be outlined with particular reference to Fig. 1 of the drawing. In this figure the battery P is located at the main office and the load at the private branch exchange is indicated by the resistance L. This load is made up of the apparatus in use at the private branch exchange which varies from time to time, but which will ordinarily remain constant for a sufficient time to permit the necessary measurements to be made. The transmission line which is known in the art as a private branch exchange battery feeder extends from the battery P to the terminal K at the private branch exchange. While the resistance of the feeder is in practice distributed along

its length it has for convenience of description been shown as a lumped resistance F which represents the resistance of the feeder as a whole, in other words the resistance to be measured. The point K is ordinarily connected to the point J, by a fuse indicated in dotted lines. The adjustable resistances A and B form a part of the test set which is connected across the points K and J and the fuse is then removed.

The first step in the method of determining the resistance of F is to adjust A to a definite ratio (usually equality) to L holding B short-circuited. The potential at the point J with A connected to ground may then be determined.

The second step consists in disconnecting A from ground, removing the short-circuit from B and adjusting the resistance B until the potential at J is the same as that previously noted. When this condition is obtained $F=nB$ where n is the ratio of A to L. If n is unity $F=B$. This may be shown mathematically as follows:

If the potential at J or E_J is to be the same under the two conditions set forth above and E_0 the potential of the battery P remains constant it follows that $\frac{E_J}{E_0}$ is the same under both test conditions.

With B short circuited and A included

$$\frac{E_J}{E_0}=\frac{\frac{AL}{A+L}}{\frac{AL}{A+L}+F}=\frac{AL}{AL+AF+FL} \quad (1)$$

With A open-circuited and B included

$$\frac{E_J}{E_0}=\frac{L}{L+B+F} \quad (2)$$

Equating 1 and 2

$$\frac{AL}{AL+AF+FL}=\frac{L}{L+B+F}$$

$$AL+AB+AF=AL+AF+FL$$

$$AB=FL$$

$$F=\frac{AB}{L}=B\frac{A}{L}$$

If $\frac{A}{L}$ is assumed to be n, $F=nB$

If $n=1$, $F=B$

In Fig. 2 the circuit arrangement used in a test set embodying the invention is particularly designed for measurement of the resistance of the private branch exchange battery feeders but is not limited to such use. In the test set as actually constructed the various resistances, keys and circuit connections are mounted in a portable box and the adjustable resistances take the form of ordinary dial type resistances such as are commonly used in ordinary Wheatstone bridge measuring devices. The set is provided with the usual binding posts for connection to the feeder to be measured and to the load of the private branch exchange. In Fig. 2 the same reference characters have been used to designate the parts which are common to that figure and to Fig. 1. The additional apparatus not shown in Fig. 1 will be now described.

There are two keys used, one of which is designated as BF and the other as AL. These keys are of the ordinary type used in telephone exchanges in which the contacts are operated by an oscillating lever. The key AL is arranged so that when its lever is thrown in one direction the contacts are in the position shown and when thrown in the other direction the contacts are moved to take up alternate or opposite positions.

The BF key contains two sets of contacts which are operated from a single oscillating lever. The contacts are shown in the neutral position. On movement from neutral position to one position, the upper set of contacts, as shown, are actuated, and on movement to the other position, the lower set of contacts are actuated. The arrangement is such that the operating lever BF in passing from one extreme position to the other causes the restoration of one set of contacts and changes the setting of the other contacts. It may also be mentioned that the contact 1 of the upper set of contacts connected with the BF key is arranged so that it is opened before the other contacts are closed and the key is returned to normal.

An inspection of the circuits will show that with the BF key in its upper position the condenser Z will be charged at a point J'. When the BF key is in upper or in its normal or neutral position the condenser Y is connected to point J' through a contact of the AL key in its normal position. When the BF key is in its lower position the condenser Y is connected to the condenser Z in opposing relation through the telephone receiver R. With the BF key in its normal or neutral position the operation of the AL key merely places the telephone receiver across the opposite points of the Wheatstone bridge formed by arms C, D, L and A.

It will now be assumed that it is desired to measure the resistance F with the test set of Fig. 2 connected as shown, and the operation of making this measurement will now be described. With the ratio of C to D at equality, the first step is to make the resistance A equal to the resistance L. If there is a difference of potential between points J' and H of the bridge a click will be heard in the telephone as the key AL is moved. The AL key is successively operated while the resistance A is adjusted until no click is heard

in the telephone receiver R which indicates that there is no difference in potential between the points J′ and H. As is usual in Wheatstone bridge measurements the ratio on arms C and D may be equal or bear any definite ratio, but they may conveniently be equal resistances possibly of low value. It will be noted that while this measurement is being made the resistance B is short-circuited through the left contact of the key BF.

Having made this adjustment the BF key is alternately operated from its uppermost to its lowermost position and the resistance B is adjusted. As pointed out in describing the BF key the manipulation of this key causes the following operations to take place. First, when the key BF is in its upper position condenser Z is charged at point J′ through contact 1. The key BF opens the contact 1 before it closes the circuit to the A resistance and before it short-circuits the B resistance, so that the charge on the condenser will not be changed by the closing of these circuits. In the neutral position of the key the condenser Y is charged to the potential of point J′ through an obvious circuit including the contact of the key AL. The key BF at its lower position or setting connects the two condensers in series with the telephone R, the charges on the condensers opposing each other. If the potential to which the condensers Y and Z have been charged is equal, no click will be heard in the receiver R. This condition indicates that the resistance B has been adjusted to the final desired value and is a measure of the resistance F. The test set as shown and described is arranged to check the potential of point J′ for the two circuit conditions, to determine if point J′ has the same potential for both conditions.

For the arrangement of Fig. 2 the equations are as follows:

With B short circuited and A included

$$\frac{E_J}{E_O}\,\frac{\frac{(A+D)\ (L+C)}{A+D+L+C}}{\frac{(A+D)\ (L+C)}{A+D+L+C}+F}=\frac{(A+D)\ (L+C)}{(A+D)\ (L+C)+AF+DF+LF+CF} \quad (3)$$

With A open-circuited and B included

$$\frac{E_J}{E_O}=\frac{L+C}{L+C+B+F} \quad (4)$$

Equating (3) and (4)

$$\frac{(A+D)\ (L+C)}{(A+D)\ (L+C)+AF+DF+LF+CF}=\frac{L+C}{L+C+B+F}$$

$$(A+D)\ (L+C+B+F)=(A+D)\ (L+C)+(A+D)F+(L+C)F$$

$$L+C+B+F=L+C+F+\frac{(L+C)}{A+D}F$$

Assume that

$$n=\frac{A+D}{L+C}$$

$$L+C+B+F=L+C+F+\frac{F}{n}$$

$$B=\frac{F}{n}$$

$$F=nB$$

which is the same result as obtained for the circuit of Fig. 1.

The keys AL and BF may be operated alternately and with considerable rapidity so that each adjustment and the final measurement may be made in a very short time. The measured value is readily checked by manipulation, first of key AL and later of key BF, while listening in the telephone receiver R to make sure there is no click. This check is a very brief or rapid step in this method of testing. If the load L is changed in the interval of taking the measurement the value of resistance A is the only value that needs to be changed.

Although the arrangement is particularly adapted to measuring the resistance of private branch exchange battery feeders by the method above set forth it is also capable of measuring other resistances. In order to more readily adapt it for this latter purpose there is provided a key G and a fixed resistance M which may be part of the set and may be used as a substitute for the load L. The resistance F may be measured independently of the load or at a point intermediate the battery supply and the normal load.

It will be obvious that a voltmeter may be substituted for each of the condensers $Y+Z$ and the comparison of potentials made directly. Alternatively a single voltmeter may be used and the potentials at point J′ may be measured successively for the two unbalanced conditions, the one voltmeter being used for both measurements.

It will also be obvious that the impedance B may be made up of a variable resistance and a variable inductance in series with one

another, and these may be adjusted to be equal to or to be a measure of the value F. An A. C. voltmeter or meters may then be used as suggested in the paragraph above in connection with this arrangement when the current in the private branch exchange feeder is an alternating current. The impedance in the two different unbalanced conditions may be then measured directly and successively. The value of impedance B will be properly adjusted when the voltmeter readings are alike for the two different unbalanced conditions.

It will be obvious that the method and apparatus disclosed is available to the measurement of resistances or impedances of any sort, whether the impedance is due to resistance, capacity or inductance, and without departing from the spirit and scope of this invention.

What is claimed is:

1. The method of measuring an electrical constant of a transmission line without disturbing the load thereon which consists in connecting an impedance in parallel with the load, said impedance being equal to that of the load, determining the potential at the junction of the load and the line, removing the first impedance from association with the line and load, and inserting sufficient impedance in series with the load to establish the same potential at the junction as was previously determined, whereby the last impedance so inserted is equal to said constant.

2. The method of measuring the impedance of a transmission line between a source of energy applied at one end of the line and any point on the line which consists in varying the impedance beyond said point, determining the potential at said point, restoring the impedance beyond said point to its original value, and inserting between said source and point an impedance sufficient to bring the potential at the point to the value previously determined, whereby said last mentioned impedance is a measure of the impedance to be measured.

3. The method of measuring the impedance of a transmission line between a source of energy applied at one end of the line and any point on the line which consists in reducing the impedance beyond said point to one half determining the potential at said point, restoring the impedance beyond said point to its original value, and inserting between said source and point an impedance sufficient to bring the potential at the point to the value previously determined, whereby said last mentioned impedance equals the impedance to be measured.

4. The method of measuring the impedance of a transmission line between a source of energy and a point which consists in breaking the line at the point and inserting a shunted variable impedance at the point, connecting a second variable impedance in parallel with the load beyond the point, varying the second impedance to a predetermined factor of the load, obtaining a measure of the potential at the point, disconnecting the second impedance and the shunt on the first variable impedance, and adjusting the first variable impedance until the measure of the potential at the point is the same as that previously obtained, whereby said first impedance multiplied by a factor determined by the relative values of the second variable impedance and the load beyond the point is equal to the impedance to be measured.

5. The method of measuring the impedance of a transmission line between a source of energy and a point, which consists in connecting a variable impedance to the point and in parallel with a load beyond the point, adjusting the variable impedance to a predetermined ratio of the load; storing a measure of the potential at the point, disconnecting the variable impedance, inserting between the source and point a second variable impedance, and varying the said second impedance until the measure of the potential at the point is equivalent to the previously stored measure of the potential at the point, whereby the second impedance multiplied by the ratio of the first variable impedance to the load impedance equals the impedance to be measured.

6. The method of measuring the resistance of a transmission line between a source of energy and a point, which consists in connecting a variable resistance to the point and in parallel with a load beyond the point, adjusting the variable resistance to a predetermined ratio of the load; storing a measure of the potential at the point, disconnecting the variable resistance, inserting between the source and point a variable resistance and varying the resistance until the measure of the potential at the point is equivalent to the previously stored measure of the potential at the point, whereby the second resistance multiplied by the ratio of the first variable resistance to the load impedance equals the resistance to be measured.

7. The method of measuring the impedance of a transmission line between a source of energy and any point which consists in changing the impedance beyond said point, storing a measure of the potential at the point, restoring the impedance beyond said point to its original value, inserting between said source and point a variable impedance, storing a measuring of the potential at the point and comparing said last mentioned stored measure of the potential with the previously stored measure of potential to determine if they are equal, and alternately varying the last impedance and comparing the stored potentials at the point for the two conditions until it is found that the potentials are equal,

whereby the last impedance is a measure of the value of the impedance of the line.

8. The method of measuring an electrical constant of a transmission line without disturbing the load thereon which consists in connecting an impedance in parallel with the load, said impedance being in a predetermined ratio to that of the load, determining the potential at the junction of the load and the line, removing the first impedance from association with the line and load, and inserting sufficient impedance in series with the load to establish the same potential at the junction as was previously determined, whereby the last impedance so added multiplied by the ratio of the first variable impedance to the load impedance is equal to said constant.

9. In an impedance measuring set, a plurality of condensers, an indicating device, switching means for connecting the condensers in succession to a point in a line the impedence of which is to be measured and then to said indicating device, and means for discharging the condensers in opposing relation through the indicating device.

10. In an impedance measuring device for measuring the impedance of a particular part of a line, to a given point, the combination of impedances with switching means and circuits for alternately changing the impedance of the line beyond said point by a given multiple, and for substituting such an impedance on the other side of said point as to maintain the potential at said point, unchanged.

11. In an impedance measuring set, means for multiplying the impedance on one side of a point in a transmission line by a predetermined value, means for determining the potential at the point, means for restoring the original impedance beyond the point and means for adding sufficient impedance on the other side of said point to bring the potential at said point to the value already determined, said added impedance serving as a measure of the impedance of the transmission line to the said point.

12. In an impedance measuring set, means for multiplying the impedance on one side of a point in a transmission line, means for storing a measure of the potential at the point under varying conditions, means for restoring the original impedance beyond the point, means for adding impedance on the other side of said point in order to bring the potential at such point to its former value, means for storing a measure of potential at the point for varying added impedances and means for comparing the stored measures of potential at the point.

13. A resistance measuring device for measuring the resistance of battery feeding lines between telephone exchanges comprising means for alternately connecting a resistance in parallel with the load supplied by said feeding line and connecting an adjustable resistance in series with said load, and means for indicating the relation between the two potentials at the point of connection adjacent the load for each alternative circuit condition.

14. In a test set, two fixed ratio arms and a variable arm of a Wheatstone bridge, means for connecting a fixed impedance such as a private branch exchange load to form the fourth arm of the bridge, a variable impedance, a receiver, a switch to connect said receiver across said bridge to test the balance thereof, two condensers each connected on one side to ground, a second switch for grounding the variable arm, for shunting or for connecting the variable impedance in series with the bridge and between the point of connection of the bridge and the line of the private branch exchange, and for charging one condenser, and a third switch controlled by the key of said second switch and arranged to charge the other condenser at the potential of the point in the line or when operated by the key of said second switch to discharge both condensers, in opposition, to said receiver.

15. In a test set, a Wheatstone bridge, means for connecting one end of the bridge to a point in a line to be tested, means for connecting the other end to ground, means to disconnect one arm of said bridge and to substitute therefor a load such as that of a private branch exchange in parallel with the variable arm of the bridge, a shunted variable impedance connected in series with the bridge and with the load of the private branch exchange, but on the other side of the point of connection to the private branch exchange, a receiver, two condensers each connected on one side to ground, a switch operable to connect said receiver across said bridge to test the balance thereof, and to charge the other condenser at the potential of the point in the line when the variable impedance is shunted, a switch arranged to take the shunt from said impedance, to remove the variable arm from the Wheatstone bridge and to close a path to charge one condenser at the potential of the point of connection of the private branch exchange load, and a third switch controlled by the key of the second switch for connecting the other sides of the condensers simultaneously to opposite sides of the receiver.

In witness whereof, I hereunto subscribe my name this 27th day of May, A. D. 1927.

JOSEPH W. DEHN.