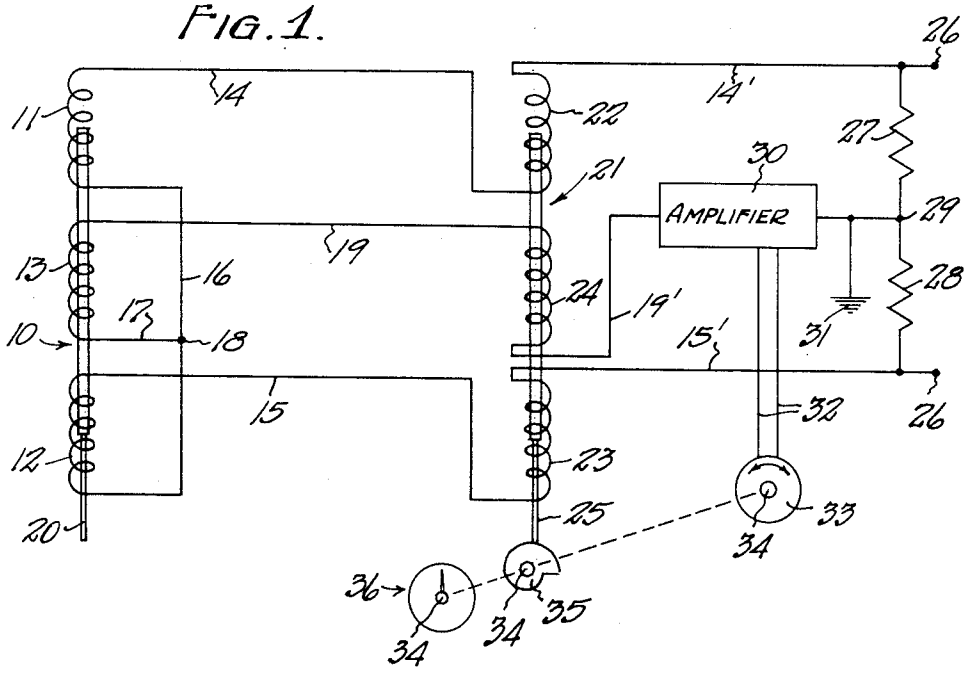
Oct. 19, 1954 J. R. NILSON 2,692,357

ELECTRICAL SYSTEM FOR REMOTE TRANSMISSION OF MECHANICAL MOVEMENTS

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FIG. 1.



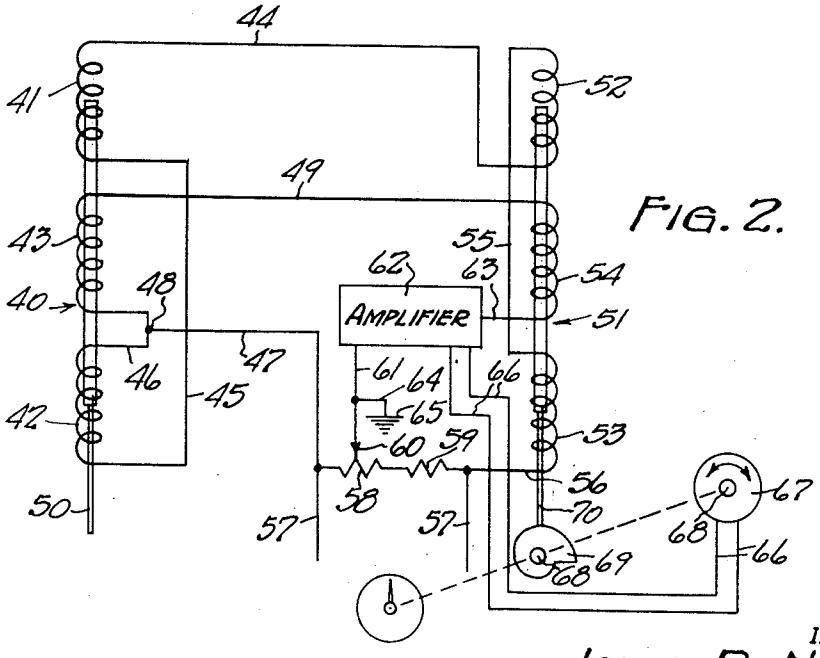


FIG. 2.

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FIG. 3.

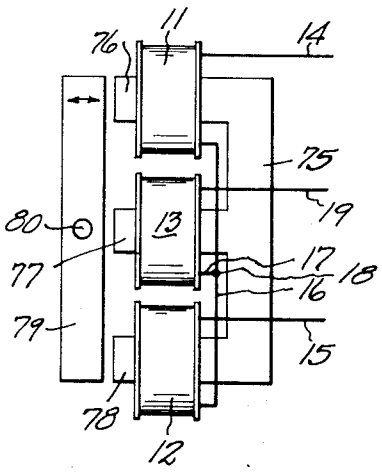
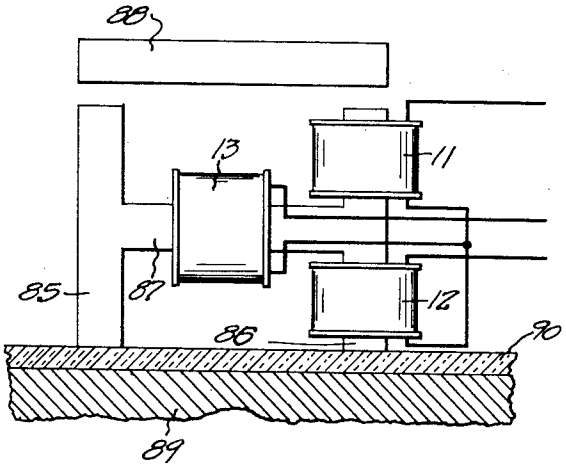


FIG. 4



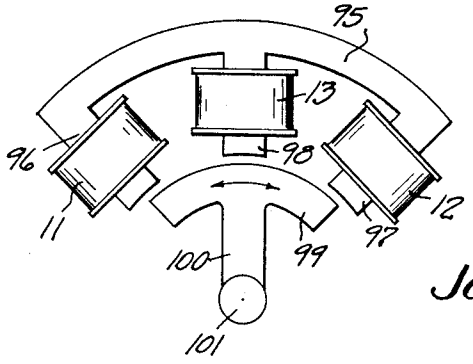


FIG. 5.

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UNITED STATES PATENT OFFICE

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ELECTRICAL SYSTEM FOR REMOTE TRANSMISSION OF MECHANICAL MOVEMENTS

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Application April 21, 1953, Serial No. 350,173

8 Claims. (Cl. 318—28)

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This invention relates to improvements in electrical systems for the remote transmission of mechanical movement, and, more particularly, it relates to such a system employing differential transformers as mechanical-electrical transducers.

The primary object of this invention is to provide a system of this character wherein only three wires are required for the transmission lines of the system, thereby effecting economy of time and materials for the installation of the system over that of other systems requiring four or more wires, and also making possible the installation of the present system in place of obsolete equipment in existing telemetering systems employing three or more wires.

A further object is to provide a system of this character wherein changes in temperature of one of the transducers will not change the ratio of the voltage existing in the primary and secondary circuits, even though such changes in temperature cause a change in resistance of the windings of the transducers and cause a change in the current in the entire system.

A further object is to provide a system of this character which is balanced in the transmission line so that different resistances caused by different lengths of transmission lines in different installations will have no deleterious effect.

A further object is to provide a system of this character employing a differential transformer in which the circuit is so arranged that the output of the transformer is increased as compared to other systems heretofore employed.

Other objects will be apparent from the following specification.

In the drawings:

Fig. 1 is a wiring diagram illustrating one embodiment of the invention;

Fig. 2 is a wiring diagram illustrating another embodiment of the invention;

Fig. 3 is a detail view of a differential transformer illustrating a modified arrangement;

Fig. 4 is a detail view of another modified arrangement of the transformer; and

Fig. 5 is a detail view of still another modified form of differential transformer.

Referring to the drawings, and particularly to Fig. 1, the numeral 10 designates a differential transformer having two primary windings 11 and 12 and a single secondary winding 13. A conductor 14 carries primary current to the primary winding 11, and a conductor 15 carries primary current to the primary winding 12. A conductor 16 connects the two windings 11 and 12. A

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lead 17 is tapped at 18 to the conductor 16 and is connected to the winding 13. A conductor 19 is also connected with the winding 13 and cooperates with conductors 14 and 15 to constitute the third line of a three-conductor transmission line. The windings 11, 12 and 13 of the differential transformer 10 are so arranged that an alternating current passed through the two primary windings 11 and 12 produces a magnetic flux in each primary winding, and the secondary is so arranged with respect to the two primaries that the combined magnetic flux of the primary windings produces a net effective flux of zero in the secondary winding 13.

A shiftable magnetic member 20 is juxtaposed to the windings 11, 12 and 13 in such a manner that it may have a neutral or zero position at which the net effective flux in the secondary winding 13 is zero. The member 20, however, may be shifted with respect to the windings 11, 12 and 13 in such a manner as to cause an increase in the magnetic coupling of one primary winding with the secondary winding, while decreasing the magnetic coupling of the other primary winding with the secondary winding. Such action results in the production of a variable magnetic flux in the secondary winding 13. The variable magnetic flux in the secondary winding produces a variable voltage whose phase is determined by the predominance of the flux from one primary winding over the flux from the other primary winding when the fluxes are combined within the secondary winding. The mechanical displacement or movement of the magnetic member 20, therefore, produces in the secondary winding 13 of the differential transformer 10 a voltage whose magnitude and phase are functions of the direction and extent of the movement of the magnetic member 20 with respect to a magnetic neutral point at which the coupling of each of the primary windings with the secondary winding produces a net effective flux of zero within the secondary winding 13.

A second differential transformer 21 similar to the transformer 10 is located at a point remote from the transformer 10. This transformer consists of the primary windings 22 and 23 and the secondary winding 24. A magnetic member 25 is shiftable relative to the various windings 22, 23 and 24. The primary winding 22 is connected in series in the conductor 14—14'; the primary winding 23 is connected in series in the conductor 15—15'; and the secondary winding 24 is connected in series in the conductor 19—19'. This arrangement causes the three wires 14—14',

15—15' and 19—19' constituting the transmission line, to connect the first differential transformer 10 with the second differential transformer 21 in such a manner that the four primary windings 11, 12, 22 and 23 are connected in a series loop, using the two conductors 14—14' and 15—15' of the transmission line to carry the primary current.

The secondary winding 13 of the first differential transformer 10 has one end thereof connected by conductor 17 with the junction 18 of the two primary windings 11 and 12 of the transformer 10, the other end of the secondary winding 13 being connected by conductor 19 with the secondary winding 24 of the transformer 21 in series relation. This arrangement results in the junction 18 of the two primaries of the first differential transformer being at the mid-point of the potential difference existing at the supply terminals 26 with which the conductors 14—14' and 15—15' are connected, it being remembered that the electrical characteristics of the primary windings 11, 12, 22 and 23 are similar.

A pair of resistors 27 and 28 of like resistance are connected in series between the conductors 14' and 15' adjacent the supply terminals 26. The conductor 19' connected to the secondary winding 24 of the differential transformer 21, is tapped at 29 at the junction of the two resistors 27 and 28. An amplifier or relay 30 is interposed in the line 19' between the tap 29 and the secondary winding 24 of the transformer 21. The system may be grounded at 31 by connection with the conductor 19'.

The output leads 32 from the amplifier 30 are connected to a reversible electric member, such as motor 33. This motor has a drive shaft 34 upon which is mounted a cam 35 juxtaposed to and adapted to engage the armature or magnetic member 25 of the second differential transformer 21.

It will be understood that the second differential transformer 21 is so arranged that its movable magnetic member 25 is caused to be moved by the cam 35 or other drive connection with the electric motor 33. In this connection the use of a motor and cam is understood to be illustrative and is not intended to be limiting, as any electro motive means, such as a solenoid, may be employed to respond to the output of the amplifier 30 for the purpose of controlling the position of the magnetic member 25. In the operation of the second differential transformer 21 the voltage induced in the secondary winding 24 has a magnitude which is a function of the magnitude of the movement of the magnetic member 25 and whose phase is a function of the direction of the movement of the member 25 from a magnetic neutral position, as previously described.

As previously mentioned, the point 18 at which the lead 17 to the secondary winding 13 of the differential transformer 10 is tapped is at a mid-point of the potential difference existing at the supply terminals 26 by virtue of the fact that the impedances of the primary windings 11, 12, 22 and 23 are similar. Similarly, since the resistors 27 and 28 are similar, the tap point 29 for the conductor 19' is at the mid-point of the potential existing between the supply terminals 26.

The secondaries of the two differential transformers are in a series circuit composed of the secondary windings 13 and 24, the third conductor 18—18' of the transmission line, the relay or amplifier 30, and a "phantom" connection between the points 18 and 29. In reality the so-called "phantom" consists of the two circuits carrying the primary current, namely 14', 22, 14 and 11, and 15', 23, 15 and 12, respectively; since the voltage drops in each of these primary current circuits are equal and opposite, and the two conductors 14—14' and 15—15' are effectively connected in parallel by the center junction 18 of the two primary windings 11 and 12 of the first differential transformer 10 and the center tap 29 of the two resistors 27 and 28 across the supply. The voltage between the mid-points 18 and 29 is zero and yet the impedance is not infinite and, therefore, a path for electric current exists, and hence a "phantom" conductor exists between the two points.

It is therefore apparent that the voltage appearing across the input terminals of the amplifier or relay 30 will be the difference in the voltages between the secondary windings 13 and 24 of the two differential transformers. The amplifier or relay 30 controls the direction of operation of the drive member 33 connected to position the magnetic member 25 of the second transformer 21 in such a manner as to reduce to zero the difference in the voltage at the two secondary windings 13 and 24. Stated differently, as a change in the position of the magnetic member 20 of the first transformer 10 unbalances that first transformer so that the output of the secondary winding 13 thereof is different from the output of the secondary winding 24 of the second transformer 21, that difference is sensed and amplified at 30 and produces operation of the power member 33 for the purpose of changing the position of the magnetic member 25 to restore the balance between the outputs of the secondary windings 13 and 24, or to equalize the output of the two secondary windings 13 and 24. When such balance or equality is reached, the output of the amplifier or relay 30 is zero and operation of the power member 33 ceases.

The parts will be so correlated that the position of the magnetic member 25 bears a known relationship to the position of the movable magnetic member 20 of the first transformer 10 and this is indicated or recorded, as by indicator 36 associated with shaft 34. Thus the system has transmitted the intelligence of the mechanical position of the member 20 to a remote point accurately and quickly.

One of the advantages of this system is that the voltage change in the system is greater than that which is produced in the secondaries of the differential transformers alone, thus increasing the strength of the signal supplied to the sensing means and amplifier 30 and improving both the sensitivity and the responsiveness of the system to small changes. This result occurs as follows: The current of the primary circuit is common to all of the four primary windings 11, 12, 22 and 23. The voltages in those four primary windings 11, 12, 22 and 23 are therefore proportional to the impedances of the respective windings. When the magnetic members 20 and 25 are in the geometric center or at the point at which the magnetic coupling of the primary windings with the secondary winding is equal, the voltage in winding 11 is equal to the voltage in winding 12, and the voltage in winding 22 is equal to the voltage in winding 23, since the impedances of the respective windings are equal. Assuming then that the magnetic member 20 is displaced toward the winding 11, the impedance of the winding 11 is increased and that of the winding 12 is decreased. This results in the voltage in

winding 11 being greater than the voltage in the winding 12. The difference between the voltages in windings 11 and 12 is effectively added to the voltage induced in the secondary winding 13. This results in a total voltage in the secondary winding 13 which is greater than that which would be due to the change in the positioning of the magnetic coupling member 20 only. This greater voltage change per unit of displacement serves to reduce possible errors caused by stray magnetic and electric fields. It will be understood that the same voltage relationship described above exists at the receiver transformer 21 so that high sensitivity and accuracy are achieved at all parts of the system, and superior operating results are obtained.

Another embodiment of the system is illustrated in Fig. 2. In this instance a first differential transformer 40 has the primary windings 41 and 42 and the secondary winding 43. A conductor 44 is connected to one end of the primary winding 41. A lead 45 connects the other end of the primary winding 41, here shown as the inner end, with the remote or outer end of the other primary winding 42. A lead 46 connects the other or inner end of the winding 42 with the adjacent end of the secondary transformer winding 43. A conductor 47 is tapped to the lead 46 at tap point 48. A conductor 49 extends from the other end of the secondary winding 43. A movable magnetic member 50 is juxtaposed to the windings 41, 42, 43 and is shiftable between a position in which the transformer is electrically neutral or balanced, and an unbalanced position.

A second differential transformer 51 has primary windings 52 and 53 and a secondary winding 54. The conductor 44 is connected to the end of the winding 52 opposite to the end at which it is connected to the winding 41, so that the winding 52 is in series relation to the winding 41. A lead 55 connects the other or outer end of the winding 52 with the inner end of the winding 53. A lead 56 extends to one terminal 57 of a supply line. The other terminal 57 of that supply line has connection with the conductor 47.

A pair of resistors 58 and 59 are connected in series across the terminals 57. The resistor 58 is a variable resistor and has a slider 60 connected by a lead 61 to an amplifier or relay 62 to provide one input lead for the amplifier. The other input lead to the amplifier constitutes a lead 63 which is connected with a secondary winding 54 and through that winding with the lead 49 and the secondary winding 43. A branch lead 64 extending from the lead 61 is connected to ground at 65.

The output lead 66 from the amplifier 62 extends to a power member, such as a positioning motor 67, whose shaft 68 operates the member 69, here shown as a cam, by means of which the position of the core or magnetic member 70 of the second differential transformer 51 is positioned.

One of the characteristics of this embodiment of the invention is that the slider 60 in contact with the variable resistor 58 accommodates adjustment of resistance to produce a voltage drop from terminal 57 to slider 60 to equal the voltage drop in conductor 47 between terminal 57 and point 58. This condition is likely to vary in each installation and may vary from time to time in the same installation, as ambient temperature changes.

This embodiment also possesses the advantage that only the three wires 44, 47 and 49 are required for the transmission to connect the two differential transformers and the other elements of the system. This facilitates the installation of the system with the requirement of a minimum number of wires, and also facilitates the use of the system as a replacement in existing telemetering systems requiring only three wires as is common.

Another advantage of the Fig. 2 embodiment, as well as the Fig. 1 embodiment, is that changes in temperature in any one of the differential transformers will not materially change or unbalance the system. The effect of any such temperature changes will be to change the resistance of the primary windings and, consequently, to change the current in the entire system, but it will not change the ratio of the voltage existing in the primary and secondary circuits. Since this is a mill-balance system, such variations of resistance are of no consequence.

In the Fig. 1 embodiment, another advantage is that there is no change in the operation of the system responsive to changes in the lengths of transmission lines in different installations. It will be apparent that any change of this character, that is, an increase in resistance due to increase in the length of transmission lines, adds the same resistance at each of the primary conductors and does not affect or destroy the balance of the system. Instead, the only result is a reduction in the primary current in the system.

This system also has the same advantages of increased potential of the differential transformers as a result of the circuit arrangement as is possessed in the Fig. 1 embodiment.

The specific construction of differential transformer may take any of a number of different forms. As shown in Figs. 1 and 2, only a diagrammatic showing of the construction of transformer is incorporated. In Figs. 3, 4 and 5, specific structural representations which the differential transformers may take are shown.

The embodiment of the invention illustrated in Fig. 3 is shown connected electrically with leads in the manner shown for differential transformer 10 in Fig. 1. In this construction an E-shaped magnetizable member 75 having arms 76, 77 and 78 extending therefrom in substantially parallel equispaced relation, provides the means for mounting the windings 11, 12 and 13 which are shown in the nature of coils. These coils are mounted in substantial registration with one another, with the coil 11 on arm 76, the coil 12 on arm 78, and the secondary coil winding on the arm 77, which is positioned intermediate the length of the frame member 75. The conductor 14 is connected to the coil 11, the conductor 15 is connected to the coil 12, and the conductor 16 connects the two coils, and lead 17 is tapped to the lead 16 at 18 and extends to the secondary winding 13. The conductor 19 is connected with the secondary winding 13 and cooperates with the conductors 14 and 15 to complete the three-wire transmission system. In this form the movable magnetic member takes the form of a bar 79 elongated and pivoted at its center at 80 adjacent to the tip of the central arm 77. The bar 79 is adapted to swing about the pivot 80 so that one end thereof is spaced from one of the outermost arms 76, 78 a distance greater than the other end thereof is spaced from the other of said frame members 76, 78. The magnetic

member 79 is here shown as in its neutral position.

In the embodiment of the invention shown in Fig. 4 the parts are again shown with the same connections and bearing the same identifying members as those in the differential transformer 10 of Fig. 1. This construction is characterized by a magnetic frame member which is formed in two parts, the two parts being fixedly related to one another, but being shiftable as a unit with respect to the third part. Thus an H-shaped frame is provided, having side members 85 and 86 and a central connecting bar 87. The primary windings 11 and 12 are in the nature of coils mounted symmetrically upon the member 86 at opposite sides of the crossbar 87. Secondary winding 13 is shown in the nature of a coil mounted substantially centrally upon the crossbar 87. The various leads and electrical connections are the same as those discussed previously and bear the same reference numerals. The bar 88 of the frame extends substantially parallel to the crossbar 87 with its opposite ends equispaced from the adjacent end portions of the arms 85 and 86 of the H-shaped frame part. In this embodiment of the invention the lower ends of the frame parts 85 and 86 constitute the sensing members for the purpose of sensing the spacing of their tips from the uppermost surface of a magnetizable member or plate 89, upon which a non-magnetizable sheet 90, such as a sheet of glass, is supported, the thickness of which is to be determined and compared to the spacing of parts 85 and 86 from the part 88. In the use of this device, since the various coils or windings 11, 12 and 13 remain in stationary relation to each other and to the bar 88, the only variation which occurs and which is subject to measurement is the spacing between the parts 85 and 86, on the one hand, and the member 89 on the other hand, as determined by the thickness of the glass 90 whose thickness is to be measured. As variations in the thickness of the glass 90 occur, the spacing between the parts 85, 86 and 89 varies and the measurement is secured, which is transmitted through the transmission lines 14, 15 and 19 to the secondary differential transformer 21 and the follow-up mechanism of the device.

The third form of differential transformer is shown in Fig. 5, wherein a frame member constitutes an arcuate portion 95 from which project in radial relation to one another outer arms 96 and 97 at opposite ends thereof which serve to mount the primary windings 11 and 12. Equispaced from and equiangularly related to the arms 96 and 97 is another fixed arm 98 upon which the secondary winding 13 of the transformer is mounted. The movable magnetic member constitutes an arcuate member 99 mounted upon an arm 100 rotatable about the center member 101 which is concentric with the arcuate member 95. In this arrangement the member 99 is equispaced from the tips of each of the frame members 96, 97 and 98 in all rotative positions thereof, but is of such a length that it normally acts upon a portion only of the tips of the frame members 96 and 97 magnetically considered. Consequently, as the member 99 is swung in either direction about its axis, an increased magnetic coupling occurs in the direction toward which it is swung, and a decreased magnetic coupling occurs in the opposite direction.

It will be understood that the forms of differential transformers which are illustrated in Figs. 3, 4 and 5 are all well adapted or suited for use in the systems shown in Figs. 1 and 2. It will also be understood that the form of differential transformers in Figs. 3, 4 and 5 are illustrative only of the types of transformers which may be used in this system, and it is not intended that use of these transformers must be made in this system. In other words, any other form or construction of differential transformer possessing two primaries of equal impedance but not necessarily of the same physical shape, a secondary and a movable magnetic member whose magnetic relation with the secondary remains essentially constant but whose magnetic relations with the two primaries are subject to variation in opposite sense upon movement thereof, may be employed in this system.

While the preferred embodiments of the invention have been illustrated and described herein, it will be understood that changes in the construction may be made within the scope of the appended claims without departing from the spirit of the invention.

I claim:

1. An electrical system for remote transmission of mechanical movements, comprising a transmitter, a receiver, said transmitter and receiver being similar and each including two primary windings, a secondary winding and a movable magnetic member, the primary windings being connected with a power source by two conductors in series loop arrangement, the secondary windings being connected in series with each other by a third conductor connecting a mid-point between the primary windings of the transmitter and a mid-point of the potential of the power source, means sensitive to the current in said third conductor, and means responsive to said current sensing means for shifting the movable magnetic member of said receiver.

2. An electrical system for remote transmission of mechanical movements comprising a transmitter, a receiver, means for sensing electrical unbalance between said transmitter and receiver, means responsive to said sensing means for actuating said receiver in a rebalancing sense, each of said transmitter and receiver having two primary windings, a secondary winding, and a movable magnetic member having a variable magnetic reaction upon said primary windings, a pair of conductors connected to a power source and to each other at a midpoint, each conductor having one primary winding of each of said transmitter and receiver interposed therein and a third conductor connected at said midpoint and at a point of midpotential at said source, said secondary windings being connected in series in said third conductor.

3. A system as defined in claim 2, wherein a resistance containing lead is connected across said first conductors adjacent said source and said third conductor is connected to said last named lead at a point of midpotential.

4. A system as defined in claim 2, wherein a pair of similar resistors are connected in series across said first conductors adjacent to said source and said third conductor is connected between said resistors.

5. A system as defined in claim 2, wherein a lead connects said first conductors adjacent said source and has a variable resistor interposed therein, said resistor having a slider with which said third conductor is connected.

6. A system as defined in claim 2, wherein said sensing means constitutes an amplifier and said

receiver actuating means is directionally responsive to the phase of the output of said amplifier.

7. An electrical system for remote transmission of mechanical movements comprising a transmitting differential transformer, a receiving differential transformer, said transformers being similar and each having two primary windings, a secondary winding and a movable magnetic member, a sensing member responsive to electrical unbalance, a rebalancing member responsive to said sensing member for adjusting the movable magnetic member of said receiving transformer, and three conductors connecting said transformers to each other and to a power source, one conductor having said secondary windings and sensing member connected in series therein, the other conductors each having a primary winding of each transformer connected in series therein and being connected to the opposite ends of said first conductor at points thereof at which the potential thereof is equal.

8. An electrical system as defined in claim 7, wherein said differential transformers have a normal balanced position and a normal rate of voltage induction in the secondary winding thereof, and wherein movement of said magnetic member from balanced position varies the impedances of said primary windings to vary the voltages thereof and adds the difference between said primary voltages to said normally induced secondary voltage.

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