

W. L. McGRATH

CONTROL SYSTEM

Fig. 1

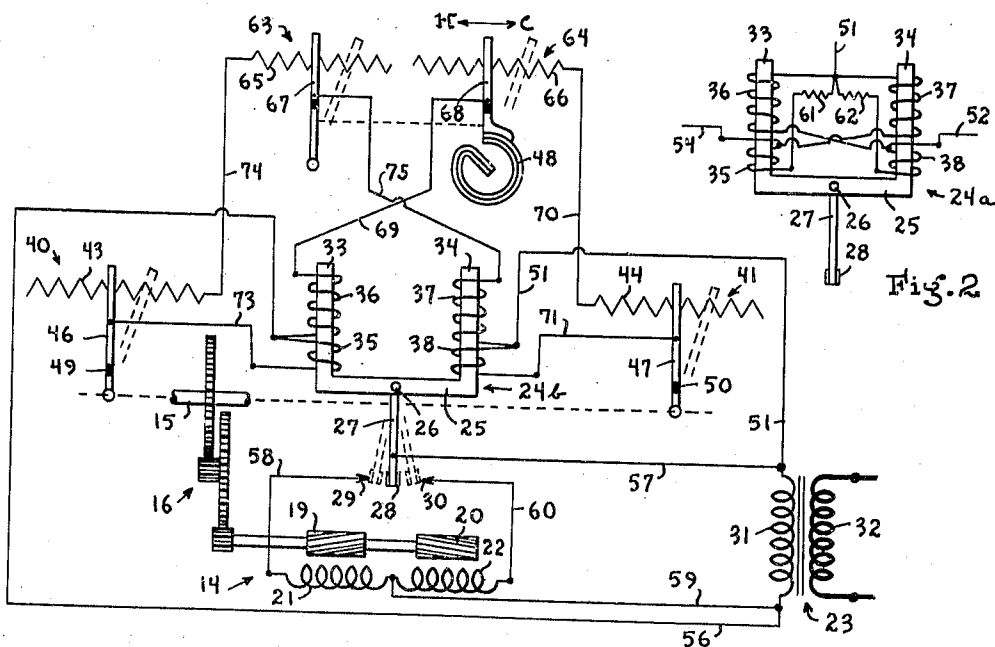


Fig. 2

Fig. 3

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CONTROL SYSTEM

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The present invention relates to control systems but more particularly to control systems of the follow-up type wherein an element responsive to variations in the value of a condition creates an unbalance in circuits normally balanced in accordance with a normal value of the condition, and wherein an element responsive to unbalance in the circuits controls a condition controlling device to establish the normal value of the condition and normal balance of the circuits.

Generally, control circuits of this type comprise parallel impedance paths each having means for separately actuating the unbalance responsive element but normally holding it in equilibrium. The element is actuated when the energization of one path is increased and the energization of the other path is correspondingly decreased. As such, the sensitivity of response of the unbalance responsive element depends entirely upon variations in the relative energizations of the impedance paths. The present invention concerns the novel combinations and arrangements of parts in circuits of this type whereby the effect of unbalance in such circuits is amplified to increase the sensitivity of the unbalance responsive element.

Accordingly, a general object of the present invention is to provide improvements in control systems increasing the efficiency thereof.

More specifically, a particular object of this invention is to provide balanced circuits wherein an unbalance responsive element is extremely sensitive to unbalance in said circuits.

More specifically, it is a particular object in this invention, wherein an element is normally held in a condition of equilibrium by the opposed and normally equal actuating means of normally balanced circuits but is actuated in response to the unbalancing of said circuits, to combine a portion of each actuating means with its opposed actuating means whereby the effect of unbalance in the circuits is amplified by a resulting predominating combination of actuating means thereby increasing the responsive sensitivity of the element.

A further object in this invention is to provide sensitive relays for balanced circuits.

Still further objects are those inherent or implied in the novel combination, constructions, and arrangement of parts hereinafter illustrated, described and claimed.

In the drawing:

Figure 1 is a schematic view of one embodiment of the control system of this invention

wherein a balanced circuit includes a sensitive relay which is responsive to unbalance in the circuit,

Figure 2 is a schematic view of a modification of the relay of Figure 1,

Figure 3 is a modification of the control circuit of Figure 1 wherein the balanced circuit includes a relay, the actuating windings of which have center taps connected to a source of power for energizing the circuit.

Referring to Figure 1, a valve, generally represented by the numeral 10, controls the flow of a suitable condition changing medium through a pipe line 11 to a radiator 12. The valve 10 has a valve stem 13 actuated by a reversible motor 14, which drives a shaft 15 through a reduction gear train 16, a crank disc 17 secured to the shaft 15 being operatively connected to the valve stem 13 by a link 18.

The motor 14 is provided with two rotors 19, 20, each having an associated winding 21, 22 respectively, which windings when separately energized produce opposite rotor rotation. For this purpose the windings 21, 22 are separately connected across the secondary terminals of a transformer, generally designated 23.

Energization of windings 21, 22 is controlled by a relay, generally designated 24, having U-shaped armature 25 which is mounted for pivotal movement about an axis indicated at 26. Suitably secured to armature 25 for pivotal movement therewith is a switch blade 27 which carries a contact 28. Movement of contact 28 to the left brings it into engagement with a fixed contact 29 electrically connected to the outer terminal of winding 21, and movement of contact 28 to the right brings it into engagement with a fixed contact 30 electrically connected to the outer terminal of winding 22. The inner terminals of windings 21, 22 are joined and electrically connected to the lower terminal of secondary winding 31 of transformer 23 by a wire 59. The upper terminal of secondary winding 31 is electrically connected to switch blade 27 by wire 51. Primary winding 32 of transformer 23 is connected to any suitable source of A. C. power, not shown.

Armature 25 comprises legs 33, 34 each having associated therewith a pair of actuating windings 35, 36 and 37, 38 respectively. Winding 35 is connected in series with winding 37. Winding 36, in turn, is connected in series with winding 38. Windings 36, 37 are provided with an equal number of turns, and windings 35, 38 are also provided with an equal number of turns but with

fewer turns than windings 36, 37 for reasons hereinafter to appear. While relay 24 is shown schematically in Figure 1, it will be understood that the windings 35, 36 and 37, 38 may be wound, superimposed one on the other about the legs 33, 34 respectively, the legs moving axially of the windings as the armature 25 swings about the axis 26.

Armature 25 is actuated in response to variations in the relative energizations of the actuating windings which relative energizations are controlled by three variable impedance controllers 39, 40, and 41, each having an impedance such as wound wire resistors 42, 43, and 44, and a contact arm 45, 46, and 47 respectively. Resistor 42 is electrically connected to resistors 43, 44 and contact arms 46, 47 are electrically connected to the upper terminals of windings 35, 33 respectively.

The actuating windings and impedance controllers comprise a normally balanced circuit, the energization of which is also provided by transformer 23, the lower terminal of secondary winding 31 being electrically connected with contact arm 45 and the upper terminal of secondary winding 31 being connected to the joined terminals of actuating windings 36, 37.

Contact arm 45 is actuated by a suitable temperature responsive element, herein shown as a conventional bimetallic strip 48. Contact arms 46, 47 are connected to shaft 15 for rotation therewith. Consequently, any movement of shaft 15 in regulating valve 10 actuates arms 46, 47 for a purpose hereinafter explained. Insulation pieces 49, 50, formed as a part of arms 46, 47 respectively, prevent current from flowing along shaft 15 from one arm to the other.

Controller 39 is situated in the space heated by radiator 12, the bimetallic strip 48 being responsive to temperatures in the space such that upon an increase in temperature the arm 45 moves to the left and upon a decrease in temperature moves to the right as indicated by the legends H and C, respectively, on the drawing.

In the operation of Figure 1, when the space heated by radiator 12 is at a normal desired temperature, the contact arms 45, 46, 47 are in their full line positions. Under such a condition current flowing from transformer 23 flows through a balanced circuit having two equal parallel impedance paths. Current, at any instant, flows as follows: from secondary winding 31, through conductor 51 to the junction of windings 36, 37, thence through the equal impedance paths dividing equally at the junction with one half flowing down through winding 36 and up through winding 38, thence through conductor 52, contact arm 47, resistor 44, thence through conductor 53 and resistor 42 to contact arm 45 which comprises the first impedance path, and with the other half flowing down through winding 37 and up through winding 35, thence through conductor 54, contact arm 46, resistor 43, thence through conductor 55, and resistor 42 to contact arm 45 which comprises the second impedance path, the currents in the two paths then joining and thence flowing through contact arm 45, bimetallic strip 48, and thence through conductor 56 back to secondary winding 31.

Actuating windings 36, 38 are connected in circuit with the first impedance path, and windings 35, 37 are connected in circuit with the second impedance path. Since, under a condition of balance the same value of current flows in both paths, all of the windings carry the same value

of current, and the current through each tends to set up a flux. The flux set up by one winding of each associated pair 35, 36 and 37, 38, however, tends to neutralize the flux set up by the other winding since the windings of each associated pair have been connected and wound so that the currents therethrough flow in opposite directions. As previously stated windings 35, 33 are provided with fewer turns than windings 36, 37. Consequently, the flux set up by winding 36 is greater than, and is not completely neutralized by the flux set up by winding 35, and a net flux results which tends to pull leg 33 and pivot armature 25 in a clockwise direction. However, an equal net flux is set up by windings 37, 38 in a like manner as the net flux produced by windings 35, 36 which tends to pull leg 34 and pivot armature 25 in a counter clockwise direction. Consequently, the armature 25 is held in equilibrium with contact 28 held midway between the fixed contacts 29 and 30. The equal net fluxes acting on legs 33, 34, serve as a damper in holding armature 25 against erratic movement.

When the temperature in the space heated by radiator 12 drops, the bimetallic strip 48 moves the arm 45 to the right to the dotted line position, for example. A smaller portion of resistor 42 is then included in the first impedance path including windings 36, 38, and a larger portion is included in the second impedance path including windings 35, 37. The impedance of the first path is less and accordingly, the current therethrough is greater. The impedance of the second path is greater, and accordingly, the current therethrough is less. Accordingly, the flux set up by winding 36 is greater than before, and the flux set up by winding 35 which tends to neutralize it is less than before. Therefore, a greater net flux tending to pull leg 33 and pivot armature 25 clockwise results, which is considerably greater than before. On the other hand, the flux set up by winding 37 is less, and the flux set up by winding 38 which tends to neutralize it is greater than before. The next flux acting on leg 34, therefore, is considerably less than before. Consequently, the predominating net flux acting on leg 33 pivots the armature 25 until the contact 29 engages the fixed contact 29 which completes a circuit to motor winding 21 as follows: from secondary winding 31 through conductor 57, switch blade 27, contacts 28, 29, conductor 58, winding 21, and conductor 59 back to secondary winding 31. Rotor 19 then drives shaft 15 to open valve 10, and shifts contact arms 46, 47 to the right to their dotted line positions in which positions the impedance paths are again equal and the contact 28 moves to the position midway between contacts 29 and 30.

From the foregoing it is now apparent that in a condition of unbalance in the circuit by the interassociation of the windings of each impedance path with the windings of the other path, the windings of the path of greater energization not only tend to actuate the armature in one direction but further weaken the tendency of the windings of the lesser energized path to actuate the armature in the other direction. Accordingly, the effect of unbalance in the circuit is amplified thereby increasing the sensitivity of response of the armature to unbalance in the circuit.

To this end it will be further understood that for all conditions of unbalance the fluxes set up by windings 35, 38 must never exceed, but only serve to neutralize the fluxes set up by their asso-

ciated windings 36, 37 respectively. For this purpose, windings 35 and 38 are provided with a fewer number of turns than their associated windings. However, if desirable, all of the windings may comprise the same number of turns with the windings 35, 38 having a greater impedance per turn. Moreover, any expedient which will provide windings 35, 38 with fewer ampere turns than their associated windings 36, 37 will serve the above purpose, and I do not wish to be limited to the use of any single expedient.

When the contact arm 45 returns to the full line position as a result of the rise in temperature of the space heated by radiator 12 due to the increased supply of heat thereto, the circuit is again unbalanced, the first impedance path now having the greater and the second path, the lesser impedance. Accordingly, it will be understood without further explanation, that the net flux acting on leg 34 now predominates, armature 25 pivots counter clockwise and contact 28 engages fixed contacts 30 to complete a circuit to motor winding 22 as follows: From secondary winding 31 through conductor 57, switch blade 21, contacts 28, 30, conductor 60, winding 22, and conductor 59 back to secondary winding 31. Rotor 20 then drives shaft 15 to close valve 10 and return contact arms 46, 47 to their full line positions in which positions the circuit is again balanced and one cycle of operation has been completed. A similar cycle occurs when contact arm 45 moves to the left in the direction of legend H in response to a rise in temperature.

In Figure 2 is shown a relay generally designated 24a which is a modification of the relay 24 of Figure 1. Except for the internal connections of the relay windings and the use of a pair of resistors 61, 62, the relay is in all other respects the same as relay 24 and similar reference characters designate similar parts. Windings 36, 38 which form a part of the first impedance path, and windings 35, 37 which form a part of the second impedance path of Figure 1, however, in Figure 2 are connected in parallel in their respective paths. Since windings 35 and 38 have a fewer number of turns than their associated windings 36 and 37 respectively, it is necessary to insert resistors 61, 62 in series with windings 35, 38 to limit the current therethrough in order that the fluxes set up by said windings never exceed the fluxes set up by their associated windings as explained in the operation of Figure 1. To this end windings having a greater resistance per turn than windings 36, 37 may be substituted for windings 35, 38 in which case the resistors 61, 63 may be dispensed with.

In the operation of relay 24a, assuming that it has been substituted for relay 24 of Figure 1, when the circuit of Figure 1 is balanced, equal currents flow in the two impedance paths. Current in the first path, at any instant, flowing in conductor 52 divides and flows in part down through winding 38 and through resistor 62 to conductor 51, and flows in part up through winding 36 to conductor 51. An equal current flowing in the second path through conductor 54 divides and flows in part down through winding 35, through resistor 61, to conductor 51, and flows in part up through winding 37 to conductor 51. The resultant fluxes set up by the oppositely flowing currents in associated windings 35, 36 and 37, 38 are equal and hold armature 25 in equilibrium thereby serving as a damper to hold the same against erratic movement. In a condition

of unbalance in the circuit, one impedance path carries a greater current, and consequently, a predominating resultant flux acting on one leg of armature 25 actuates the same as explained in connection with the operation of Figure 1.

In Figure 3 a modification of the control circuit of Figure 1 and a third modification, 24b of relay 24 are shown. In Figure 3 the secondary potential of transformer 23 is applied across the connected terminals of windings 35, 36 and 37, 38. Also, two impedance controllers 63, 64 are substituted for the single impedance controller 39 of Figure 1. Each impedance controller 63, 64 is provided with a resistor 65, 66 and a contact arm 67, 68 respectively, these resistors acting as impedances. Contact arm 67 is coupled to contact arm 68 for movement therewith, contact arm 68 being actuated by the bimetallic strip 48 in the same manner as contact arm 45 of Figure 1 is actuated. The coupling between arms 67, 68, of course, is insulated to prevent a current flow between the arms. In all other respects the apparatus embodiment of Figure 3 is the same as Figure 1, and similar reference characters are used to designate similar parts. Furthermore, as in the case of Figure 1, windings 36, 38 are connected in series in a first impedance path, and windings 35, 37 are connected in series in a second impedance path as will be apparent from a description of the operation of Figure 3.

In the operation of Figure 3, when the circuit is balanced the contact arms 46, 47, 67, 68 are in their full line positions as shown. Under such a condition current flowing from secondary winding 31 flows as follows: From secondary winding 31, through conductor 56 to the junction of windings 35, 36, divides equally through the equal impedance paths, one half flowing up through winding 36, through conductor 69, bimetallic strip 48, contact arm 68, resistor 66, conductor 70, resistor 44, contact arm 47, conductor 71, thence up through winding 38 to conductor 51 which comprises a first impedance path, and the other half flowing down through winding 35, through conductor 73, contact arm 46, resistor 43, conductor 74, resistor 65, contact arm 67, conductor 75, thence down through winding 37 to conductor 73 which comprises a second path, the currents then joining and flowing through conductor 51 back to secondary winding 31. The oppositely flowing currents in associated windings 35, 36 and 37, 38 set up resultant fluxes which hold the armature 25 in equilibrium as in the case of Figure 1.

When the temperature drops in the space in which the radiator 12 (not shown in Fig. 3) is situated, the bimetallic strip 48 moves the contact arms 67, 68 to the right to their dotted line positions, for example. The impedance of the first path including windings 36, 38 is now less, and the impedance of the second path including windings 35, 37 is now greater than before. Accordingly, a greater current flows in the first path and a lesser current flows in the second path. A predominating resultant flux then acts on leg 33 and the armature 25 pivots clockwise and contact 28 engages contact 29 to energize winding 21. Rotor 19 then drives shaft 15 to open valve 10 (not shown in Fig. 3) and shifts contact arms 46, 47 to their dotted line positions in which positions the impedance paths are again equal and the circuit balanced. From the foregoing it is apparent that the operation of Figure 3 is the same as the operation of Figure 1 and

further explanation is thought unnecessary. It is further apparent that the windings 35, 36 and 37, 38 may comprise single windings with center taps brought out to which the secondary potential of transformer 23 may be applied. In this connection it will be understood that the taps may be chosen so that the winding portions 35, 38 have fewer turns than their associated portions 36, 37 respectively.

From the foregoing it is now readily evident that I have provided novel combinations and arrangements of parts in a balanced control system, said combinations and arrangements comprising control systems of unusual utility, efficiency, and extreme sensitivity. Moreover, it is apparent that I have provided various modifications of a sensitive relay for such systems.

While I have illustrated and described several specific embodiments of my invention, it will be apparent to those skilled in the art that various modifications, combinations, substitutions, additions, and omissions may be made which will be within the spirit and scope of my invention as defined by the appended claims.

I claim as my invention:

1. In a control system, the combination of a normally balanced circuit having normally equal impedance paths, an element actuated in response to unbalancing of said circuit, one of said impedance paths having means associated with said element for actuating the same in one direction, and the other impedance path having means associated with said element for actuating the same in an opposite direction, said element being actuated in response to variations in the relative energizations of said actuating means, and a permanently connected portion of the actuating means of each said impedance path being associated with the other portion of the actuating means of the other impedance path to partially neutralize the actuating effect of said each other portion.
2. In a control system, the combination of a normally balanced circuit having normally equal impedance paths, each path having a pair of windings connected in series, an element associated with said pairs of windings for actuation thereby in response to unequal energization thereof, said element normally assuming a neutral position upon equal energization of said pairs of windings, the windings of each pair being connected together when said element is in said neutral position, one winding of each said pair being associated in opposition with the other winding of the other said pair whereby in a condition of unbalance, the impedance path of greater energization further weakens the actuating strength of the lesser energized impedance path.
3. In a control system, the combination, of a normally balanced circuit having normally equal impedance paths, each path having a pair of windings connected in parallel, an element associated with said pairs of windings and actuable thereby in response to unequal energization thereof, said element normally assuming a neutral position upon equal energization of said pairs of windings, the windings of each pair being connected together when said element is in said neutral position, one winding of each said pair being associated in opposition with the other winding of the other said pair whereby in a condition of unbalance, the impedance path of greater energization further weakens the actuating strength of the lesser energized impedance path.

4. In a control system, the combination of a normally balanced circuit having normally equal impedance paths, each path having a pair of windings, an element associated with said pairs of windings for actuation thereby in response to unequal energization thereof, said element normally assuming a neutral position upon equal energization of said pairs of windings, the windings of each pair being connected together when said element is in said neutral position, one winding of each said pair being associated in opposition with the other winding of the other said pair to partially neutralize the actuating effect of each said other winding whereby in a condition of unbalance the impedance path of greater energization further neutralizes the actuating effect of the lesser energized path and the impedance path of lesser energization neutralizes the actuating effect of the greater energized path to a lesser extent.

5. In a control system the combination of a normally balanced circuit, an element, a pair of means in said circuit associated with said element for actuating the same in response to unbalance in said circuit, and a source of power connected to said actuating means for energizing said circuit, said source of power being connected across said circuit at an intermediate point in each actuating means of said pair, said connections providing parallel impedance paths in said circuit, each said impedance path including a portion of each actuating means of said pair defined by said connections, and said intermediate point being chosen such that said portions of each said actuating means are unequal and the lesser portion of each said actuating means partially neutralizes the actuating effect of the greater portion of each said actuating means.

6. In a control system, the combination of a normally balanced circuit having normally equal impedance paths, an element, two windings associated with said element and acting in opposition to each other, said windings having intermediate taps for dividing each winding into two portions, each said impedance path normally including a portion of each winding, and a source of power connected across said taps for energizing said circuit.

7. In a control system of the follow-up type, a balanced circuit, said circuit comprising parallel impedance paths, said circuit comprising three variable impedance controllers for creating variations in the relative energizations of said paths, each impedance path comprising winding means for actuating an element responsive to unbalance in said circuit, a portion of said windings means of each said path being associated in opposition with the winding means of each other path, and each said impedance path including one of said controllers and a proportional part of said third controller.

8. A sensitive relay for balanced circuits comprising an armature, and two pairs of windings for actuating said armature, said windings comprising three terminals for connection in a balanced circuit, one winding of each pair providing first and second terminals, said windings being connected to the other winding of each other pair, and said other windings of each pair being connected to provide a third terminal.

9. A sensitive relay for balanced circuits comprising an armature, and two pairs of windings for actuating said armature, said windings comprising three terminals for connection in a balanced circuit, the windings of each said pair being

connected and said connections being connected to provide a first terminal, and one winding of each said pair being connected to the other winding of each said pair, said last mentioned connections comprising second and third terminals.

10. A sensitive relay for a normally balanced circuit having normally equal impedance paths comprising a substantially U-shaped armature, a pair of windings associated with each leg of said armature, means pivotally mounting said armature whereby the legs thereof move substantially axially of said windings in response to unequal energization thereof, one winding of each pair being connected in circuit with one of said impedance paths, and the other winding of each pair being connected in circuit with the other of said impedance paths whereby in a condition of unbalance the responsive sensitivity of said armature is amplified.

11. A sensitive relay for a normally balanced circuit having normally equal impedance paths comprising a substantially U-shaped armature, a pair of windings associated with each leg of said armature, means pivotally mounting said armature whereby the legs thereof move substantially axially of said windings, one winding of a first pair being connected in circuit with one of said impedance paths and in circuit with one winding of the other pair, and the other winding of said other pair being connected in circuit with the other impedance path and in circuit with the other winding of said first pair whereby in a condition of unbalance the responsive sensitivity of said armature is amplified.

12. A sensitive relay for balanced circuits comprising an armature, a pair of windings associated with said armature, said windings having center taps for connection with a source of power for energizing the same, said windings having terminals for connection in a balanced circuit, and said armature being mounted with respect to said windings for relative movement therewith in response to variations in the energizations of said windings.

13. A sensitive relay for balanced circuits comprising a substantially U-shaped armature, an actuating winding associated with each leg of said armature, said windings having center taps for connection to a source of power, and said windings having terminals for connection in a balanced circuit.

14. In a control system, the combination of a normally balanced circuit having two normally equal impedance paths, an electromagnetic con-

troller having two armature portions tending when attracted to move said controller in opposite directions, a pair of windings associated with each armature portion, each of said impedance paths normally including one winding of each pair connected so that the two windings of each pair oppose each other so that in a condition of electrical unbalance the impedance path of greater energization further neutralizes the actuating effect of the lesser energized path and the impedance path of lesser energization neutralizes the actuating effect of the greater energized path to a lesser extent.

15. In a control system, the combination of a normally balanced circuit having two normally equal impedance paths, an electromagnetic controller having two armature portions tending when attracted to move said controller in opposite directions, a pair of windings associated with each armature portion, each of said impedance paths normally including one winding of each pair connected so that the two windings of each pair oppose each other so that in a condition of electrical unbalance the impedance path of greater energization further neutralizes the actuating effect of the lesser energized path and the impedance path of lesser energization neutralizes the actuating effect of the greater energized path to a lesser extent, said impedance paths each including a portion of a variable impedance controller acting as a main controller.

16. In a control system for a motor, a motor, a normally balanced circuit having two normally equal impedance paths, an electromagnetic relay controlling said motor and having two armature portions tending when attracted to move said controller in opposite directions, a pair of windings associated with each armature portion, each of said impedance paths normally including one winding of each pair connected so that the two windings of each pair oppose each other so that in a condition of electrical unbalance the impedance path of greater energization further neutralizes the actuating effect of the lesser energized path and the impedance path of lesser energization neutralizes the actuating effect of the greater energized path to a lesser extent, a main variable impedance controller, and a follow up variable impedance controller adjusted by said motor, said normally equally energized impedance paths each including a portion of the impedance of each of said controllers.

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