A. J. HALL.

SYSTEM OF CONTROL.

APPLICATION FILED OCT. 3, 1917.

1,365,316.

Patented Jan. 11, 1921.

4 SHEETS—SHEET 1.

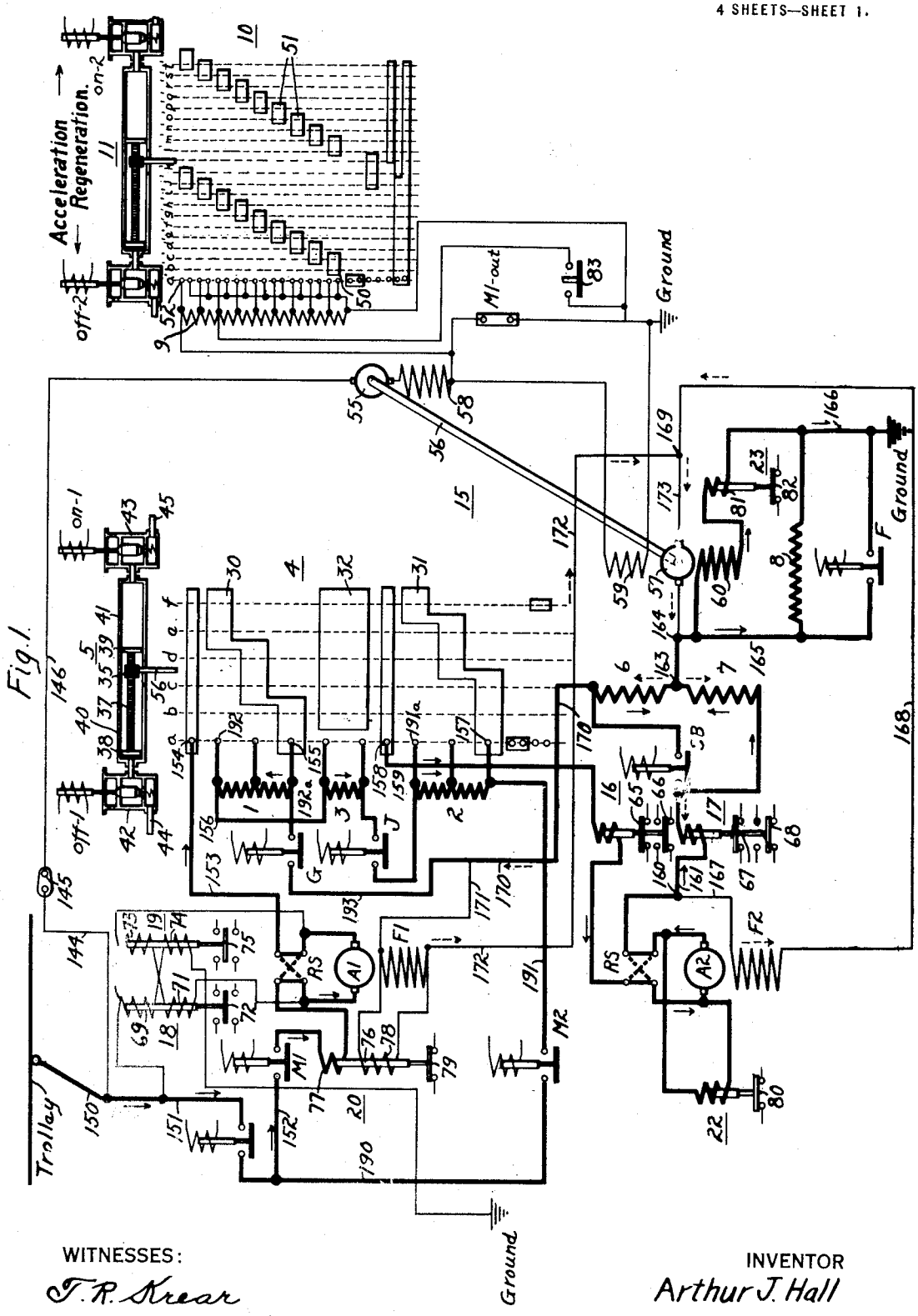


Fig. 1.

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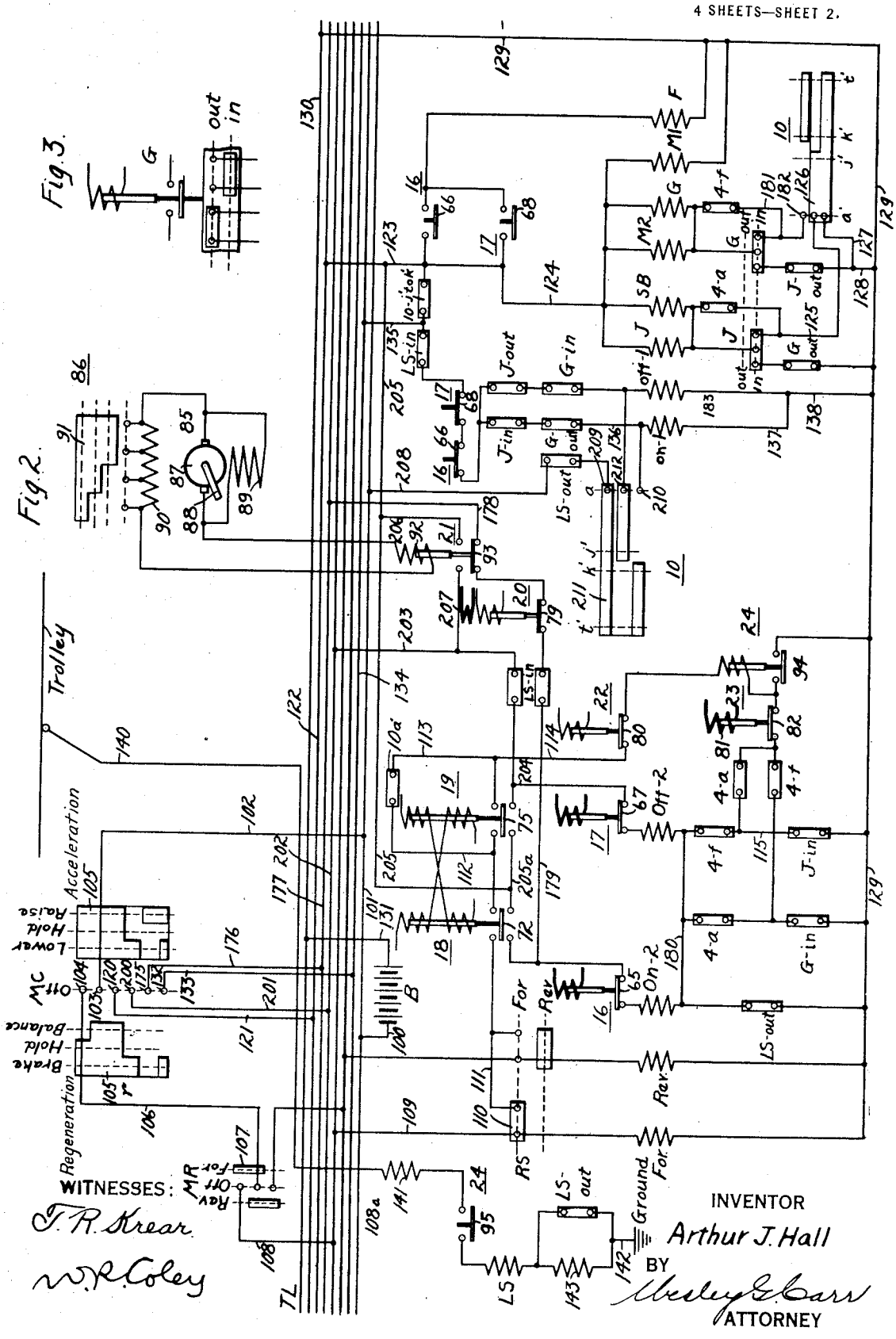
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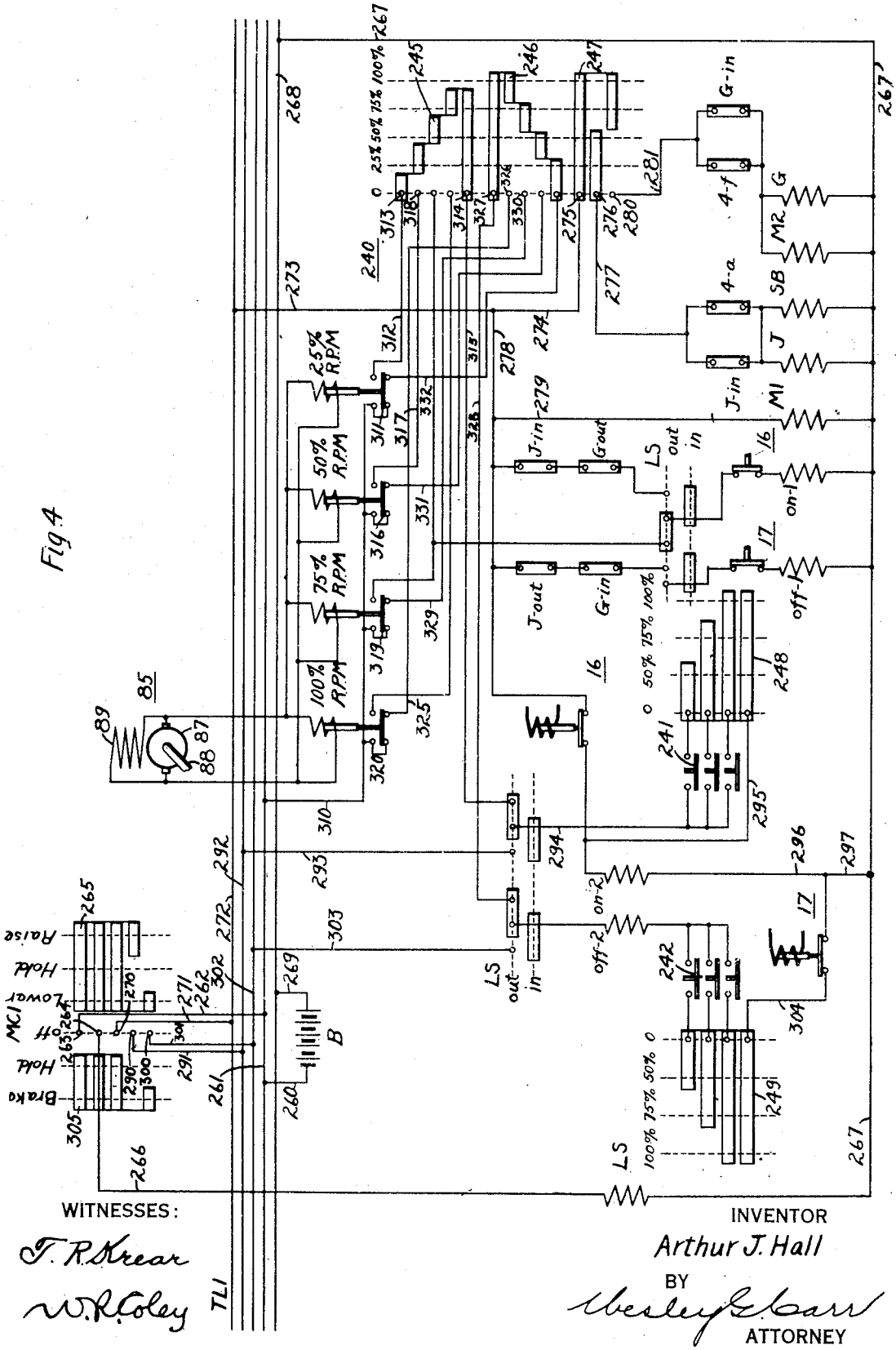
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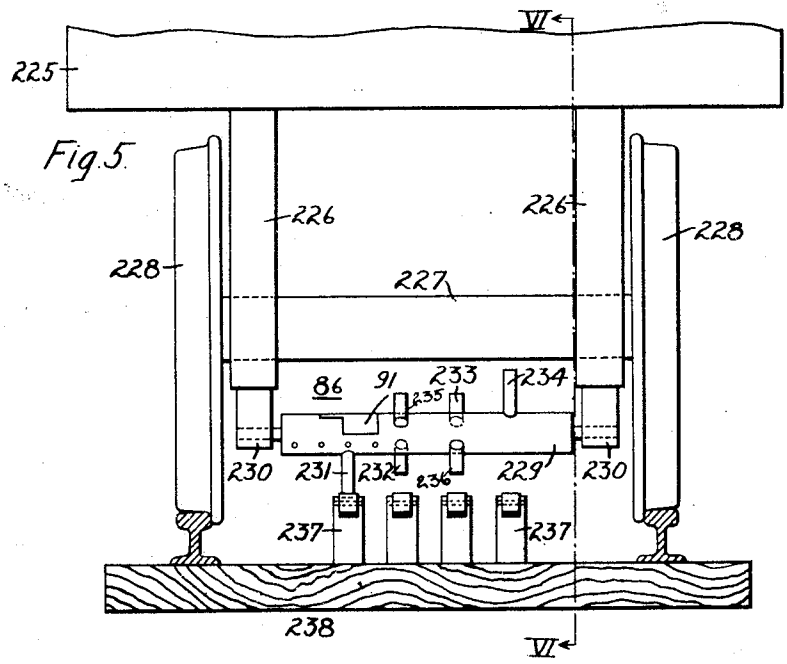


Fig. 5.

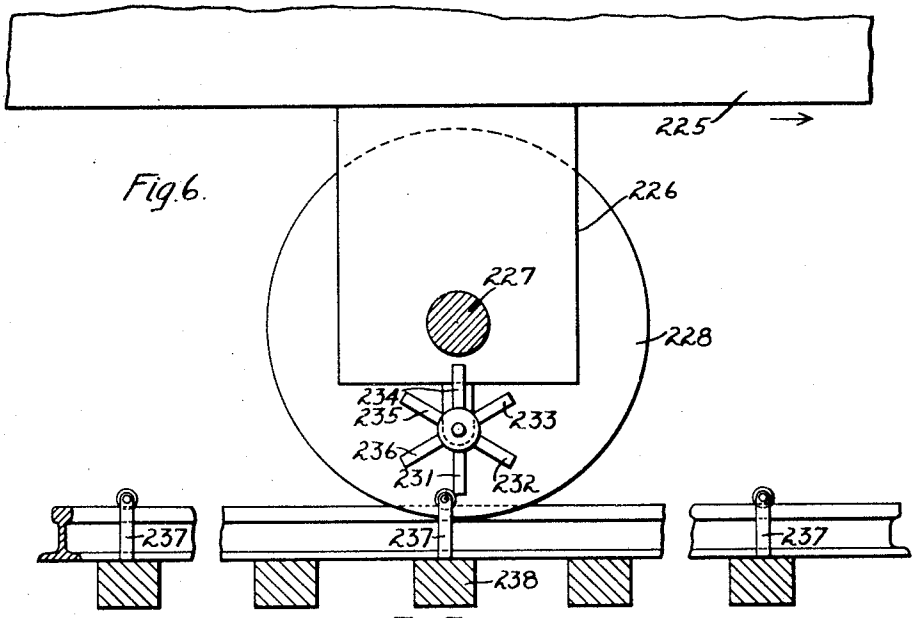


Fig. 6.

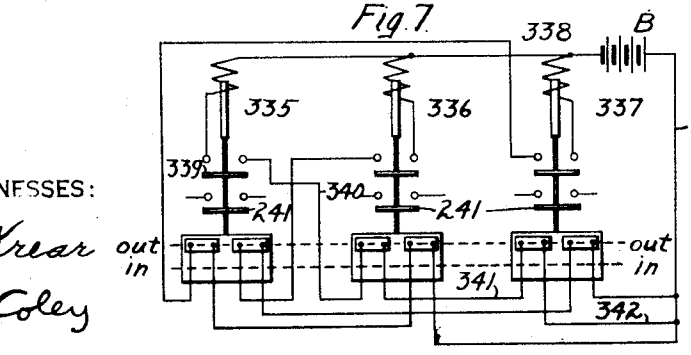


Fig. 7.

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ARTHUR J. HALL, OF WILKINSBURG, PENNSYLVANIA, ASSIGNOR TO WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA.

SYSTEM OF CONTROL.

1,365,316. Specification of Letters Patent. Patented Jan. 11, 1921.

Application filed October 3, 1917. Serial No. 194,436.

To all whom it may concern:

Be it known that I, ARTHUR J. HALL, a subject of the King of Great Britain, and a resident of Wilkinsburg, in the county of Allegheny and State of Pennsylvania, have invented a new and useful Improvement in Systems of Control, of which the following is a specification.

My invention relates to systems of control and especially to the automatic control of electric railway-vehicle motors during the accelerating and the regenerative periods.

The object of my invention is to provide a relatively simple and inexpensive system of the above-indicated character which shall involve a plurality of desirable automatically-operating features whereby an efficient, reliable and substantially fool-proof system is obtained.

More specifically stated, it is the object of my invention to provide a relatively simple control system that is adapted for both accelerating and regenerative operation of a plurality of dynamo-electric machines, the system being automatically controlled not only in accordance with the value of the machine current as is usual, but also in accordance with the speed.

Other minor objects of my invention relating to certain improvements of portions of the control system will be evident from the subsequent description and are pointed out with particularity in the accompanying claims.

My invention may best be understood by reference to the accompanying drawings, wherein Figure 1 is a diagrammatic view of the main circuits of a system of control embodying the invention; Fig. 2 is a diagrammatic view of an auxiliary governing system for the main circuits that are shown in Fig. 1; Fig. 3 is a detailed diagrammatic view of one of the main-circuit switches; Fig. 4 is a diagrammatic view of an auxiliary system, corresponding to Fig. 2, illustrating a modification of the invention; Fig. 5 and Fig. 6 are semi-diagrammatic views, in end elevation and in longitudinal section on the line VI—VI, respectively, of a portion of a vehicle carrying a control accessory that is employed in the present invention; and Fig. 7 is a diagrammatic view of an auxiliary interlocking system that is associated with the system of Fig. 4 in a manner to be set forth.

Referring to Fig. 1 of the drawings, the system shown comprises supply-circuit conductors Trolley and Ground; a plurality of main dynamo-electric machines respectively having commutator-type armatures A1 and A2 and field windings F1 and F2 of the series type; a reversing switch RS, preferably of a familiar electrically-controlled type, as indicated in Fig. 2, but here shown in a conventional manner, for the purpose of reversing the connections of each main armature; an auxiliary motor-generator set 15 that is fed from the supply circuit for the purpose of providing an auxiliary excitation to the main-field windings during both acceleration and regeneration; a plurality of variable accelerating resistors 1, 2 and 3 that are connected in the main circuits, in a manner to be set forth, to be varied by a controller 4 having an actuating mechanism 5; a plurality of stabilizing resistors 6 and 7 that are associated with both the main-armature circuits and the exciting circuits; a plurality of auxiliary resistors 8 and 9 for governing the operation of the motor-generator set 15; a controller 10 having an actuating mechanism 11, similar to the above-mentioned mechanism 5, for varying the active circuit value of the resistor 9; a plurality of switches LS, M1, J, SB, M2, G and F; and a plurality of relay devices 16, 17, 18, 19, 20, 22 and 23, which may be respectively designated as acceleration limit switch, regeneration limit switch, line-balancing relay, motor-balancing relay, differential relay, over-voltage relay and field relay.

The acceleration controller 4 is provided with a plurality of contact segments 30, 31 and 32 for varying the active circuit values of the accelerating resistors 1, 2 and 3 in a peculiar and novel manner, as hereinafter set forth in detail. The controller is adapted to occupy a plurality of positions *a* to *f*, inclusive, the normal or initial position being *a*, as illustrated. A plurality of auxiliary-circuit contact segments and control fingers, a portion of which is illustrated in Fig. 1, are employed for various purposes to be set forth in connection with Fig. 2.

The actuating mechanism 5 is of an electrically-controlled, fluid-pressure-operated

type, comprising a pinion 35 which is secured to the upper end of the operating shaft 36 for the controller 4 to mesh with a horizontally-movable rack member 37, the opposite ends of which constitute pistons 38 and 39 that travel within appropriate operating cylinders 40 and 41, respectively. A normally open valve 42, having an actuating coil Off—1 for effecting closure of the valve, communicates with the outer end of the cylinder 40, and a similar valve 43, having an actuating coil On—1, is associated with the outer end of the other cylinder 41. Fluid pressure from any suitable source (not shown) may be supplied to the valves 42 and 43 through inlet pipes or passages 44 and 45, respectively.

The mechanical operation of the actuating mechanism 5 requires but a brief description. By energizing the actuating coil On—1, the valve 43 is closed to permit the normally present fluid pressure in the cylinder 41 to exhaust to the atmosphere, while the normally present fluid pressure in the other cylinder 40 actuates the pistons 38 and 39 toward the right, and therefore moves the controller 4 toward the left through its successive operative positions. Movement in the opposite direction may be accomplished in an equally simple manner by energizing only the Off—1 magnet, whereby movement of the controller 4 toward its off or initial position *a* is produced.

To arrest either of the movements just recited at any time, it is of course merely necessary to deënergize the active magnet coil, whereupon balanced high-pressure-fluid conditions again obtain in the mechanism and a positive and reliable stoppage thereof is produced.

The field-excitation controller 10 is employed for varying the active circuit value of the resistor 9 to correspondingly change the delivered voltage of the motor-generator set 15, and, therefore, the excitation of the main machines, as subsequently set forth in detail. A plurality of sets of independent contact segments 50 and 51 are provided to suitably engage control fingers 52 that are connected to various points of the resistor 9, the contact segments 50 successively engaging the control fingers 52 to gradually short-circuit the resistor 9 as the controller is actuated from its initial or off position *a'* to its intermediate position *j'*, corresponding to series operation of the main machines, while the contact segments 51 successively engage control fingers 52 to perform a similar function as the controller is moved from intermediate position *k'* to final position *t'*, corresponding to parallel connection of the main machines. A plurality of auxiliary-circuit contact segments and control fingers, a portion of which are illustrated in Fig. 1, are also provided for effecting certain control operations to be set forth in connection with Fig. 2.

The actuating mechanism 11 is an exact counterpart of the previously-described mechanism 5, but, to distinguish the actuating coils thereof from those of the mechanism 5, the designations On—2 and Off—2 have been adopted, signifying, as before, that the energization of the "on" coil produces forward movement of the controller in the direction of the arrow labeled "Acceleration," while energization of the "off" coil effects a return movement of the controller in the direction of the arrow marked "Regeneration."

The motor-generator set 15 is shown as comprising an auxiliary motor or driving armature 55 which is mechanically coupled by a shaft 56, for example, to an exciting or generator armature 57. The driving armature 55 is provided with a series-related field winding 58, while the exciting armature 57 has a plurality of field windings 59 and 60 which are respectively connected in series relation with the auxiliary driving armature 55 and with the main dynamo-electric machines. The two field windings 59 and 60 are adapted to act differentially or buck each other under accelerating conditions and to act cumulatively or boost each other during regeneration. The field winding 59 is shunted by the variable resistor 9, whereby the main-field winding excitation may be varied in accordance with the movements of the controller 10. The main current-excited field winding 60 is preferably shunted by a surge-absorbing resistor 8 and may be short-circuited by the closure of the switch F under predetermined abnormal conditions, as subsequently described.

The acceleration limit switch 16 may have its actuating coil connected in the customary series relation with the main armature A2, for example, and the movable core or plunger member is provided with bridging contact members 65 and 66 for governing certain auxiliary circuit connections to be set forth in the description of Fig. 2.

The regeneration limit switch 17 has its actuating coil connected in series relation with the stabilizing resistor 7 and is provided with a plurality of auxiliary-circuit bridging contact members 67 and 68.

The line-balancing relay 18 comprises a magnetizable core member 69 and a plurality of differentially-related actuating coils 70 and 71 that are respectively energized in accordance with the supply circuit or line voltage and with the voltage of the main armature A1. The motor-balancing relay 19 is similarly constructed, having a plurality of actuating coils 73 and 74 that are respectively connected in series-circuit relation with the actuating coils 71 and 70 of the other balancing relay 18. The relays

18 and 19 are respectively provided with auxiliary-circuit bridging contact members 72 and 75. The preferred structure of the balancing relays 18 and 19 is set forth and claimed in a copending application of C. C. Whittaker, Serial No. 175,595, filed June 19, 1917.

The object of the relays 18 and 19 is to automatically balance the line voltage and the motor voltage during coasting periods by suitably actuating the field-excitation controller 10, whereby the main-machine generated voltage may be of proper value to permit connection to the supply circuit. Under conditions of balanced voltage relation, the relays occupy their upper positions, while an excess of machine voltage causes the relay 18 to be actuated to its lower position, and an excess of supply-circuit voltage effects the actuation of the relay 19 to its lower position to produce the desired regulating operation, as set forth in detail in connection with Fig. 2.

The differential relay 20 comprises a movable core member 76, an actuating coil 77 that is connected in series relation with the main armature A1, a differentially-wound coil 78 that is connected across the main field winding F1, and an auxiliary-circuit bridging contact member 79. Under normal operating conditions, the differential relay 20 remains in its illustrated lower position, but whenever the armature ampere-turns exceed the field-winding ampere-turns by a predetermined amount slightly less than the critical value liable to produce "flash-over" conditions, the relay lifts to open certain auxiliary circuit connections and prevent such undesirable conditions.

The over-voltage relay 22 has its actuating coil connected across the main armature A2 to interrupt certain auxiliary circuits in the event of abnormal voltage conditions, such as may be caused, for example, by the sudden failure of supply-circuit voltage during the regenerative period.

The field relay 23 has an actuating coil 81 that is connected in series relation with the main-current-excited field winding 60 for the exciting armature 57, and is provided with a bridging contact member 82 for permitting the closure of the line switch LS only under substantially stable field-excitation conditions, as subsequently set forth in detail. A second bridging contact member 83 is also provided for the purpose of short-circuiting a portion of the regulating resistor 9 under unstable or fluctuating field-excitation conditions, when the relay occupies its upper position.

Reference may now be had to Fig. 2, wherein the auxiliary governing circuits shown comprise the supply-conductors Trolley and Ground; the various actuating coils and auxiliary contact members that are illustrated in Fig. 1, together with a plurality of electrical interlock members of the familiar type that is illustrated in detail in Fig. 3; a master controller MC having a plurality of operative positions "Lower", "Hold" and "Raise" for governing the accelerating operation of the main machines, and "Balance", "Hold" and "Brake", corresponding to regeneration; a master reverser MR of the customary type; an auxiliary source of energy, such as a battery B; an axle-driven generator 85 having a regulating controller 86 for governing the operation of a speed relay 21 to control certain auxiliary circuits; a line-switch relay 24 for controlling the closure of the line switch LS; and a plurality of train-line conductors TL for permitting the familiar multiple-unit operation of the system.

The axle-driven generator 85 comprises a commutator-type armature 87 that may be mounted upon an idle truck-axle 88 or that may be mechanically driven from the wheel axles or armature shafts in any other convenient manner; and a suitable exciting field winding 89, which is here shown as being of the shunt type. A resistor 90 is adapted to be varied in active circuit value by a suitable contact segment 91 of the controller 86, thus adjusting the setting of the speed relay 21, which has its actuating coil 92 in series relation with the axle-driven armature 87 and the variable resistor 90. Since the voltage of the axle-driven machine is a measure of the vehicle speed, it follows that, by adjusting the controller 86, the speed relay 21 may be so energized that it will lift to interrupt any desired circuits whenever the vehicle speed exceeds a predetermined value. In this way, the speed relay 21 prevents the vehicle from exceeding a given speed value without, however, opening the machine circuits. If desired, more than one speed relay may be utilized to maintain the vehicle speed within two predetermined limits, as set forth, for example, in a copending application of Rudolf E. Hellmund, Serial No. 171,166, filed May 26, 1917, and assigned to the Westinghouse Electric & Manufacturing Company. This application has matured into Patent No. 1,328,514, granted Jan. 20, 1920.

The adjustment of the controller 86 may be manual, if desired, but, under certain operating conditions, such as when traveling in thickly populated districts or in a subway having a heavy volume of traffic, it may be desired to automatically limit the vehicle speed, which may be accomplished through the agency of track ramps that may or may not be controlled from the customary signal towers. Such operation of the controller 86 will be subsequently described in connection with Fig. 5 and Fig. 6.

The line-switch relay 24 is provided with

an actuating coil that is connected in a preliminary auxiliary circuit, as about to be traced, and is also provided with a plurality of bridging contact members 94 and 95. The purpose of the relay is to permit the use of a quick-opening line switch that is energized from the supply circuit and that may be caused to drop out upon sudden low-voltage surges, such as occur in the event of a short-circuit upon the trolley system, so that the main machines will be disconnected from the supply circuit before the occurrence of the high-voltage surge which immediately follows the instantaneous low-voltage conditions just recited, as is well known.

Assuming that it is desired to effect acceleration of the main machines from rest, the master reverser MR may be actuated to its "forward" position and the master controller MC to its "raise" position.

A circuit is thereupon established from the positive terminal of the battery B, through conductor 100, train-line conductor 101, conductor 102, control fingers 103 and 120, which are bridged by contact segment 105 of the master controller, conductor 121, train-line conductor 122, conductors 123 and 124, the parallel-related actuating coils of the switches J and SB, interlock 4—*a* of the controller 4 in its initial position *a*, conductor 125, auxiliary contact segment 126 of the field-excitation controller 10 in its position *a'*, conductors 127, 128 and 129, train-line conductor 130 and conductor 131 to the negative terminal of the battery B. A holding circuit for the actuating coils of the switches J and SB is formed, upon the closure of the switch J, from the lower terminals of the actuating coils through interlock J—in to conductor 125, whence a circuit is completed as just traced. A further holding circuit, for preventing the opening of the switch J during the transition of the machines from series to parallel relation, is provided by connecting the interlock J—in, just mentioned, through interlock G—out to the negative battery conductor 129.

Another circuit is simultaneously completed from the conductor 124, through the actuating coil of the switch M1, to the negative conductor 129.

A further auxiliary circuit is then established from the master controller contact segment 105 through control finger 104, conductor 106, contact segment 107 of the master reverser MR in its forward position, conductor 108, train-line conductor 108*a*, conductor 109, contact segment 110 of the main-reversing switch RS in its forward position, conductor 111, bridging contact member 72 of the line-balancing relay 18, which is initially held in its upper position by reason of the substantially zero voltage that is impressed upon the lower coil thereof from the main machines and is subsequently held in that position under normal operating conditions, conductor 112, contact segment 10—*a'* of the field-excitation controller 10, which interlock is necessary since the motor-balancing relay 19 occupies its lower position, conductors 113 and 114, bridging contact member 80 of the over-voltage relay 22 in its normal or lower position, actuating coil of the line-switch relay 24, bridging contact member 82 of the field relay 23 in its normal or lower position, contact segment 4—*a*, conductor 115, and interlock J—in, to the negative conductor 129.

Upon the energization of the circuit just traced, the line-switch relay 24 is closed to complete a holding-circuit for itself from its actuating coil through its contact member 94 to the negative conductor 129, whereby the closure of the line switch is subsequently independent of the position of the accelerating controller 4.

Another circuit is then completed from the trolley through conductor 140, voltage-reducing resistor 141, bridging contact member 95 of the line-switch relay 24 in its upper position, the actuating coil of the line switch LS, interlock LS—out and conductor 142 to ground, thus effecting the closure of the line switch after the relays 18, 22, 23 and 24 occupy the proper positions. Since the energy required to maintain the line switch closed is materially less than that required to effect the closure, a resistor 143 may be connected in series relation with the actuating coil of the line-switch after its closure by reason of the interruption of a shunt circuit around the resistor 143 by the interlock LS—out.

A further circuit is established from the master-controller contact segment 105 through control finger 132, conductor 133, train-line conductor 134, conductor 135, interlock LS—in, bridging contact members 68 and 66 of the regeneration limit switch 17 and acceleration limit switch 16 in their lower positions, interlocks J—in and G—out, conductor 136, actuating coil On—1, and conductors 137 and 138 to the negative conductor 129. The accelerating controller 4 is thus actuated through its successive positions *a* to *f*, inclusive, in accordance with the movements of the acceleration limit switch 16, as is familiar practice.

Under the above-described conditions, therefore, the main circuit, indicated by the solid arrows, (Fig. 1), is established from the trolley through conductors 150 and 151, line switch LS, conductor 152, switch M1, actuating coil 77 of the differential relay 20, reversing switch RS and main armature A1, conductor 153, control finger 154, contact segment 30 and control finger 155 of the controller 4, the entire resistor 1, conductor 156, resistor 3, switch J, the entire resistor 2, control finger 157, contact segment 31,

control finger 158, conductor 159, actuating coil of the acceleration limit switch 16, reversing switch RS and main armature A2, junction-point 160, conductor 161, the actuating coil of the regeneration limit switch 17, stabilizing resistors 6 and 7, which are connected in parallel relation by the switch SB during series operation of the main machines, to equalize the excitation of the main field windings, junction-point 163, conductors 164 and 165, where the circuit divides, one branch including field winding 60 for the auxiliary generator armature 57 and the actuating coil of the field relay 23, and the other branch including shunting resistor 8, circuit being completed through conductor 166 to ground.

The exciting or main-field-winding circuit, indicated by the dotted arrows, is established from the positive terminal of the auxiliary generator armature 57 through conductor 164 to junction-point 163, where the circuit divides, one branch including stabilizing resistor 7, conductors 161 and 167; main field winding F2 and conductor 168 to another junction-point 169, and the other branch traversing stabilizing resistor 6, conductors 170 and 171, main field winding F1 and conductor 172, to the junction-point 169, whence a common circuit is completed through conductor 173 to the negative terminal of the generator armature.

The main armatures A1 and A2 are thus connected in series relation with the accelerating resistors 1, 2 and 3 and the stabilizing resistors 6 and 7 across the supply circuit, while the main field windings F1 and F2 are connected through the common exciting armature 57 across the stabilizing resistors 6 and 7, respectively.

An auxiliary circuit is established from the trolley through conductor 144, switch 145, conductor 146, auxiliary driving armature 55, series-related field winding 58 therefor and field winding 59 for the auxiliary generator armature 57 to the negative supply-circuit conductor Ground.

As the acceleration controller 4 is gradually moved toward its final position *f*, the resistors 1, 2 and 3 are excluded from circuit in the following sequence. In position *b*, contact segment 32 bridges resistor 3, which remains short-circuited in positions *b* to *f*, inclusive, of the controller. In position *c* and position *e*, certain sections of the resistor 1 are first short-circuited and then open-circuited by reason of the peculiar arrangement of circuit elements, while, in the alternate positions *d* and *f*, similar manipulation of the resistor 2 is effected. The main machines are thus accelerated in a step-by-step manner to full series relation as soon as the accelerating controller occupies its position *f*.

A further auxiliary circuit is thereupon established from the master controller contact segment 105 through control finger 175, conductor 176, train-line conductor 177, conductor 178, bridging contact member 93 of the speed relay 21 in its lower position, bridging contact member 79 of the differential relay 20 in its lower position, interlock LS—in, conductor 179, bridging contact member 65 of the acceleration limit switch 16, when occupying its lower position, actuating coil On—2 of the operating mechanism 11, conductor 180, contact segment 4—*f*, conductor 115 and interlock J—in, to the negative conductor 129.

The field-excitation controller 10 is thus actuated through its operative position *a'* to *j'*, inclusive, corresponding to series operation of the main machines, in accordance with the movements of the limit switch 16, the resistor 9 being thus gradually short-circuited to decrease the delivered voltage of the auxiliary generator armature 57 and thereby weaken the main-field-winding excitation to produce higher operating speeds, in accordance with familiar principles.

When the field-excitation controller 10 passes beyond position *j'*, to the transition position, the entire resistor 9 is reconnected in circuit in readiness for operation during the parallel connection of the main machines. As soon as the controller 10 has reached its position *k'*, a circuit is established from the positively-energized conductor 124 through the parallel-related actuating coils of the switches M2 and G, contact segment 4—*f*, conductor 181, control finger 182, which engages contact segment 126 of the controller 10 in its position *k'*, and thence through conductors 127 and 128, to the negative conductor 129. A holding circuit for the actuating coils of the switches M2 and G is formed, upon the closure of the switch G, from the lower terminals of the actuating coils through interlock G—in to the control finger 182, whence circuit is completed as just traced.

During the movement of the controller 10 from its final series position *j'* to its initial parallel position *k'*, the previously-traced circuit for the actuating coil of the switch J, including conductors 125 and 127, is interrupted at the contact segment 126 before the circuit of the actuating coils for the switches M2 and G is completed. However, an open-circuit transition is effectively avoided by the provision of the interlock G—out in series relation with interlock J—in and the actuating coil of the switch J, whereby the switch J is opened only after the switch G has closed to complete the desired transition of the main machines. To avoid the possibility of the field-excitation controller 10 halting in a transition position at any time, a contact segment 10—*j'* to *k'* directly connects conductors 123 and 135, to

insure the energization of the coil On—1 or the coil Off—1 during the transitional operation of the controller.

The switch SB is opened at the same time as the switch J to connect the stabilizing resistors 6 and 7 in series circuit relation with the respective main armatures, which affords better operating conditions during the parallel-connected period of the armatures.

An auxiliary circuit is next completed from the positively-energized conductor 135 through interlock LS—in, bridging contact members 68 and 66 of the regeneration limit switch 17 and the acceleration limit switch 16, respectively, interlocks J—out and G—in, actuating coil Off—1 and conductors 183 and 138 to the negative conductor 129, to effect a backward step-by-step movement of the acceleration controller 4 in accordance with the movements of the acceleration limit switch 16.

Referring temporarily to Fig. 1, the main circuits completed by the series-parallel "bridging" transition just described may be traced as follows: from the line switch LS, one circuit is continued through conductor 190, switch M2, conductor 191, the entire resistor 2 in the opposite direction from that taken during series acceleration of the machines, control finger 191*a*, contact segment 31 and control finger 158 of the controller 4, conductor 159, actuating coil of the acceleration limit switch 16, reversing switch RS and main armature A2, and thence to ground, as previously traced. A similar parallel-related circuit is continued from the line switch LS through conductor 152, switch M1, main armature A1 and conductor 153, to the control finger 154 of the acceleration controller 4, as hereinbefore set forth, from which point circuit is now completed through contact segment 30, control finger 192, entire resistor 1, in the opposite direction from that taken during series acceleration, conductor 192*a*, switch G, conductors 193 and 170, and thence through the stabilizing resistor 6 to ground.

By actuating the controller 4 backwardly in a step-by-step manner, it will be observed that the resistors 1 and 2 are gradually excluded from circuit by reason of the peculiar interrelation of contact segments and control fingers that are associated with the resistors and the previously-mentioned reversal of current through the accelerating resistors. The removal of the short-circuit from the resistor 3 when the controller has returned to its position *a*, is of no consequence, since the switch J is opened and the resistor 3 is not included in any active circuit.

As soon as the acceleration controller 4 has reached its position *a*, the movement of the field-excitation controller 10 from position *k'* to the final position *t'* is permitted. The controller 10 is held in its position *k'* during the backward movement of the controller 4 by reason of the interruption of the previously-traced energizing circuit for the actuating coil On—2 at the interlock J—in. However, after the controller 4 has returned to its position *a*, a new energizing circuit is established from the lower terminal of the actuating coil On—2 through conductor 180, contact segment 4—*a* and interlock G—in, to the negative conductor 129. The resistor 9 is thus again gradually short-circuited, in accordance with the movements of the acceleration limit switch 16, as the controller 10 is actuated toward its final position *t'* after the main machines have been connected in full parallel relation by the exclusion of the accelerating resistors 1 and 2 from their circuits.

To summarize, therefore, the main armatures A1 and A2 are initially connected in series-circuit relation with the accelerating resistors 1, 2 and 3, the main field windings F1 and F2 being energized from the auxiliary generator armature 57. The accelerating resistors are then gradually excluded from circuit by forward movement of the controller 4, whereupon the field excitation controller 10 is manipulated to further weaken the main field-excitation. "Bridging" transition of the main armatures to parallel relation is then effected, after which reverse movement of the acceleration controller 4 is utilized to exclude the resistors 1 and 2 from circuit, and the field-excitation controller 10 is then again moved in a forward direction to further weaken the main field-excitation.

If the master controller is returned to its position "hold" the contact segment 105 becomes disengaged from the control fingers 175 and 132, whereby the previously-traced circuits for the actuating coils On—2 and On—1 or Off—1 are deënergized to permit the reëstablishment of balanced fluid-pressure conditions in the operating mechanisms 5 and 11 and thus hold the corresponding controllers in whatever position they happen to occupy.

In the "lower" position of the master controller, control finger 132 is again engaged to permit energization of either the On—1 or the Off—1 coil to gradually exclude the accelerating resistors from circuit, while a new auxiliary circuit is established from the contact segment 105 through control finger 200, conductor 201, train-line conductor 202, conductor 203, interlock LS—in, conductor 204, bridging contact member 67 of the regeneration limit switch 17 in its lower position, the actuating coil Off—2, and thence through either contact members 4—*f* and J—in or 4—*a* and G—in, dependent upon concurrent main-circuit conditions, to the negative conductor 129. The field-excitation controller

10 is thus moved backwardly to gradually increase the main field-excitation and thus reduce or lower the main-machine speed.

In case the vehicle speed exceeds the predetermined limit that corresponds to the adjustment of the controller 86 for the axle-driven generator 85, the speed relay 21 is raised to its upper position to interrupt the circuit of the actuating coil On—2, thus preventing further forward movement of the field-excitation controller 10, and then completing a new circuit from the positively-energized conductor 123 through conductors 205 and 206, bridging contact member 93 of the speed relay, in its upper position, and conductor 207 to interlock LS—in, and thence to the actuating coil Off—2, whereby the field-excitation controller 10 is reversed in direction to accomplish a similar result to the manipulation of the master controller to its "lower" position.

Assuming that the master controller has been moved to its "off" position to deënergize the governed circuits and allow coasting of the main machines, and that it is desired to effect regenerative braking, the master controller may be moved to its initial regenerative position marked "Balance," whereby the control fingers 103 and 120 are bridged by contact segment 105*r* of the master controller. The switch M1 is thereupon closed in accordance with previously-traced circuits, but the parallel-connecting switches M2 and G and the series-connecting switches J and SB are not initially closed by reason of the interruption of the energizing circuits for their actuating coils in either the accelerating controller 4 or the field-excitation controller 10.

However, another circuit is continued from the positively-energized conductor 123 through conductor 205 to conductor 205*a*. Consequently, in the event that the line or supply-circuit voltage temporarily exceeds the momentum-driven machine voltage, the motor-balancing relay 19 is moved to its lower position by reason of the predominance of its lower coil 74, and a circuit is thus completed from the conductor 205*a* through bridging contact member 75 of the relay 19, conductor 204, bridging contact member 67 of the regeneration limit switch 17 in its lower position, actuating coil Off—2, conductor 180 and interlock LS—out to the negative conductor 129. The field-excitation controller 10 is thus moved backwardly to gradually strengthen the excitation of the main field windings and thus increase the main-armature voltage to the desired substantially equal value with the supply-circuit voltage.

On the other hand, if, by reason of a relatively high rate of coasting speed, the momentum-driven armature voltage is temporarily higher than the supply-circuit voltage, the line-balancing relay 18 is actuated to its lower position by reason of the predominance of its lower actuating coil 71, whereby a circuit is completed from the conductor 205*a* through bridging contact member 72 of the relay 18, bridging contact member 65 of the acceleration limit switch 16, actuating coil On—2 and the previously-mentioned interlock LS—out to the negative conductor 129. In this way, the controller 10 is moved forwardly to decrease the main field-excitation and thus reduce the voltage of the main armatures to the desired value.

During the coasting period, a further auxiliary circuit is established from the train-line conductor 101 through conductor 208, interlock LS—out, control fingers 209 and 210, which are bridged by contact segment 211 of the field-excitation controller 10 in any of its positions *t'* to *k'*, inclusive, and thence through the actuating coil On—1, or through control fingers 209 and 212 which are bridged by the contact segment 211 in positions *j'* to *a'*, inclusive, and through the actuating coil Off—1. Thus, if the controller 11 occupies its positions corresponding to parallel connection of the main armatures, the acceleration controller 4 is moved forwardly toward its position *f* to gradually insert the resistors 1 and 2 in circuit, while, if the controller 11 occupies any of its positions corresponding to series connection of the main machines, the acceleration controller 4 is moved backwardly toward its position *a* to again gradually insert the accelerating resistors in circuit. The position of the acceleration controller 4, therefore, that it finally assumes, is the one corresponding to active circuit inclusion of the accelerating resistors for the particular (parallel or series) connection that the main armatures take.

Consequently, as soon as the acceleration controller 4 has reached either of its extreme positions *a* or *f*, the corresponding sets of series-connecting or parallel-connecting switches J and SB, and M2 and G, respectively, are closed by reason of the energization of their actuating coils through the interlocks 4—*a* of 4—*f* and the remainder of the previously-traced circuits.

In this way, the field-excitation controller 10 is automatically manipulated in accordance with the relation of supply-circuit voltage to main-armature voltage and the proper sets of switches are closed, dependent upon the speed of the vehicle; that is, the parallel-connecting switches are closed under high-speed conditions and the series-connecting switches under low-speed conditions when parallel regeneration of the main armatures would not be feasible.

If the master controller has been actuated to its position "Brake" when the desired balance of supply-circuit voltage and mo-

mentum-driven armature voltage is attained, as evidenced by the location of both of the balancing relays 18 and 19 in their upper positions, the previously traced circuit through the line-switch relay 24 will be established, provided that the over-voltage relay 22 remains in its lower position and that the field-excitation conditions have become sufficiently stable to permit the field relay 23 also to occupy its lower position. In this case, however, the bridging contact member 75 of the motor-balancing relay 19 is substituted for the contact segment 10—*a'*.

The line switch LS is then closed through the line-switch relay 24, as previously set forth, and regenerative operation begins. The actuating coils Off—1 and On—1 of the acceleration controller 4 are then successively energized during parallel and series relation of the momentum-driven armatures, respectively, in accordance with the movements of the regeneration limit switch 17. The controlling circuits are the same as those previously traced in connection with acceleration.

The backward movement of the field-excitation controller 10 is controlled by the intermittent energization of the actuating coil Off—2 in accordance with the movements of the regeneration limit switch 17, the initial energization of the coil Off—2 being prevented, until the acceleration controller 4 has excluded the accelerating resistors 1 and 2 from circuit, by reason of the inclusion of the contact segments 4—*a* and 4—*f* and the interlocks G—in and J—in in the circuit of the coil Off—2.

Without further description, it will be understood that the transition of the regenerating machines from parallel to series relation is accomplished in a manner opposite to that set forth for series-parallel transition during acceleration, an open circuit being again prevented by reason of the illustrated interlocking of the switches J and G.

The field-excitation controller 10 is thus gradually moved backwardly to its initial operative position *a'* to increase the main field-excitation as the retardation speed of the main machines gradually decreases.

The functions of the several relay devices 16 to 24, inclusive, have, for the most part, been set forth in detail, and it is believed that no additional description further than brief mention of the differential relay 20 and the over-voltage relay 22 is necessary.

In the event of a predetermined undesirable increase of main-armature ampere-turns over main-field-winding ampere-turns, the differential relay 20 is raised to its circuit-opening position to interrupt the energization of the actuating coil On—2 and thus prevent further weakening of the main field-excitation until the normal ratio of ampere-turns again obtains.

Under conditions of an unduly high main-armature voltage, which may occur in the illustrated system in the event of a sudden interruption of supply-circuit voltage during the regenerative period, the over-voltage relay 22 is lifted to its circuit-opening position, whereby the circuit for the actuating coil of the line-switch relay 24 is interrupted to consequently open the line switch and disconnect the main machines from the supply circuit.

During periods of inactivity of the control system, that is, while the master controller occupies its "Off" position, it is desirable to reduce the current traversing the main field windings to correspondingly decrease the heat and magnetic losses. Such operation is automatically effected by the use of an interlock M1—out for short-circuiting the field winding 59 for the auxiliary generator armature 57, as illustrated in Fig. 1.

It will be observed that the actuating coil for the switch F is connected between the positive conductor 123 and the negative conductor 129 through either of the limit switches 16 and 17. Consequently, in the event of a relatively high accelerating or regenerative current, the corresponding limit switch is raised to the position that energizes the actuating coil for the switch F. In this way, the main-current-excited field winding 60 for the auxiliary exciter armature 57 is short-circuited to reduce the main field-excitation and, therefore, the main-armature current.

Reference may now be had to Fig. 5 and Fig. 6, wherein an apparatus that is associated with the track is shown for manipulating the controller 86 of Fig. 2 in accordance with predetermined speed requirements over a certain zone of travel.

The structure shown comprises a suitable car body 225 which is provided with a plurality of downwardly-extending journal boxes 226 for supporting a rotatable truck-axle 227, to the opposite ends of which wheels 228 are attached to run along the usual rails of the track.

The main journals 226, or any other convenient stationary portion of the vehicle underframing, may be employed for carrying a pair of small bearing members 230, within which is rotatably mounted the operating shaft for the controller 86. The controller is preferably of the familiar drum type, comprising a cylinder or body member 229, upon which the contact segment 91 is mounted in the customary manner, and which is provided with a plurality of longitudinally and circumferentially spaced pins or arms 231 to 236 inclusive, for the purpose of respectively engaging a plurality of track ramps or posts 237, which are laterally spaced in accordance with the longitudinal spacing of the drum arms and are located along the

track at predetermined intervals, being fixedly mounted upon the ties 238 or, if desired, being of a movable character and controlled from a signal tower in any suitable manner.

Assuming that the vehicle is traveling in the direction indicated by the arrows in Fig. 6, when the downwardly-extending pin or arm 231 strikes an alined post or ramp 237, the drum 229 will be rotated in a clockwise direction to a degree corresponding to one notch of the controller, the position of the succeeding arm 232 at this time being substantially perpendicular, in readiness for engagement with another track ramp 237, if such is provided.

In this way, the resistor 90 (Fig. 2) may be partially excluded from circuit to strengthen the energization of the actuating coil 92 for the speed relay 91 and thus cause the lifting of the relay at a lower speed than that corresponding to the utilization of the entire resistor 90. Any desired speed requirements throughout a given zone or stretch of track may thus be automatically imposed upon the traveling vehicle irrespective of the operation of the master controller, since the actuation of the speed relay to its upper position effects a backward movement of the field-excitation controller 10 and, therefore, a reduction of vehicle speed, as previously explained. It will be understood that the semi-diagrammatic views of Figs. 5 and 6 are presented for illustrative purposes only and that any other type of mechanism for performing similar functions, in accordance with the location along the track of the traveling vehicle, may be employed.

Referring to Fig. 4, the auxiliary governing system shown may be substituted for a portion of the previously-described auxiliary system of Fig. 2, if desired, for controlling the main circuits of Fig. 1. The modified system, in general, employs a plurality of speed relays that are controlled by the axle-driven generator 85 for automatically varying circuit connections in accordance with the vehicle speed under predetermined conditions, and a plurality of track-controlled switches, for performing a function similar to that set forth in connection with Fig. 5 and Fig. 6, are also provided.

For the sake of simplicity and clearness, certain desirable parts of the control system have been omitted in order to emphasize the differences between the two systems that are shown in Fig. 2 and Fig. 4. It will be understood, therefore, that certain of the automatic control features that are shown in Fig. 2, in practice are preferably incorporated in the modified system.

The system of Fig. 4 is shown as comprising the actuating coils of the various switching devices that are shown in Fig. 1, together with a plurality of corresponding electrical interlocks and relay contact members; a field-excitation controller 240; a plurality of sets of track-controlled switches 241 and 242; a plurality of speed relays for governing the vehicles speed in steps, as indicated by the legends "25% R. P. M.," "50% R. P. M.," "75% R. P. M.," and "100% R. P. M.," the relays being energized by the axle-driven generator 85; a master controller MC1 for primarily governing the operation of the system; a plurality of train-line conductors TL1; and a battery B or other suitable source of auxiliary energy.

The field excitation controller 240 is only partly shown, and it will be understood that a section corresponding to the drum 10 of Fig. 1, for governing the excitation of the main field windings, actually forms a part of the controller 240 in the complete system. The auxiliary circuit contact members shown are numbered as 245 to 249, inclusive, and have notches or positions corresponding to the several speed relays and denoted by similar characters. In the interests of clarity and simplicity, the contact segments 248 and 249 are shown separated from the remainder of the contact segments for the drum 240, and are respectively associated with the sets of track-controlled switches 241 and 242, as subsequently described in detail.

The master controller MC1 is adapted to occupy a plurality of positions designated as "Lower", "Hold" and "Raise" for governing acceleration and "Hold" and "Brake" for controlling regeneration.

Assuming that it is desired to effect accelerating operation of the main system that is shown in Fig. 1, the master controller MC1 may be actuated to its position "Raise", whereby an auxiliary circuit is established from the positive terminal of the battery B through conductor 260, train-line conductor 261, conductor 262, control fingers 263 and 264, which are bridged by contact segment 265 of the master controller, conductor 266, actuating coil of the line switch LS, conductor 267, train-line conductor 268 and conductor 269 to the negative terminal of the battery B.

A second circuit is continued from the contact segment 265 of the master controller through control finger 270, conductor 271, train-line conductor 272, conductors 273 and 274, control fingers 275 and 276, which are bridged by the contact segment 247 of the field-excitation controller 240, conductor 277, contact segment 4—*a* of the acceleration controller 4, and the parallel-related actuating coils of the switches J and SB to the negative conductor 267. Upon the closure of the switch J, a holding circuit comprising the interlock J—in is connected in parallel relation to the contact segment 4—*a*, thus rendering the energization of the actuating coils for the switches J and SB inde-

pendent of the subsequent operation of the acceleration controller.

Another circuit is simultaneously completed from the positively-energized conductor 273 through conductors 278 and 279 and the actuating coil of the switch M1 to the negative conductor 267.

The machines are thus connected in series-circuit relation with the acceleration resistors 1, 2 and 3, as previously traced in connection with Fig. 1.

The governing circuit for the acceleration controller 4 is completed from the conductor 278 through interlocks J—in, G—out, LS—in and the acceleration limit switch 16, when occupying its lower position, to the actuating coil On—1. The acceleration controller 4 is thus gradually moved to its final position *f* in accordance with the position of the limit switch 16.

When the field-excitation controller 240 reaches its position intermediate the notches designated at 50% and 75%, a new circuit is completed from the contact segment 247 through control finger 280, conductor 281, contact member 4—*f*, the acceleration controller by this time occupying its final position *f*, and the actuating coils of the switches M2 and G. The series-connecting switches J and SB are then opened by reason of the interruption of the auxiliary controlling circuits by the contact segment 247. In this way, series-parallel or the reverse transition of the main machines may be accomplished in a manner similar to that previously set forth, and no further exposition thereof is deemed necessary.

During the parallel operation of the main machines, the energization of the actuating coil On—1 is discontinued and a new circuit is completed from the conductor 278 through interlocks J—out, G—in and LS—in and the regeneration limit switch 17 to the actuating coil Off—1, whereby the acceleration controller 4 is rotated in the reverse direction in a manner similar to that set forth in connection with Fig. 2.

A further circuit is established in the "raise" position of the master controller from the contact segment 265 through control finger 290, conductor 291, train-line conductor 292, conductor 293, interlock LS—in, conductor 294, one of the track-controlled switches 247, contact segment 248 of the field-excitation controller 240, conductor 295, actuating coil On—2 for the controller and conductors 296 and 297, to the negative conductor 267.

The field-excitation controller 240 is thus forwardly actuated to a position corresponding to the particular track switch 241 that is closed. For example, if the upper switch 241 is alone closed, the circuit of the actuating coil On—2 is interrupted when the controller is moved to its position marked "75%," while the remaining track-controlled switches act in a similar capacity for other speed values.

The energization of the actuating coil On—2 is further controlled from the positively-energized conductor 278 through the acceleration limit switch 16 in its lower, or light-current, position so that, upon the occurrence of predetermined low-current conditions, the actuating coil On—2 is energized to move the field-excitation controller forwardly and decrease the main field strength to thereby reduce the main-armature current.

To manually arrest the movement of the field-excitation controller 240 at any time, it is merely necessary to return the master controller MC1 to its intermediate position "Hold" to deënergize the governing circuit for the actuating coil On—2 and thus produce a state of balanced high pressure in the actuating mechanism 11 for the controller.

If the master controller is returned to its position "Lower," the circuit of the actuating coil On—2 is interrupted and a new circuit is established from the contact segment 265 through control finger 300, conductor 301, train-line conductor 302, conductor 303, interlock LS—in, actuating coil Off—2, one of the track-controlled switches 242, contact segment 249 of the field-excitation controller, conductor 304 and the regeneration limit switch 17, when occupying its low-current position, to the negative conductor 297. Thus, the controller 240 is backwardly actuated to increase the main field-excitation whenever the main-armature current drops to a certain relatively low value, the final position of the controller being determined by the particular track switch 242 that is closed.

The operation of the speed relays, during the machine-coasting period, when the line switch LS is open, may be set forth as follows: if the main motors are coasting at a speed equaling, for example, 25% of the "balancing" or maximum operating speed. the actuating coil of the relay marked "25% R. P. M." is energized from the axle-driven armature 87 sufficiently to lift the relay to its upper position, whereby a circuit is established from the positively-energized train-line conductor 261 through conductor 310, bridging contact member 311 of the 25% speed relay, conductor 312, control finger 313, contact segment 245 and control finger 314, of the field-excitation controller, conductor 315, interlock LS—out, and thence through conductor 294 and the actuating coil On—2, as already traced.

The energization of the actuating coil On—2 is thus maintained until the notch marked "25%" of the field-excitation controller 240 is reached, whereupon the circuit just traced is interrupted by the contact segment 245. The controller, therefore, remains

in the 25% notch unless the speed of the vehicle, and, consequently, the voltage of the axle-driven armature 87, by reason of traveling along a down-grade, have increased to a value sufficient to lift the 50% relay, whereupon a new circuit is completed from the positively-energized conductor 310, through bridging contact member 316 of the 50% speed relay, conductor 317 and control finger 318, to the contact segment 245. The controller 240 is thereby actuated to its 50% notch, whereupon the energizing circuit for the controller is again interrupted. Similar actions occur when the vehicle speed increases to 75% and 100% of its full value, in which cases bridging contact members 319 and 320, respectively, of the 75% and 100% speed relays are utilized to energize a new circuit for effecting a further step forward of the controller 240.

If the initial coasting speed of the vehicle is substantially equal to the full-speed value of the motors, the controller 240 remains in its final position, marked "100%." Assuming that the speed then decreases a certain amount, the 100% speed relay will drop to its lower position by reason of insufficient energization from the axle-driven generator, whereupon a new circuit is established from the positively-energized conductor 310, through bridging contact member 320 of the 100% speed relay in its lower position, conductor 325, control finger 326, contact segment 246 and control finger 327 of the controller 240, conductor 328, interlock LS—out and thence through the actuating coil Off—2, as previously described. The controller 240 is thus moved backwardly one step to its position marked "75%," wherein the circuit just traced is interrupted.

However, when the vehicle speed decreases below such 75% value, the corresponding speed relay drops to its lower position to complete a new circuit from the conductor 310 through bridging contact member 319 of the relay, conductor 329 and control finger 230, which engages the contact segment 246, to effect a further backward step of the controller. Similar actions occur if the vehicle speed further decreases to permit the 50% and 25% speed relays to drop to their lower positions.

Thus, the field-excitation controller 240 is automatically maintained during the coasting period in a position suitable for energizing the main-field windings to such a degree that rapid connection of the machines to the supply circuit under proper voltage conditions may be effected.

For regenerative operation of the system, the master controller MC1 is moved to its "brake" position to effect the closure of the line switch LS under proper conditions, (the necessary relay devices being herein omitted for the sake of simplicity) after the parallel-connecting or series-connecting switches have been closed in accordance with the position of the field-excitation controller 240.

The actuating coil Off—2 for the controller 240 is energized in the "brake" position of the master controller, from contact segment 305, and thus a backward step-by-step movement of the controller is effected in accordance with the position of the regeneration limit switch 17 and also dependent upon the position of the track switches 242.

It is believed that no further exposition of the regenerative operation of the system is necessary in view of its similarity to the previously-described operation of Fig. 4 and also of Fig. 2.

In Fig. 7, an interlocking arrangement, that is preferably associated with both sets of track-controlled switches 241 and 242, is illustrated. In general, the illustrated fragmentary portion of the complete control system is adapted to maintain closed any track switch after it has once been operated to a closed position by a track ramp, such as that illustrated in Fig. 5 and Fig. 6, and to open the other corresponding track switches at the same time.

For example, numbering the complete track-controlled switches having the contact segments 241 that are illustrated in Fig. 4, as 335, 336 and 337, respectively, if switch 336 is assumed as previously closed, and switch 335 is then actuated to its closed position by one of the track ramps, the energizing coil for the switch 336 is immediately deënergized through an interlock 335—out, while a new circuit is established from the positive terminal of the battery B or other suitable source of energy through conductor 338, actuating coil of the switch 335, bridging contact member 339 of the switch in its upper position, conductor 340, interlock 336-out, conductor 341, interlock 337—out and conductors 342 and 343, to the negative terminal of the battery B. The switch 335 is thus held in its closed position until one of the other switches is actuated by the track ramps to its closed position, whereupon the energizing circuit for the switch 335 is interrupted and the other switch is then held closed by being interlocked through itself and through the other switches in their "out" or open position.

I desire it to be understood that although, in the interests of clarity and simplicity, I have shown "limit switches" of the familiar solenoid type, in actual operation, I prefer motor-type or torque-operated devices, such as those set forth in the above-identified co-pending application of Rudolf E. Hellmund, wherein the armature and field winding of the relay device are preferably energized in accordance with the main-armature current and main-field-winding voltage respectively.

In this way, a more smoothly-operating and more commercial system obtains.

I do not wish to be restricted to the specific circuit connections, structural details or arrangement of parts herein set forth, as various further modifications thereof may be effected without departing from the spirit and scope of my invention. I desire, therefore, that only such limitations shall be imposed as are indicated in the appended claims.

I claim as my invention:

1. In a system of control, the combination with a plurality of dynamo-electric machines, of means for connecting said machines for series and for parallel operation, a plurality of variable resistors and a controller having one segment operable in opposite directions during series and parallel connections of the machines to gradually exclude each resistor from circuit in either case.

2. In a system of control, the combination with a circuit to be governed, of a plurality of switches, a plurality of multi-section resistors each having one terminal connected to the same switch and having their other terminals connected to different switches, a plurality of control fingers located near the joined terminals of the respective resistors, and a plurality of reversible-controller contact segments, each in one extreme position engaging one of said terminals and the adjacent control finger and in the other extreme position engaging the other corresponding terminal and said adjacent control finger.

3. In a system of control, the combination with a supply-circuit and a plurality of dynamo-electric machines severally having armatures and field windings, of means for connecting said machines for series and for parallel operation, a controller for varying the voltage relations of the armatures and the supply circuit, a second controller for varying the excitation of said field windings, and means for successively operating said controllers in similar directions during series machine operation and in opposite directions during parallel machine operation.

4. In a system of control, the combination with a supply-circuit and a plurality of dynamo-electric machines severally having armatures and field windings, of means for connecting said machines for series and for parallel operation, a controller for gradually eliminating the voltage difference between the armatures and the supply circuit irrespective of the direction of controller movement, a second controller having two sets of positions for similarly varying the excitation of the main field windings, and means for successively operating the first controller in one direction through all its positions and the second controller through one set of positions in the same direction during series machine operation and for successively operating the first controller in the opposite direction through all its positions and the second controller through the second set of its positions during parallel machine operation in the same direction as before.

5. In a system of control, the combination with a dynamo-electric machine, and a controller for regulating the operation thereof, of an actuating mechanism for said controller having a plurality of coils for effecting movement thereof in the one or the other direction, and means dependent upon predetermined operating conditions of said machine for governing the controller movement in either direction.

6. In a system of control, the combination with a dynamo-electric machine, and a controller for regulating the operation thereof, of a fluid-pressure-operated mechanism for said controller having a plurality of normally open valves, a plurality of valve-actuating coils for effecting controller movement in the one or the other direction, and a plurality of relays energized in accordance with certain machine currents for intermittently energizing the respective valves during the corresponding controller operation.

7. In a system of control, the combination with a supply-circuit and a dynamo-electric machine having an armature and a field winding, of means for connecting said machines for a plurality of speed ranges, movable means for varying the voltage relations of the armature and the supply circuit, movable means for varying the excitation of said field winding, and means operative during the machine coasting period and dependent upon one of said movable means for insuring a movement of the other to produce certain circuit conditions before the connection of the machine to the supply-circuit for either of said speed ranges.

8. In a system of control, the combination with a supply-circuit and a plurality of dynamo-electric machines severally having armatures and field windings, of means for connecting said machines for series and for parallel operation, a controller for varying the voltage relations of the armatures and the supply circuit, a second controller for varying the excitation of said field windings, and means operative during the machine coasting period and dependent upon the position of the second controller for insuring a movement of the first controller to produce the maximum available voltage difference between the armatures and the supply-circuit before the connection of the machines to the supply-circuit for either series or parallel operation.

9. In a system of control, the combination with a supply-circuit and a plurality of

dynamo-electric machines severally having armatures and field windings, of means for connecting said machines for series and for parallel operation, a plurality of resistors in circuit with the respective armatures, a controller for gradually excluding said resistors from circuit irrespective of the direction of controller movement, a second controller having two sets of positions respectively corresponding to series and to parallel machine operation for varying the excitation of the main field windings, a switch for connecting the machines to the supply-circuit, means dependent upon the open condition of said switch during the machine coasting period and also dependent upon the occupied position of the second controller for electrically effecting a movement of the first controller to the corresponding extreme position for inserting the entire resistors in circuit, and means for thereupon effecting the proper mutual relation of the machines and closing said switch to collectively connect the machines to the supply-circuit.

10. In a system of control, the combination with a supply-circuit and a plurality of dynamo-electric machines severally having armatures and field windings, of means for connecting said machines for series and for parallel operation, a plurality of resistors in circuit with the respective armatures, a controller for gradually excluding said resistors from circuit irrespective of the direction of controller movement, a second controller having two sets of positions respectively corresponding to series and to parallel machine operation for varying the excitation of the main field windings, a switch for connecting the machines to the supply-circuit, means dependent upon the relation of supply-circuit and armature voltages during the machine coasting period for automatically maintaining the second controller in a position to produce a substantial equality of such voltages, means dependent upon the open condition of said switch during the machine coasting period and also dependent upon the occupied position of the second controller for electrically effecting a movement of the first controller to the corresponding extreme position for inserting the entire resistors in circuit, and means for thereupon effecting the proper mutual relation of the machines and closing said switch to collectively connect the machines to the supply circuit.

11. In a system of control, the combination with a plurality of dynamo-electric machines, of a plurality of switches for connecting the machines for series and for parallel operation, a plurality of variable resistors, a controller operable in opposite directions during series and parallel connections of the machines to gradually exclude the resistors from circuit in either case, and means dependent upon the positions of said switches for reversing the direction of movement of said controller.

12. In a system of control, the combination with a plurality of dynamo-electric machines, of a plurality of switches for connecting the machines for series and for parallel operation, a plurality of variable resistors, a controller operable in opposite directions during series and parallel connections of the machines to gradually exclude the resistors from circuit in either case, a plurality of actuating coils for said controller to effect movement thereof in the one or the other direction, and interlocking means governed by said switches for energizing the proper coil to reverse the direction of movement of said controller upon the transition of machine relations from series to parallel or vice versa.

13. In a system of control, the combination with a dynamo-electric machine, of multi-position means for regulating the operation thereof, and a plurality of means each dependent upon the machine speed for independently effecting step-by-step actuation of said multi-position means in either direction.

14. In a system of control, the combination with a dynamo-electric machine, of a controller for regulating the operation thereof, a plurality of actuating coils for said controller to effect movement thereof in the one or the other direction, and a plurality of relay devices actuated in accordance with different vehicle speeds, the energization of said actuating coils during the machine coasting period being dependent upon said relay devices and the controller positions to produce a step-by-step controller movement in either direction.

15. In a system of control, the combination with a dynamo-electric machine, of multi-position means for regulating the operation thereof, and a plurality of means dependent upon different machine speeds and upon the controller position for effecting step-by-step actuation of said multi-position means.

16. In a system of control, the combination with a dynamo-electric machine, of a controller for regulating the operation thereof, and a plurality of relay devices dependent upon the machine speed for effecting step-by-step actuation of said controller in either direction during the machine coasting period.

17. In a system of control, the combination with a dynamo-electric machine, of a controller for varying the field excitation of said machine, a plurality of actuating coils for said controller to effect movement thereof in the one or the other direction, an auxiliary generator rotatable with said

machine, and a plurality of two-position relay devices energized by said generator, the energization of one of said actuating coils during the machine coasting period being dependent upon the upward movement of said relay devices and the controller positions to produce a step-by-step controller movement in the one direction and the energization of the other actuating coil being dependent upon the downward movement of said relay devices and the controller positions to produce a step-by-step movement in the other direction.

18. In a system of control, the combination with a plurality of dynamo-electric machines, of means for connecting said machines for a plurality of different operating relations, a plurality of variable resistors and a single contact member operable in different directions during such operating relations to gradually exclude each resistor from circuit in either case.

19. In a system of control, the combination with a supply circuit and a plurality of dynamo-electric machines severally having armatures and field windings, of means for connecting said machines for a plurality of different operating relations, a controller for varying the voltage relations of the armatures and the supply circuit, a second controller for varying the excitation of said field windings, and means for successively operating said controllers in similar directions during one of said operating relations and in different directions during the other operating relation.

20. In a system of control, the combination with a dynamo-electric machine, of multi-position means for regulating the operation thereof, a plurality of independent means electrically controlled in accordance with different machine speeds for each effecting step-by-step movement of said multi-position means in either direction.

In testimony whereof, I have hereunto subscribed my name this 14th day of Sept., 1917.

ARTHUR J. HALL.

Corrections in Letters Patent No 1,365,316.

It is hereby certified that in Letters Patent No. 1,365,316, granted January 11, 1921, upon the application of Arthur J. Hall, of Wilkinsburg, Pennsylvania, for an improvement in "Systems of Control," errors appear in the printed specification requiring correction as follows: Page 1, line 104, for the word "is" read *are;* page 7, line 115, for the word "of" read *or;* page 12, lines 97–98, claim 7, for the word "machines" read *machine;* and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 22d day of February, A. D., 1921.

[SEAL.]

L. B. MANN,
Acting Commissioner of Patents.

Cl. 172—179.

Corrections in Letters Patent No 1,365,316.

It is hereby certified that in Letters Patent No. 1,365,316, granted January 11, 1921, upon the application of Arthur J. Hall, of Wilkinsburg, Pennsylvania, for an improvement in "Systems of Control," errors appear in the printed specification requiring correction as follows: Page 1, line 104, for the word "is" read *are;* page 7, line 115, for the word "of" read *or;* page 12, lines 97–98, claim 7, for the word "machines" read *machine;* and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 22d day of February, A. D., 1921.

[SEAL.]

L. B. MANN,
Acting Commissioner of Patents.

Cl. 172—179.