No. 777,778. PATENTED DEC. 20, 1904.

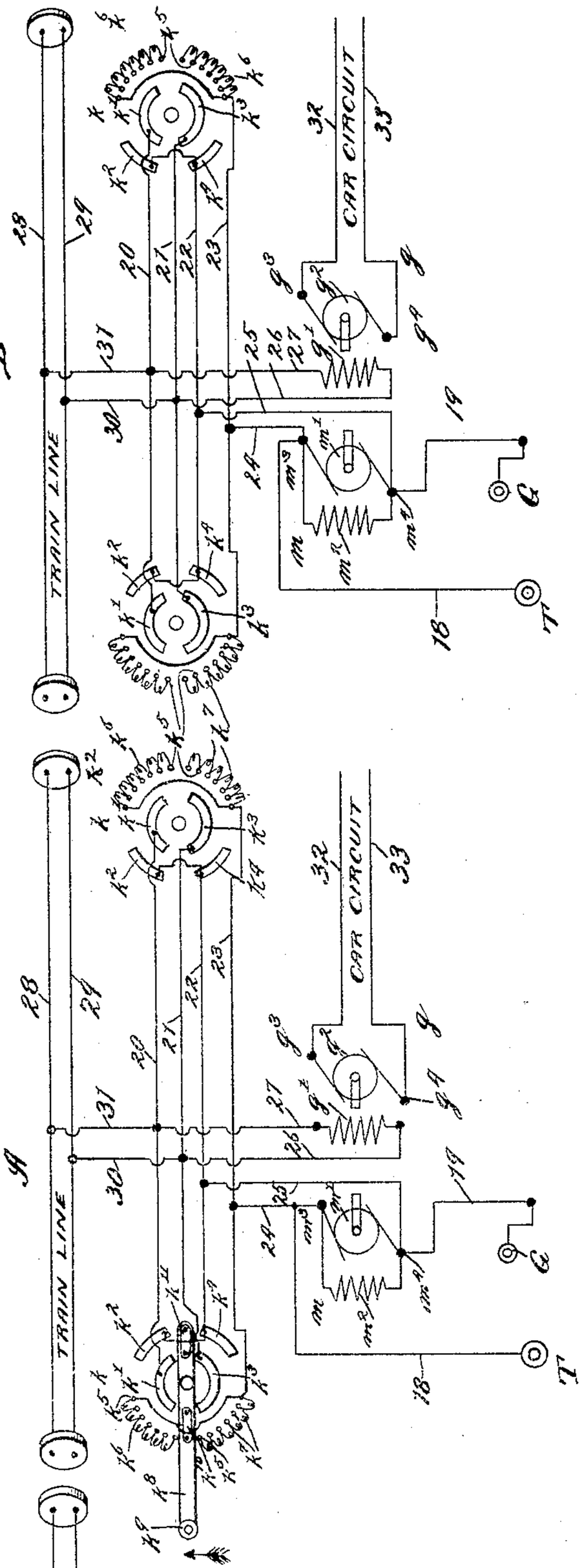
H. H. CUTLER.

SYSTEM FOR CONTROLLING ELECTRIC MOTORS.

APPLICATION FILED JULY 6, 1903.

NO MODEL. 2 SHEETS—SHEET 1.

Fig. 1.



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NO MODEL. 2 SHEETS—SHEET 2.

Fig. 3.

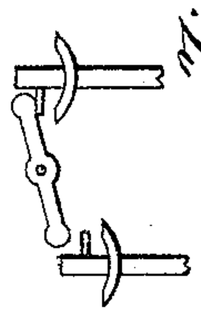
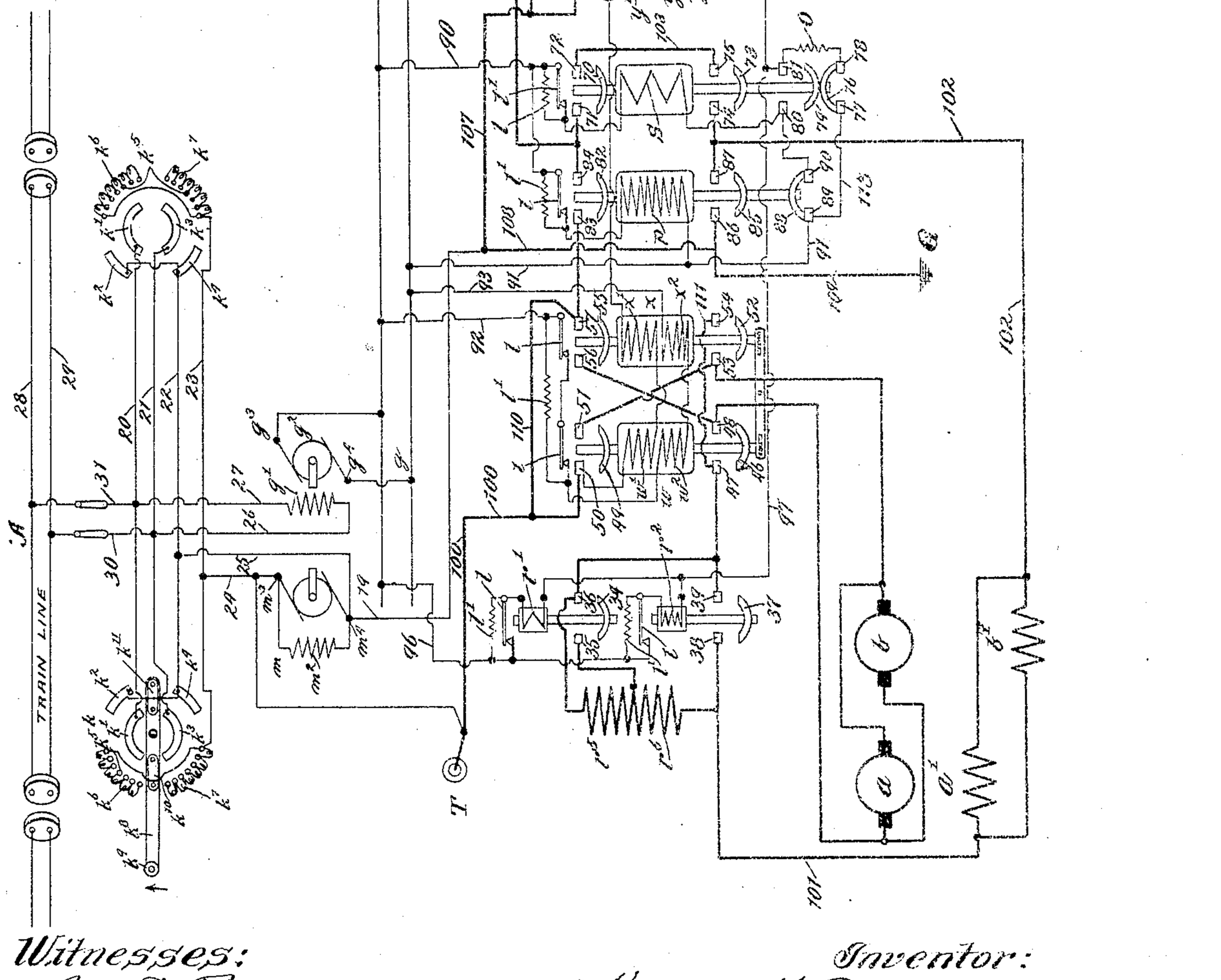


Fig. 2.



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No. 777,778. Patented December 20, 1904.

UNITED STATES PATENT OFFICE.

HENRY H. CUTLER, OF MILWAUKEE, WISCONSIN, ASSIGNOR TO THE CUTLER-HAMMER MANUFACTURING COMPANY, OF MILWAUKEE, WISCONSIN, A CORPORATION OF WISCONSIN.

SYSTEM FOR CONTROLLING ELECTRIC MOTORS.

SPECIFICATION forming part of Letters Patent No. 777,778, dated December 20, 1904.

Application filed July 6, 1903. Serial No. 164,377.

To all whom it may concern:

Be it known that I, HENRY H. CUTLER, a citizen of the United States, residing at Milwaukee, in the county of Milwaukee and State of Wisconsin, have invented a certain new and useful Improvement in Systems for Controlling Electric Motors, of which the following is a full, clear, concise, and exact description, reference being had to the accompanying drawings, forming a part of this specification.

My invention relates particularly to a system for controlling electric motors, and although it has been especially designed to operate a train of cars or other vehicles on the multiple-unit plan it may be applied in different relations, and certain of its features may be utilized with other instrumentalities than those which I will particularly describe for the purpose of disclosing my invention.

The system which I have worked out for operating a train of cars on the multiple-unit plan I have illustrated in the accompanying drawings, in which—

Figure 1 is a diagrammatic view of a part of the circuit and apparatus in each car. Fig. 2 is a diagrammatic view of the complete circuit arrangement and apparatus for controlling a single car, and Fig. 3 is a detail view of the interlocking lever for the series-parallel switch.

In the embodiment of my invention shown in the drawings a plurality of circuits is provided, one of said circuits being located upon each car in the train. For convenience I will designate these circuits the "controlling-circuits." With each of the controlling-circuits a plurality of electromagnetic windings is connected. These windings are adapted to respond selectively by a variation in the voltage or other electrical conditions upon the controlling-circuits. The controlling-circuits each have a separate source of current-supply, and in a suitable way the voltage of other electrical conditions upon all of the controlling-circuits may be simultaneously varied.

In Fig. 1 of the drawings are indicated portions of the controlling-circuits in cars A and B. In each car is installed a motor-generator, the motor m and the generator g of which are each preferably of the shunt-wound type. The motor-armature m' and the field m^2 thereof are arranged in parallel paths between the motor-terminals m^3 and m^4, the former being connected with the trolley T by wire or conductor 18 and the latter with the ground G by wire 19. At each end of each car is situated a controller k, which has segments k', k^2, k^3, and k^4 and two sets of contacts k^5. The resistance k^6 has its sections connected between the contacts of one set and the other resistance, k^7, is similarly connected with the other set of contacts. The two resistances are here shown for the purpose of making it possible to readily follow the circuits for the current; but in practice only a single resistance would be employed.

A centrally-pivoted arm k^8, having a handle k^9, is arranged in its initial position between the contacts of resistance k^6 and segments k' and k^2 on the one side and resistance k^7 and segments k^3 and k^4 on the other side and carries brushes k^{10} and k^{11}, which are disposed to engage the contacts and segments. When the arm or brush carrier is in its initial or off position, the brushes make no connection between the segments and the contacts of the resistance. When, however, the arm is moved in one direction—say by moving the handle upwardly in the direction of the arrow—the brush k^{10} would bridge the contacts of resistance k^6 and segment k' and the brush k^{11} would bridge the segments k^3 and k^4. The movement of the arm in the opposite direction or downwardly would connect the segments and contacts in a different relation, the brush k^{10} in this direction of movement bridging the contacts of resistance k^7 and the segment k^3 and the brush k^{11} bridging the segments k' and k^2.

Between the two controllers of each car extend four wires 20, 21, 22, and 23, which in practice would be formed into a single cable. The wire 20 connects the segments k' and the wire 21 connects the segments k^3. The segments k^2 and k^4 are connected by a wire 22, and a wire 23 connects the resistances, said

wire 23 being connected to the last contact of each resistance. The wire 23 is connected with the motor-terminal m^3 by wire 24, and a wire 25 connects the wire 22 with the motor-terminal m^4. The field g' of the generator has one side connected with the wire 21 by the wire 26 and the opposite side with the wire 20 by the wire 27.

For the purpose of tracing the circuits attention will now be directed particularly to Fig. 1 and the controller situated at the left-hand end thereof. The current flows from the trolley T by wires 18, 24, and 23 to the resistances of the controller. If the controller-arm be moved upward so that the brush k^{10} bridges the contacts of resistance k^6 and segment k' and the brush k^{11} bridges segments k^3 and k^4, the current will flow through the sections of resistance not cut out over the brush k^{10} to the segment k' and thence by wires 20 and 27 to the field of the generator g'. After traversing the generator-field it will pass by wires 26 and 21 to the segment k^3, and here it will cross the brush k^{11} to segment k^4 and flow over wires 22, 25, and 19 to the ground. The first contact of the resistance k^6 engaged by the brush k^{10} in its movement upwardly includes the greatest amount of resistance in circuit, and as the brush engages the successive contacts the resistance is cut out section by section until the brush rests upon the last contact, and then all resistance will be removed from the circuit. The reverse movement of the contact-arm connects the contacts of the resistance k^7 by brush k^{10} with the segment k^3 and bridges the segments k' and k^2 by brush k^{11}. With the segments and contacts thus connected the current will flow from the trolley by wires 18, 24, and 23 to the resistance k^7 and across the brush k^{10} to the segment k^3. It will then pass from the segment k^3 by the wires 21 and 26 to the field g' of the generator and traverse said field in the opposite direction from that which it did when the controller-arm was moved in the other direction. From the field of the generator the current will flow by the wires 27 and 20 to the segment k'. Thence it will cross the brush k^{11} to the segment k^2 and follow the wires 22, 25, and 19 to the ground. As in the movement of the arm upwardly the downward movement of the arm over the contacts of resistance k^7 will successively cut out sections of resistance until all resistance is removed from the circuit. Of course when the most resistance is in circuit the least current will traverse the field g' of the generator, and therefore the energization of said field will be the minimum. As the controller-arm is moved to cut down the resistance in circuit with said field the current which traverses said field will be increased, and consequently the strength of the field will be increased, and when all the resistance has been removed from the circuit of the generator-field the maximum current will flow through said field and the same will be energized to its greatest extent.

In addition to varying the strength of the field in the manner above set out the polarity of said field may also be changed by the movement of the arm in different directions. If the arm is moved upwardly, the current will traverse the field in one direction and produce a certain polarity. A movement of the arm downwardly will establish paths for the current by which the current will traverse said field in the opposite direction, and therefore the polarity of said field will be reversed. As the handle is moved in either direction from its initial position over the resistance-contacts the current in the field will be increased, and therefore the strength of said field will also be increased.

The several cars of the train are each equipped with a train-line, which comprises wires 28 and 29 and which in practice would consist of a single cable with the two wires arranged therein and suitably insulated from one another. A suitable coupling is provided at the end of each train-line and is of such construction that it will connect the wires of the train-line symmetrically throughout the entire train—that is, it will connect the train-lines in such a manner that all wires 28 will be connected with one another, and the wires 29 will be similarly connected. The wire 29 of each train-line is connected by wire 30 with the wire 21, extending between the controllers, and the wire 28 is connected with the wire 20 by the wire 31. These wires 30 and 31 supply the wires 28 and 29 with current from the wires 20 and 21, and therefore if the train-lines of cars A and B be connected and the arm of the controller at the left-hand end of the car A be operated to make the circuit then the current, in addition to pursuing the path before set out to energize the field g' of the generator of car A, will pass by conductor—say 31—if the controller-arm be moved upwardly to the wire 28 of the train-line, and thence it will flow by the wire 28 from car A to car B. From wire 28 in car B it will pass by conductors or wires 31 and 27 to the field g' of the generator of car B and after traversing said field will return to the wire 29 through the wires 26 and 30. By wire 29 it will flow back to car A from car B and thence flow by wire 30 to the wire 21. From here it will follow the same course as the current flowing through the generator-field g' of the generator of car A. It will therefore be observed that from the controller at the left-hand end of Fig. 1 the current may be sent through the field of the generator in each of the cars, and the direction which said current pursues in traversing the fields of the several generators will depend upon the direction in which the handle of the controller is moved; also, that the strength of all said fields may be varied by changing the resistance included in circuit

with the fields. In a similar manner to that described in connection with the controller at the left-hand side of car A, may the fields of each of the generators be controlled from any one of the controllers.

The armature g^2 of the generator part of each motor-generator is normally driven at a uniform speed from the armature of the motor, and the terminal g^3 of said generator is connected with the wire 32 of the car or controlling-circuit, and the other terminal, g^4, of said generator is connected with the wire 33 of said circuit. As the armature of the generator normally runs at a uniform speed, the strength and direction of the current developed thereby will depend upon the polarity and strength of the field. It was before described how the strength and polarity of the field g' might be changed by the manipulation of one of the controllers, and therefore it will be readily appreciated how the polarity and voltage of the current upon the controlling-circuit may be varied. The field of each of the generators being within the control of the master-controller, the strength and direction of the current on the controlling-circuit may be varied at will from said controller.

I will now proceed to a description of that part of the system which operates the elements of the apparatus for controlling the motors which propel the cars, and in describing the same reference will be had particularly to Fig. 2 of the drawings, which shows the complete circuit arrangement for a single car. Two sets of motors of two motors each are preferably employed in propelling each car, one set of motors being arranged on the forward truck and the other set on the rear truck; but while I will describe my invention as arranged for use with two sets of motors it will be understood that it may be equally advantageously employed for controlling a single motor. Moreover, the motors may be employed for other purposes than operating cars or vehicles, and in many ways the system of my invention may be adapted to accomplish various ends which are not herein specified. It will be noted that the armatures a and b of one set of motors are connected in parallel paths and also that the fields a' and b' of said set of motors are likewise connected in parallel. The armatures c and d of the other set of motors are similarly connected in parallel, as are also fields c' and d'. At the left of the figure are solenoids r' and r^2, which control sections r^5 and r^6 of the resistance for the armatures a and b. At the right are solenoids r^3 and r^4, which control sections r^7 and r^8 of the resistance for the armatures c and d. The core of the solenoid r' carries contact 34, which when lifted bridges terminals 35 and 36 to cut out the section of resistance r^5. The core of the solenoid r^2 lifts the contact 37, which, when raised, bridges terminals 38 and 39 to cut out the resistance r^6. The core of the solenoid r^3 has contact 40, which when raised bridges terminals 41 and 42 to cut out the resistance r^7, and the core of the solenoid r^4 has contact 43, which when lifted bridges terminals 44 and 45 to remove the resistance r^8. The several solenoids r', r^2, r^3, and r^4 are connected across the controlling-circuit in parallel paths. The solenoids r' and r^2 respond to different voltages, as do also the solenoids r^3 and r^4, the solenoids r' and r^3 being adapted to respond to a lower voltage than the solenoids r^2 and r^4. Therefore when the voltage on the controlling-circuit has risen to a predetermined point the solenoids r' and r^3 will respond and cut their respective resistances out of circuit. When the voltage has further increased sufficiently to energize the solenoids r^2 and r^4, said solenoids will lift their cores, and thereby the sections of resistances controlled by said solenoids will be removed from the circuits of the armatures. On the left-hand side of the diagram is illustrated a reversing-switch for the motors a and b, which operates to send the current through the motors a and b in the direction required to produce the rotation of their armatures in the proper direction to propel the car. This switch comprises two solenoids w and x, respectively. Each solenoid consists of two windings, the solenoid w having windings w' and w^2 and the solenoid x having windings x' and x^2. The upper windings w' and x' are connected in series between the trolley T and the ground G and are constantly supplied with current from the source of the main supply. The lower windings w^2 and x^2 are connected in series between opposite sides of the controlling-circuit, and therefore the direction of the flow of the current therein depends upon the direction of the flow of the current on the controlling-circuit; but in the other windings, w' and x', of said solenoids the current flows continuously in one direction. The winding w^2 is arranged to energize the solenoid w with polarity opposite to that which the solenoid w produces when the current flows in one direction through the winding w^2 and to produce the same polarity of the solenoid as the winding w' when the current flows in the opposite direction—that is, if the winding w' produces at the upper end a north pole and at its lower end a south pole then when the winding w^2 tends to produce an opposite polarity to that of the winding w' said winding w^2 would tend to create a north pole at its lower end and a south pole at its upper end, and when the lower winding w^2 tends to produce the same polarity as the winding w' then said winding w^2 would produce a north pole at its upper end and a south pole at its lower end. Therefore when the winding w^2 tends to produce different polarity from that of winding w' like poles would be in proximity, and therefore the effect of one winding would neutralize or destroy the effect of the other

winding, so that the solenoid would remain inert. If the winding w^2 has the current flowing therein in a direction which tends to produce the same polarity as the winding w', then the solenoid will be energized and raise its core, the two windings assisting each other. The windings x' and x^2 of the solenoid x are similar to those of the solenoid w, and when the current flows through the winding x^2 in one direction, it tends to produce opposite polarity to that of the winding x', and when it flows through the winding x^2 in the opposite direction said latter winding tends to produce the same polarity as the upper winding x'. The windings of the two solenoids w and x are so arranged that when the current flows through the windings w^2 and x^2 in one direction, one solenoid will be energized and the other remain inert, and when the current flows in the opposite direction the reverse result will be effected. The solenoid w has its core provided at the lower end with a contact 46, which bridges terminals 47 and 48, and at its upper end with a contact 49, which bridges when raised the terminals 50 and 51. The solenoid x also has its core provided at the lower end with contact 52, which bridges terminals 53 and 54, and at its upper end with a contact 55, which bridges terminals 56 and 57. When one solenoid is energized to lift its core, the contacts carried by said core bridge their respective terminals and close the circuit through the armatures a and b in one direction, and when the core of the other solenoid, x, is lifted its contacts close the circuit through their respective terminals in a manner to cause the current to flow through the armatures a and b in the opposite direction. As before explained, when one solenoid of the reversing-switch is energized the other solenoid remains inert through the neutralization of its windings. The energization of either of the solenoids w or x is dependent, it will be observed, upon the direction of the flow of the current in the windings w^2 and x^2, and as said latter windings are included in the controlling-circuit on which the direction of the flow of the current is within the control of the operator of the master-controller either one of the solenoids w or x may be energized at the will of the operator by the proper movement of the master-controller arm. Therefore, the current may be sent through the motors a and b in either direction, depending, as before stated, upon the position of the master-controller arm. In practice to insure the lowering of the core of one solenoid when the opposite solenoid is energized a suitable interlocking lever is arranged between the two cores, and normally the two cores are situated in an intermediate position, so that the contacts carried thereby will not be in engagement with their respective terminals. The reversing-switch at the right of Fig. 2 for the motors c and d is the same as the reversing-switch for the motors a and b. Said switch has two solenoids y and z, the solenoid y having windings y' and y^2 and the solenoid z having windings z' and z^2, the upper windings y' and z' of the two solenoids being connected in series between the trolley and the ground and constantly supplied with current in one direction. It will be observed that the windings w' and x' of one reversing-switch and the windings y' and z' of the other reversing-switch are all connected in series. The lower windings y^2 and z^2 of the solenoids y and z are connected in series between opposite sides of the controlling-circuit and are wound to produce opposite polarity like the windings w^2 and x^2, so that when the current traverses said windings in one direction one solenoid will be energized while the other remains inert. The core of the solenoid y carries at its upper end a contact 58, which bridges terminals 59 and 60 when the core is raised, and at its lower end a contact 61, which bridges terminals 62 and 63. The core of the other solenoid has at its upper end a contact 64, which when the core is raised bridges terminals 65 and 66, and at its lower end a contact 67 to bridge terminals 68 and 69. Like the other reversing-switch, the cores in practice are suitably interlocked, and while one solenoid is energized the other always remains inert. One solenoid when energized establishes a path for the current to flow through the armatures c and d in one direction, and the other solenoid when energized causes the current to traverse the armatures in the opposite direction. At the center of the diagram are situated the parallel and series switches, the parallel switch being to connect all the motors across the line in a parallel relation and the series switch being to establish a series relation of said motors in circuit. The solenoid p of the parallel switch and the solenoid s of the series switch are arranged in parallel across the controlling-circuit, and the parallel solenoid is wound to respond under a higher voltage than the series solenoid. The series solenoid has its core carrying at the upper end a contact 70, which when raised bridges terminals 71 and 72, and at its lower end a contact 73, which when raised bridges terminals 74 and 75. Said core also carries at its lower end a contact 76, which when the core is lowered bridges terminals 77 and 78, and a contact 79, which when raised bridges terminals 80 and 81. The core of the parallel solenoid is provided at its upper end with a bridge 82, which when raised bridges terminals 83 and 84, and at its lower end a contact 85, which when raised bridges terminals 86 and 87. Also at the lower end of said core is arranged a contact 88, which when the core is lowered bridges terminals 89 and 90.

In the initial path for the current through each of the several solenoids above described is arranged a switch l, one being provided for

each solenoid, and in a shunt-path around each of said switches is a resistance or lamp l'. Said switch is situated in a position to be opened by the core of the solenoid when it is raised, and when said switch is opened the resistance or lamp l' is thrown into circuit with said solenoid and protects the same from excessive currents.

A better understanding of the operation of the system described will now be gained by following the circuits for the current. Assume that the current on the controlling-circuit flows in a given direction. Then it will pass by conductor 90 through the solenoid s of the series switch, it first passing through the resistance-switch l thereof. After traversing the solenoid s the current will flow to terminal 80, thence to terminal 90, across the bridge 88 to terminal 89, and then by conductor 91 to the opposite side of the controlling-circuit. At the same time the current will flow from one side of the controlling-circuit by conductor 92, through the windings w^2 and x^2 of one reversing-switch, and thence to the opposite side of the controlling-circuit by conductor 93. The circuit through the windings y^2 and z^2 of the solenoids of the other reversing-switch can also be traced from one side of the controlling-circuit by conductor 94, through the windings, and thence by conductor 95 to the opposite side of the car-controlling circuit. Assume that the solenoid s and the solenoid of the reversing-switch respond to twenty volts, and that the master-controller arm has been moved sufficient to produce such a voltage upon the controlling-circuit. Also suppose in this instance that the direction of the flow of the current on the controlling-circuit will cause the energization of the solenoid w of one reversing-switch and the solenoid y of the other reversing-switch. These solenoids will then raise their respective cores, while the other solenoids of said reversing-switches remain inert. We will say that the solenoids r' and r^3, which control the resistances, operate under a potential of thirty volts each, and therefore when the current on the controlling-circuit has risen to thirty volts, the solenoids r' and r^3 will be energized and lift their cores, thereby removing their respective resistances from the armature-circuits. The path for the current of the solenoid r' can be followed from one side of the controlling-circuit by conductor 96, through the solenoid r', thence by conductor 97 to terminal 81, across contact 79, to terminals 80 and 90, over contact 88 to terminal 89 and conductor 91, and then to the opposite side of the controlling-circuit. The path for the current through the solenoid r^3 may be traced by conductor 98 through said solenoid, over conductor 99 to the terminal 81, and thence to the opposite side of the controlling-circuit by the same path previously traced for the current for the other resistance-solenoid. On further increase of the voltage to forty volts the solenoids r^2 and r^4 will be energized and cut their respective resistances from circuit, it being presumed that said solenoids respond under forty volts potential. The paths for the current of the solenoids r^2 and r^4 are substantially the same as those for the solenoids r' and r^3 and may be readily followed, the solenoid r^2 being situated in a shunt-path around the solenoid r' and the solenoid r^4 being likewise situated in a shunt-path around the solenoid r^3.

I will now trace the motor-circuits when said motors are connected in series and the solenoids w and y of the reversing-switches are energized. The current will follow the conductor 100 to the terminal 50 and pass over bridge 49 to terminal 51. Thenceforward it will flow to terminal 53 of the other solenoid and pass through armatures a and b to the terminal 48. Here it will cross the bridge 46 to the terminal 47, pass between the terminals 39 and 38 by contact 37, if the resistance-solenoids r' and r^2 are energized to remove their respective resistances from circuit, and thence flow by conductor 101 to the fields a' and b' of the armatures a and b. After traversing said fields it will pass by conductor 102 to terminal 74. Here it will cross the contact 73 to terminal 75 and thence flow by conductor 103, through terminal 72, contact 70, and terminal 71, to the conductor 104. At this point it will pass to terminal 44 of the solenoid r^4 and through contact 43 and bridge 45, whence it will pass over conductor 105, through fields c' and d' and to the terminal 62 by conductor 106. After crossing bridge 61 to terminal 63 it will flow through the armatures c and d to terminal 68 and thence to terminal 60, across contact 58 to terminal 59 and to the ground by conductors 107, 108, and 109. If the solenoids x and z of the reversing-switches be energized, then the current will flow through the armatures in the opposite direction and cause a reverse rotation of the armatures thereof. At the reversing-switch on the left, when the solenoid x is energized, the current instead of flowing through the terminals, as above described, will pass from conductor 100, by conductor 110 to terminal 57, thence across the contact 55 to terminal 56, terminal 48, through armatures a and b in opposite direction, the terminal 53, across contact 52 to terminal 54, and thence by conductor 111 to terminal 47. In a similar manner the circuit can be traced through the reversing-switch at the right, the current when the solenoid z is energized passing from terminal 62 to terminal 69, thence across contact 67 to terminal 68, through the armatures c and d in the opposite direction from that which it before pursued to the terminal 63, thence to the terminal 65, through the brush 64 and terminal 65 and by wire 112 to conductor 107.

With the parallel and series switches is as-

sociated in practice an interlocking mechanism somewhat similar to that employed with the cores of the reversing-switches. One form of this interlocking mechanism is diagrammatically illustrated in Fig. 3 of the drawings. Said interlocking mechanism is constructed to permit a slight freedom of movement of the core of the solenoid p, so that when said solenoid is energized the contact 88 will be lifted from terminals 89 and 90 to break the circuit through the solenoid s of the series switch. The solenoid p, as before stated, responds to a higher voltage than the solenoid s, and we will assume that sixty volts are required for its energization, so that its core will not be lifted until after all the resistance is removed from the circuit of the motors. Therefore when the voltage on the controlling-circuit rises to sixty volts the solenoid p, connected across the controlling-circuit, will be energized, and when the contact 88 is lifted to break the connection between terminals 89 and 90 the solenoid s will be cut out of the circuit and its core will fall and cause contact 76, carried thereby, to bridge the terminals 77 and 78. When the contact 88 breaks the circuit between the terminals 89 and 90, the resistance-solenoids r', r^2, r^3, and r^4 are deënergized and resistances r^5, r^6, r^7, and r^8 again inserted in the motor-circuit. A new path is now established for the current to flow through the resistance-solenoids, it being from terminal 81, through resistance o, to terminal 78, across contact 76 to terminal 77, thence by wire 113 to terminal 89 and over wire 91 to wire 33 of the controlling-circuit. This resistance o is such as to increase the respective voltages required for the energization of the resistance-solenoids, and we will assume for the present that when the resistance o is in series with the resistance-solenoids the solenoids r' and r^2 will respond to eighty volts and the solenoids r^2 and r^4 will respond to one hundred volts. Therefore after the parallel switch is operated to connect the motors in parallel the sections r^5 and r^7 of the resistances will not be cut out until the voltage impressed upon the controlling-circuit has increased to eighty volts, and a further increase of the current to one hundred volts will be required to operate the solenoid-switches r^2 and r^4 to cut out the sections of resistance r^6 and r^8.

We will now trace the power-circuits for the current when the parallel switch is closed and the solenoids w and y of the reversing-switches are energized and all the resistance for the motors is cut out of circuit. The current will flow from the trolley through the reversing-switch and the motors a and b to the wire 102, as above described when the series switch was closed. From wire 102 instead of going to the motors of the other set it will pass through terminals 86 and 87 and contact 85 to the wire 109 and thence to the ground. The current for the other motors, c and d, will pass from wire 100, connected with the trolley, through wire 110 to terminal 83, thence across contact 82 to terminal 84, over wires 104 and 105, through fields c' and d', armatures c and d of the motors to terminals 68, through terminals 60 and 59 and contact 58 to wire 107, and thence by wires 108 and 109 to the ground.

By providing each car with a controller from which the operator of the train may control the motors of all the cars a master-controller will always be situated at the forward end of the front car in the direction in which it is desired to move the train regardless of the arrangement of the cars in the train.

As before mentioned, certain portions of this system have been adopted merely for the purpose of disclosing my invention, and therefore I do not wish to limit myself thereto. Moreover, certain details of the apparatus described and other features of my invention may be changed without in any way departing from the spirit of my invention.

Having thus described my invention, what I claim, and desire to secure by Letters Patent, is —

1. The combination with a plurality of controlling-circuits, of a plurality of electromagnetic windings connected in each of said circuits and adapted to respond to variations of voltage, a separate source of supply for each of said circuits, and means for simultaneously varying at will the voltage impressed upon each of said circuits.

2. The combination with a plurality of controlling-circuits, of a plurality of electromagnetic windings connected in parallel between opposite mains of each of said circuits and adapted to respond to variations of voltage, a separate source of supply for each of said circuits, and means for simultaneously varying at will the voltage impressed upon said circuits.

3. The combination with a plurality of controlling-circuits, of a plurality of electromagnetic windings connected with each of said circuits and adapted to respond to currents of different character, a separate source of supply for each of said circuits, and means for simultaneously varying at will the characteristics of the current upon all of said circuits to selectively actuate said windings.

4. The combination with a plurality of controlling-circuits, of a plurality of electromagnetic windings connected with each of said circuits and adapted to respond to currents of different character, a separate source of supply for each of said circuits, means for simultaneously varying at will the characteristics of the current upon all of said circuits to selectively actuate said windings, and suitable instrumentalities controlled by said windings.

5. The combination with a plurality of controlling-circuits, of a plurality of electromag-

netic windings connected with each of said circuits and adapted to respond to currents of different character, a separate source of supply for each of said circuits, means for simultaneously varying at will the characteristics of the current upon all of said circuits to selectively actuate said windings, and the elements of an electric-motor controller arranged to be operated by said windings.

6. The combination with a plurality of controlling-circuits, of a plurality of electromagnetic windings connected with each of said circuits and adapted to respond to currents of different character, a separate source of supply for each of said circuits, and means for simultaneously varying at will the polarity and other characteristics of the current upon each of said controlling-circuits to actuate said windings selectively.

7. The combination with a plurality of controlling-circuits, of a generator for each of said circuits, a plurality of electromagnetic windings connected in each of said circuits and adapted to respond to variations of voltage, and means for simultaneously varying at will the voltage impressed upon said circuits by said generators.

8. The combination with a plurality of controlling-circuits, of a separate source of supply for each of said circuits, means for simultaneously varying at will the voltage impressed upon each of said circuits, a plurality of electromagnetic windings connected in each of said circuits and adapted to respond to variation in voltage, and elements of electric-motor controllers operated by said windings.

9. The combination with a plurality of controlling-circuits, of a separate source of supply for each of said circuits, means for simultaneously varying at will the voltage impressed upon each of said circuits, a plurality of electromagnetic windings arranged in each of said circuits and adapted to respond to variation of voltage, and armature resistances controlled by said electromagnetic windings.

10. The combination with a plurality of controlling-circuits, of a plurality of electromagnetic windings connected in each of said circuits and adapted to respond to variation of voltage, a separate generator for each of said circuits, and means for simultaneously varying at will the voltage developed by each of said generators.

11. The combination with a plurality of separate controlling-circuits, of a generator for each of said circuits, a plurality of electromagnetic windings connected in each of said circuits and adapted to respond to variation of voltage, and means for simultaneously varying at will the strength of the fields of said generators.

12. The combination with a plurality of controlling-circuits, of a plurality of electromagnetic windings connected in each of said circuits and adapted to respond to variation of voltage, a separate generator for each of said circuits, and a rheostat for simultaneously varying at will the strength of the fields of said generators.

13. The combination with a plurality of controlling-circuits, of a separate generator for each of said circuits, a plurality of electromagnetic windings connected in each of said circuits and adapted to respond to variation of voltage, and means for simultaneously varying at will the strength and polarity of the current developed by said generators.

14. The combination with a plurality of controlling-circuits, of a separate generator for each of said circuits, a plurality of electromagnetic windings connected with each of said circuits and responding to variation of voltage, a reversing-switch controlled by pairs of said windings in each of said circuits, and an armature resistance controlled by a plurality of said windings in each of said circuits.

15. The combination with a suitable supply-circuit, of a plurality of motor-generators having the motor parts thereof energized from said supply-circuit, a separate controlling-circuit connected with the generator part of each of said motor-generators, means for simultaneously varying at will the voltage developed by said generator part, and a plurality of electromagnetic windings associated with said controlling-circuits and adapted to respond to variation of voltage.

16. The combination with a suitable supply-circuit, of a plurality of motor-generators having the motor parts thereof energized from said supply-circuit, a separate controlling-circuit connected with the generator part of each of said motor-generators, means for simultaneously varying at will the strength of the fields of said generators, and a plurality of electromagnetic windings connected in each of said controlling-circuits and adapted to respond to different voltages.

17. The combination with a suitable supply-circuit, of a plurality of motor-generators having the motor parts thereof energized from said supply-circuit, a separate controlling-circuit connected with the generator part of each of said motor-generators, a rheostat for simultaneously varying at will the strength of the fields of said generators, and a plurality of electromagnetic windings connected in each of said controlling-circuits and adapted to respond to different voltages.

18. The combination with a suitable supply-circuit, of a plurality of motor-generators having the motor parts thereof energized from said supply-circuit, a separate controlling-circuit connected with the generator part of each of said motor-generators, means for simultaneously varying at will the voltage developed by said generator part, a plurality of electromagnetic windings connected in each of said controlling-circuits and adapted to respond to variation of voltage, and the elements of mo-

tor-controllers arranged to be operated by said windings.

19. The combination with a suitable supply-circuit, of a plurality of motor-generators having the motor parts thereof energized from said supply-circuit, separate controlling-circuits connected with the armatures of the generator parts of said motor-generators, means for varying at will the strength of the field of each of said generator parts, and a plurality of electromagnetic windings associated with each of said controlling-circuits and responding to different voltages.

20. The combination with a supply-circuit, of a plurality of motor-generators having the motor parts thereof energized by said circuit, a separate controlling-circuit connected with the armature of each of the generator parts of said motor-generators, means for simultaneously varying at will the voltage developed by said armatures, a plurality of electromagnetic windings associated with each of said controlling-circuits and responding to variation of voltage, a reversing-switch and an armature resistance controlled by the windings of each of said controlling-circuits.

21. The combination with a train of cars, of a suitable supply-circuit, a motor-generator on each car, a controlling-circuit supplied by each generator, and means for controlling all of said motor-generators in unison to vary the electrical condition of the controlling-circuits, and suitable instrumentalities associated with said controlling-circuits.

22. The combination with a plurality of separate controlling-circuits, of a plurality of electromagnetic windings suitably associated with each of said controlling-circuits, and means for imposing like electrical conditions upon each of said controlling-circuits to selectively actuate said electromagnetic windings.

23. The combination with a plurality of separate controlling-circuits, of a plurality of electromagnetic windings suitably associated with each of said controlling-circuits, a supply-circuit, a plurality of motor-generators receiving current from said supply-circuit and delivering current respectively to said controlling-circuits, and means for controlling said motor-generators in unison to cause the same to impose like electrical conditions on said controlling-circuits to selectively actuate said electromagnetic windings.

24. The combination with a plurality of separate controlling-circuits for a plurality of cars of a train, of a plurality of electromagnetic windings suitably associated with each of said controlling-circuits, a train-line extending through the train, and means controlled through the agency of said train-line for imposing like electrical conditions upon said controlling-circuits to selectively actuate said electromagnetic windings.

25. The combination with a plurality of separate controlling-circuits, of a plurality of electromagnetic windings connected in each of said circuits and adapted to respond to variations of voltage, and means for simultaneously impressing at will like voltages upon each of said circuits.

26. The combination with a plurality of controlling-circuits, of a separate source of supply for each of said circuits, and means for simultaneously impressing like voltages upon each of said circuits.

In witness whereof I have hereunto subscribed my name in the presence of two witnesses.

HENRY H. CUTLER.

Witnesses:
T. E. BARNUM,
F. R. BACON.