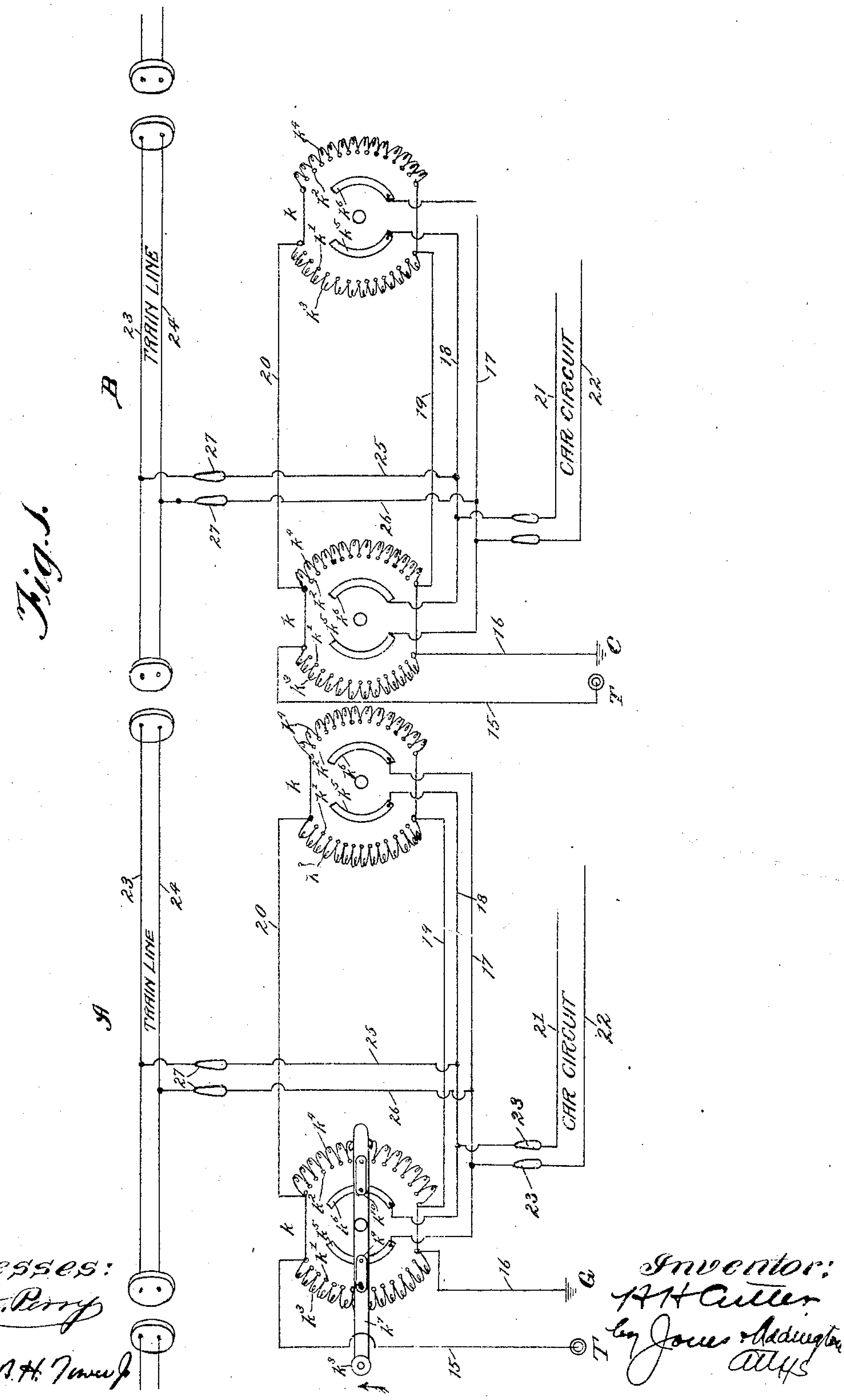
No. 786,423. PATENTED APR. 4, 1905.

H. H. CUTLER.

SYSTEM FOR CONTROLLING ELECTRIC MOTORS.

APPLICATION FILED JULY 6, 1903.

2 SHEETS—SHEET 1.



Witnesses:
Ira L. Perry
Edwin B. H. Tower Jr.

Inventor:
H. H. Cutler
by Jones & Addington
Attys

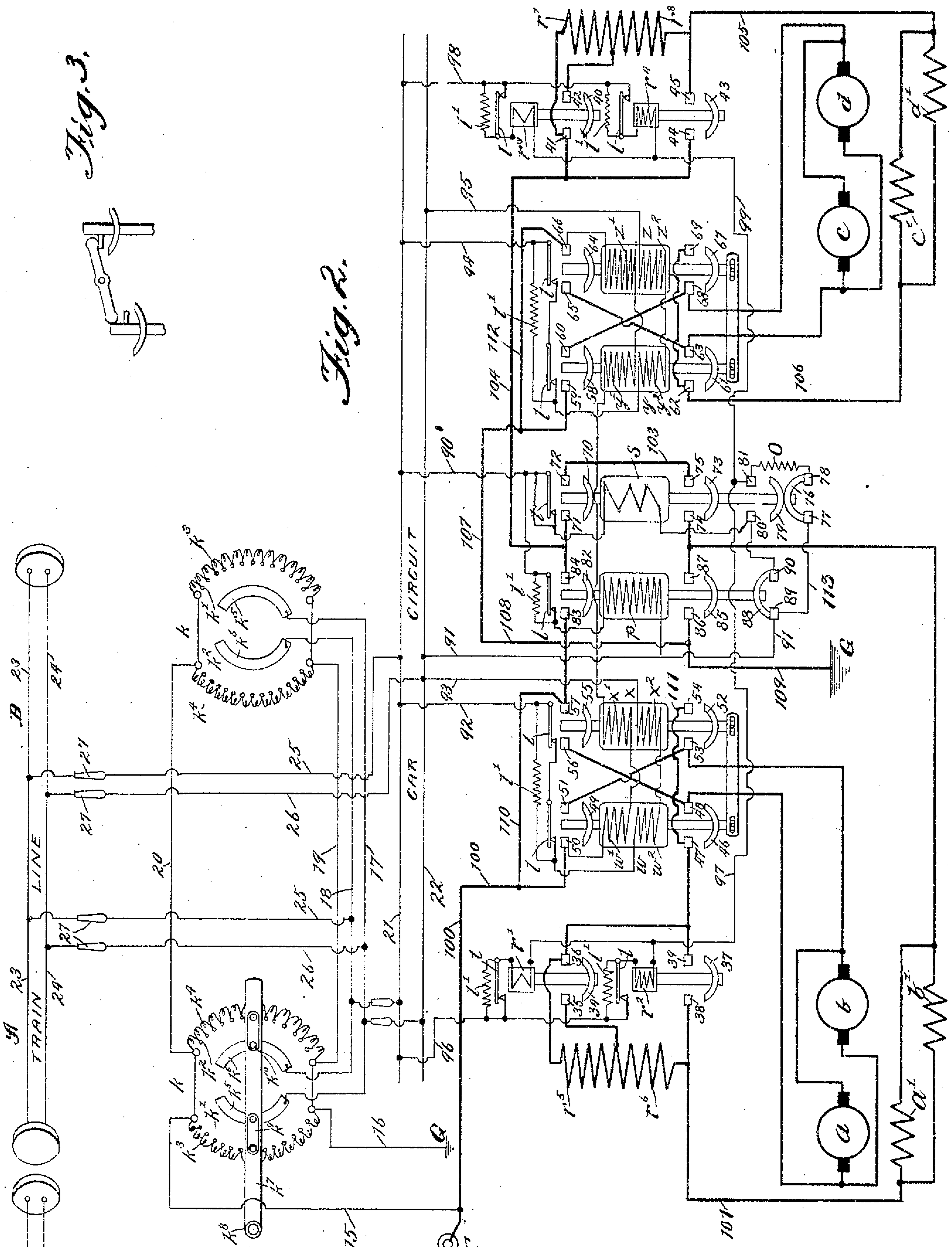
No. 786,423. PATENTED APR. 4, 1905.

H. H. CUTLER.

SYSTEM FOR CONTROLLING ELECTRIC MOTORS.

APPLICATION FILED JULY 6, 1903.

2 SHEETS—SHEET 2.



Witnesses:

Ira D. Perry

Edwin B. H. Tower, Jr.

Inventor:

Henry H. Cutler

by Jones & Addington

Attys.

No. 786,423. Patented April 4, 1905.

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. 786,423, dated April 4, 1905.

Application filed July 6, 1903. Serial No. 164,379.

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 to a system particularly designed for controlling electric motors; but it may be useful for other purposes.

The system permits an electric motor to be controlled from a distant point, and therefore it may be utilized to advantage in operating a train of cars or other vehicles on the multiple-unit plan. The system, however, is equally applicable to a single car or vehicle, and its principles may be employed for operating electric motors which are arranged for other purposes than propelling vehicles. Moreover, certain features of this invention may be applied for actuating other devices than electric-motor controllers.

A system which finds its foundation in my invention has been worked out, and for the purpose of revealing my invention the same has been diagrammatically illustrated in the accompanying drawings, in which—

Figure 1 shows a portion of the circuit arrangement for two cars, and Fig. 2 illustrates the complete circuit arrangement for a single car. Fig. 3 is a diagrammatic view of the interlocking lever of the series-parallel switch.

Although the system shown in the accompanying drawings is especially arranged for operating a train of cars upon the multiple-unit plan, it may be equally advantageously employed for operating a single car.

In carrying out my invention in the way shown in the drawings I employ a circuit, which I term the "car" or "controlling" circuit to distinguish it from the power-circuit, which supplies the motors with their operating-current, and one of these controlling-circuits is preferably arranged in each car. With each car-circuit is connected a plurality of electromagnetic windings, which are wound to respond to different voltages. These windings in the system shown herein control the elements of an electromotor-controller; but it is obvious that they may be employed in many other relations. The current is supplied to the controlling-circuit from any suitable source, and by varying the resistance or other conductive means arranged within the controlling-circuit the voltage and polarity of the current upon said circuit may be varied to selectively actuate the electromagnetic windings.

In describing the drawings by reference characters I shall first refer to Fig. 1, in which are shown portions of the circuits for two cars A and B, and as the circuit arrangements for each car are similar I shall direct attention to the diagrammatic showing of the circuits for the car A at the left-hand side of Fig. 1. The car has at each end thereof a controller k. These controllers are suitably connected, as shall be hereinafter described. For the present I shall only refer to the controller which is situated at the left-hand side of the car A, as the two controllers are alike. This controller has two sets of contacts k' and k^2, respectively, and between the contacts k' are connected the sections of resistance k^3, while between the contacts k^2 are connected the sections of resistance k^4. One end of each of these resistances is connected with the trolley T by the wire 15, while the opposite end of each of these resistances is connected by wire 16 with the ground G. It will be observed that the current will flow from the trolley T to the resistances, then it will divide and flow through said resistances, and finally it will flow to the ground by wire 16. Between the contacts k' and k^2 are segments k^5 and k^6. The segments k^5 and k^5 of the controllers on the car are connected with each other by wire 17, while the segments k^6 and k^6 of said controllers are connected by the wire 18. The ends of the resistances of the controller at the right-hand end of car A are connected with the ends of the resistances of the controller at the left-hand end of said car by wires 19 and 20, so that current from the trolley T will flow to the ground G through the resistances of said controller at the right-hand end as it does through the resistances of the controller at the left-hand end of said car. Again, referring to the controller at the left-hand end of car A, an arm k^7, having a handle k^8, is arranged so as to be movable over the contacts and segments of the controller, and said arm carries a brush k^9, arranged to bridge the contacts k' and segment k^5; and a brush k^{10}, which is disposed on the opposite side of the pivot to the brush k^9 and constructed to bridge or connect the contacts k^2 and segment k^6. The arm of the controller normally rests in a central position, as shown, so that the brush k^9 engages the center contact of the series of contacts k', while the brush k^{10} engages the center contact of the series of contacts k^2, and as each of the resistances k^3 and k^4 are equal they are divided by the center contact, so that the lower sections of resistance k^3 are the same as the lower sections of resistance k^4, while the upper sections of the resistance k^3 are the same as the upper sections of the resistance k^4. With the wire 18 is connected one side, 21, of the controlling-circuit, while with the wire 17 is connected the other side, 22, of said controlling-circuit, and switches 23 are preferably arranged in said controlling-circuit, so that the same may be opened, if desired. It will be observed that the side 21 of the controlling-circuit is connected with the segment k^6 of the controller by the wire 18 and that the side 22 of said controlling-circuit is connected with the segment k^5 of the controller by the wire 17. The segment k^5 is normally connected with the resistance k^3, through which part of the current is flowing, by the brush k^9, which engages the center contact of the series of contacts k', and the segment k^6 is likewise connected with the resistance k^4, through which the other part of the current is flowing, by the brush k^{10}, which engages the center contact of the series of contacts k^2. As the sections of resistance on each side of the center contacts of the series of contacts k' and k^2 are the same, as above explained, the potential of the current flowing through the two resistances k^3 and k^4 will be the same at the center contacts, and therefore no current will flow off from said resistances to the controlling-circuit when the controller-arm is in its initial position; but let it be supposed that the controller-arm be moved by the handle in the direction of the arrow, then the potential of the current at the contacts engaged by the brushes k^9 and k^{10} will be different, and therefore the current will flow upon the controlling-circuit by passing from one of the resistance-contacts across the brush in engagement therewith to the segment and then over the controlling-circuit back to the other segment and across the brush in engagement therewith to the opposite resistance. The reason that the current will now flow is that the potential at the brush k^9 is greater than the potential at the brush k^{10}. In the movement of the arm as just described the current will flow from trolley T to the resistance k^3, thence it will pass through the sections of said resistance not cut out of circuit until it reaches the contact which the brush k^9 engages. Here the current will flow across the brush to the segment k^5 and thence pass by wire 17 to the wire 22 of the controlling-circuit. In returning the current will flow back over wire 21 of the controlling-circuit and wire 18 to the segment k^6, where it will cross the brush k^{10} to the contact of the series of contacts k^2, with which the brush k^{10} engages, and flow through the sections of the resistance k^4 not cut out to the wire 16 and then pass to the ground G. Now if the arm be moved in the opposite direction, so that the potential at the brush k^9 is less than the potential at the brush k^{10}, then the current will flow from the trolley T through the resistance k^4 in circuit across brush k^{10} to segment k^6 and thence traverse the controlling-circuit in the reverse direction to that previously described, and therefore will return to the segment k^5. Here it will cross the brush k^9 and pass through the sections of resistance k^3 not cut out and wire 16 to the ground. In movement of the controller-arm in either direction the sections of the resistance k^3 and k^4 will be cut out of circuit one by one, and therefore the voltage upon the controlling-circuit will be increased until all the resistance has been removed from the circuit, and likewise as the controller-arm is returned to its initial position the voltage upon the controlling-circuit will be decreased as the sections of resistance are cut in. The operation of the other controller in car A, as well as the controllers in car B, is the same as that of the controller which has just been described. So that each of the controlling-circuits upon the several cars may be supplied with current through the controller of the car which is at the forward end of the train a train-line is provided, consisting of wires 23 and 24, which under commercial conditions would be formed into a single cable and made in sections, one of said sections being arranged upon each car. At each end of each section of the train-line would be provided a suitable coupling adapted to connect the wires of the sections of the train-line. The wire 23 of each section of the train-line is connected with the wire 18 by the wire 25, and the wire 24 is connected by the wire 26 with the wire 17. In order that the controlling-circuit of any one of the cars may be disconnected from the train-line, switches 27 are preferably provided. By reference to the two cars shown in Fig. 1 the manner of supplying the controlling-circuit of the car B with current will be readily understood. It will be noted that the current flows from wires 17 over wires 26 and 24 of car A and wires 24, 26, and 17 of car B to one side, 22, of the controlling-circuit of the car B and returns from the other side, 21, of said controlling-circuit by wires 18, 25, and 23 of car B and wires 23 and 25 of car A to the wire 18 of car A. Therefore as the current upon the controlling-circuit of car B is supplied from the trolley T and ground G of car A through the master-controller k the direction of the flow of the current and the voltage thereof upon the controlling-circuit of car B may be controlled in a similar manner to that of the current upon the controlling-circuit of car A. Any number of cars may be connected in train and have their controlling-circuits controlled through a master-controller upon one of the cars.

The manner of supplying each controlling-circuit with current and the means for varying both the direction and voltage of said current having been set out, I shall 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 said system reference will be had particularly to Fig. 2 of the drawings, which shows the complete circuit arrangement of 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. While I shall 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 upon each car. Furthermore, the invention may be utilized for controlling motors which are arranged for other purposes than operating a train of cars, and other forms of the arrangement which I am about to describe may be employed to operate the motor-controlling apparatus.

Referring now particularly to Fig. 2, 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 respectively 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 respectively 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 to bridge terminals 38 and 39, and thereby 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 section r^8 of the resistance from the circuit of armatures c and d. 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 respond to the same voltage, and the solenoids r^2 and r^4 respond to the same voltage with respect to each other, but require a higher voltage for their energization than the solenoids r' and r^3. Therefore when the voltage on the controlling-circuit has risen to the 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 latter solenoids will lift their cores, and thereby remove their respective resistances from the circuit of the armatures. These solenoids all respond irrespective of the direction of the current. The movement of the master controller-arm in either direction will cause a current to traverse the controlling-circuit, and when the strength of said current has been raised sufficiently to energize the resistance-solenoids said solenoids will respond, and thereby remove the resistance from the armature-circuits of the propelling-motors. 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 tend 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; but 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. 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 armature 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 now 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 controlling-arm has been moved sufficiently 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. The solenoids r' and r^3, which control the resistances, operate, for instance, 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. 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 of 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 of 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 shall 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 terminal 48. Here it will cross the bridge 46 to the terminal 47 and 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. From this point it will pass to terminal 44 of the solenoid r^4, through contact 43 and bridge 45, 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 motors 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 terminals 56 and 48, through armatures a and b to 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 armature 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 associated 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, thereby causing the contact 76 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 the 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 27 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^3 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.

I shall 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 the current instead of going to the motors of the other set 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, and over wires 104 and 105 through fields c' and d' and armatures c and d of the motors to terminal 68, through terminals 60 and 59 and contact 58 to wire 107, and thence by wires 108 and 109 to the ground.

In the system which I have described for controlling the operation of the motors the control of said motors depends upon the polarity and voltage of the current upon the controlling-circuit. As the voltage and direction of the current upon the controlling-circuit may be varied at will from the master-controller, the operation of the motors may be perfectly controlled from the distant point at which said controller is situated.

While I have described my invention as applied for controlling electric motors for propelling motor-vehicles, and particularly with reference to operating a train of electric cars upon the multiple-unit plan, it will be understood that my system is equally applicable to the control of one or more motors which are utilized for other purposes than propelling vehicles. Also, it is obvious that the windings may be employed for actuating or controlling other instrumentalities than switches for bridging armature-resistances. These different applications of my system are intended to be fully covered by this specification, and, moreover, many other changes in the system which I have described are manifest and are fully within the scope of my invention.

I claim—

1. The combination with a suitable supply-circuit, of a controlling-circuit connected with said supply-circuit, a plurality of electromagnetic windings, connected in said controlling-circuit and adapted to respond to variations in voltage, and conductive means for varying at will the voltage and polarity of the current delivered by said supply-circuit to said controlling-circuit.

2. The combination with a suitable supply-circuit, of a controlling-circuit connected therewith, a plurality of electromagnetic windings arranged in said controlling-circuit and wound to respond to variations in voltage, suitable instrumentalities controlled by said windings, and conductive means for transforming the voltage and polarity of the current delivered by said supply-circuit to said controlling-circuit.

3. The combination with a suitable supply-circuit, of a controlling-circuit connected therewith, a plurality of electromagnetic windings arranged in said controlling-circuit and adapted to respond to variations in voltage, an armature resistance controlled by said windings,

and conductive means for varying at will the voltage and polarity of the current delivered by said supply-circuit to said controlling-circuit.

4. The combination with a suitable supply-circuit, of a controlling-circuit connected therewith, a plurality of electromagnetic windings, arranged in said controlling-circuit and wound to respond to variations in voltage, an electric-motor controller having its elements controlled by said windings, and conductive means for varying at will the voltage and polarity of the current delivered by said supply-circuit to the controlling-circuit.

5. The combination of a suitable supply-circuit, of a controlling-circuit connected therewith, a plurality of electromagnetic windings, arranged in said controlling-circuit and adapted to respond to variations in voltage, suitable instrumentalities controlled by said windings, and a resistance-controller for conductively varying at will the voltage and polarity of the current upon said controlling-circuit.

6. The combination with a suitable supply-circuit, of a controlling-circuit connected therewith, a plurality of electromagnetic windings, arranged in said controlling-circuit and adapted to respond to variations in voltage, motor-controlling instrumentalities controlled by said windings, and a rheostat for conductively varying at will the voltage and polarity of the current upon said controlling-circuit.

7. The combination with a suitable supply-circuit, of a controlling-circuit connected therewith, a plurality of electromagnetic windings, arranged in said controlling-circuit and wound to respond to variations in voltage, an armature resistance and a reversing-switch controlled by said windings, and conductive means for varying at will the voltage and polarity of the current upon said controlling-circuit.

8. The combination with a suitable supply-circuit, of a controlling-circuit connected therewith, a plurality of electromagnetic windings connected in said controlling-circuit, and adapted to respond to variations in voltage, an armature resistance, a reversing and a series-parallel switch controlled by said windings, and conductive means for varying at will the voltage and polarity of the current upon said controlling-circuit.

9. The combination with a suitable supply-circuit, of a controlling-circuit connected therewith, a plurality of electromagnetic windings arranged within said controlling-circuit, and adapted to respond to variations in voltage, a reversing-switch controlled by a part of said windings and depending for its operation upon the direction of the flow of the current upon the controlling-circuit, and conductive means for varying at will the voltage and polarity of the current upon the controlling-circuit.

10. The combination with one or more electric motors, of a suitable supply-circuit therefor, a controlling-circuit connected with said supply-circuit, a plurality of electromagnetic windings connected in said controlling-circuit and adapted to respond to variations in voltage, an armature resistance controlled by said windings, a switch for reversing the armature-current of said motor also controlled by said windings, said switch depending for its operation upon the direction of the flow of the current upon the controlling-circuit, and conductive means for varying at will the voltage and polarity of the current upon said controlling-circuit.

11. The combination with two or more electric motors, of a suitable supply-circuit therefor, a controlling-circuit connected with said supply-circuit, a plurality of electromagnetic windings, connected in said controlling-circuit and adapted to respond to variations in voltage, an armature resistance controlled by said windings, a reversing-switch and a series-parallel switch for said motors also controlled by said windings, said reversing-switch depending for its operation upon the direction of the flow of the current upon the controlling-circuit, and conductive means for varying at will the voltage and polarity of the current upon said controlling-circuit.

12. The combination with a suitable supply-circuit, of resistances connected across said supply-circuit in different paths, a controlling-circuit, a plurality of electromagnetic windings connected in said controlling-circuit and adapted to respond to variations in voltage, and means for connecting the terminals of said controlling-circuit with the different points of said resistances to produce the particular voltage and polarity desired.

13. The combination with a suitable supply-circuit, of two resistances connected across said supply-circuit, a controlling-circuit, a plurality of electromagnetic windings connected in said controlling-circuit, and adapted to respond to variations in voltage, suitable instrumentalities controlled by said windings, and means for connecting the terminals of said controlling-circuit with different points of said resistances to produce the particular voltage and polarity desired upon the controlling-circuit.

14. The combination with a suitable supply-circuit, of a plurality of controlling-circuits connected therewith, a plurality of electromagnetic windings arranged in each of said circuits and adapted to respond to variations in voltage, and conductive means for varying at will the voltage and polarity of the current upon said controlling-circuit to selectively actuate said windings.

15. The combination with a suitable supply-circuit, of a plurality of controlling or car circuits connected therewith, a plurality of electromagnetic windings arranged in each of said circuits and adapted to respond to variations in voltage, an electric-motor controller asso-

ciated with the windings of each of said controlling or car circuits, and having its elements controlled thereby, and conductive means for varying at will the voltage and polarity of the current upon said car or controlling circuit.

16. The combination with a suitable supply-circuit, of a plurality of car or controlling circuits, a plurality of electromagnetic windings connected in each of said controlling-circuits, an electric-motor controller associated with the windings of each of said circuits and having its elements controlled thereby, conductive means associated with each of said controlling-circuits for varying at will the voltage and polarity of the current upon said controlling-circuits, and means whereby the voltage and polarity of the current upon all of said controlling-circuits may be varied at will from any one of the first-mentioned means.

17. The combination with a suitable supply-circuit, of a controlling-circuit connected therewith, a plurality of electromagnetic windings associated with said controlling-circuit, and conductive means for varying at will the voltage and polarity of the current delivered by said supply-circuit to said controlling-circuit to selectively actuate said windings.

18. The combination with a suitable supply-circuit, of a controlling-circuit connected therewith, a plurality of electromagnetic windings associated with said controlling-circuit, conductive means for varying at will the voltage and polarity of the current delivered by said supply-circuit to said controlling-circuit to selectively actuate said windings, and the elements of an electric-motor controller arranged to be operated by said windings.

19. The combination with a controlling-circuit, of a plurality of electromagnetic windings associated therewith, a supply or power circuit, and a resistance-controller for conductively varying the polarity and other characteristics of the current supplied to said controlling-circuit to selectively actuate said electromagnetic windings.

20. The combination with a controlling-circuit, of a plurality of electromagnetic windings suitably associated therewith, a supply or power circuit, and a resistance-controller for changing by conduction the polarity and voltage of the current supplied to said controlling-circuit to selectively actuate said electromagnetic windings.

21. The combination with a controlling-circuit, of a plurality of electromagnetic windings associated therewith, and adapted to respond under different electrical conditions, a reversing-switch and motor-speed-controlling instrumentalities controlled by said windings, a supply or power circuit, and a resistance-controller for conductively varying the electrical conditions of said controlling-circuit.

22. The combination with a controlling-circuit, of a plurality of electromagnetic windings suitably associated therewith and adapted to respond to different voltages, and conductive controlling means for transforming the current from said supply-circuit into a current suitable for use upon said controlling-circuit and for varying the polarity and other characteristics of the current imposed upon said controlling-circuit.

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.