No. 786,422. PATENTED APR. 4, 1905.

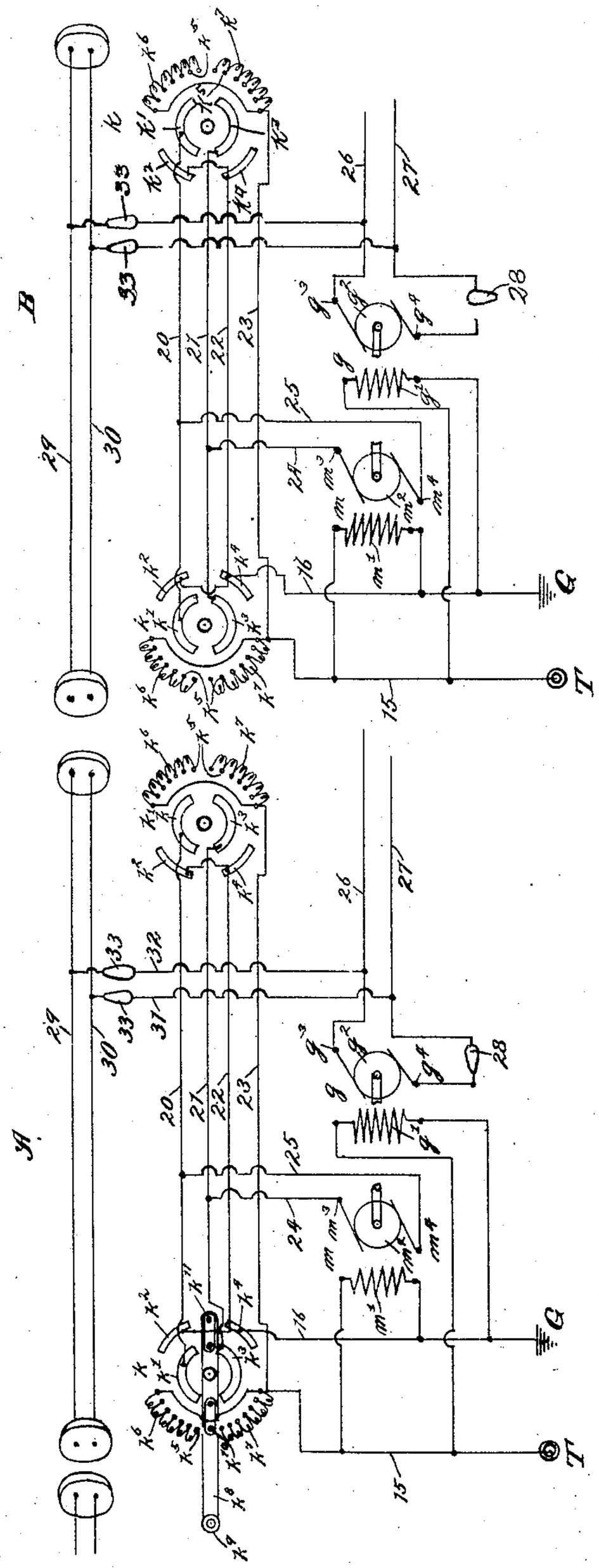
H. H. CUTLER.

SYSTEM OF CONTROLLING ONE OR MORE ELECTRIC MOTORS.

APPLICATION FILED JULY 6, 1903.

2 SHEETS—SHEET 1.

Fig. 1.



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2 SHEETS—SHEET 2.

Fig. 3.

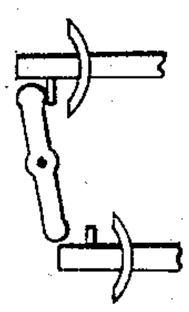
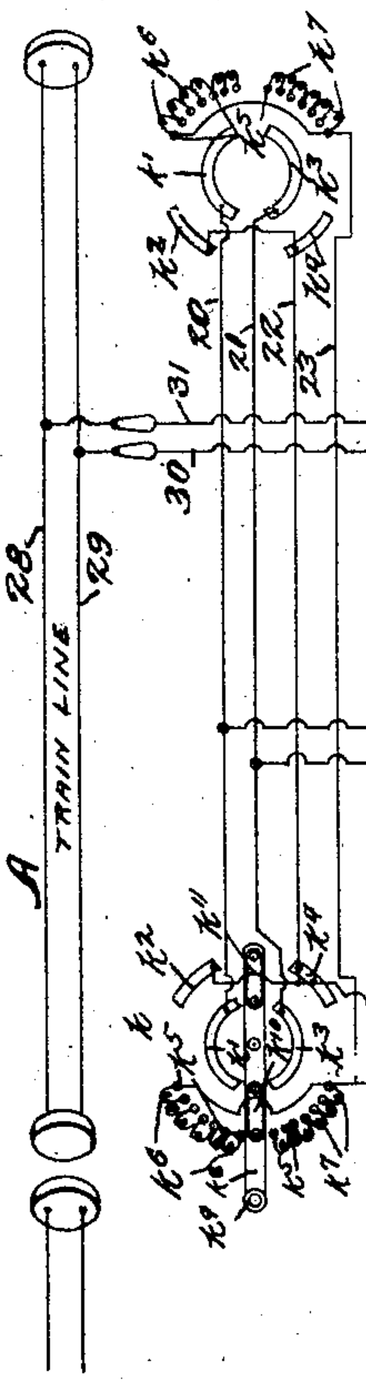


Fig. 2.



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No. 786,422. Patented April 4, 1905.

UNITED STATES PATENT OFFICE.

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SYSTEM OF CONTROLLING ONE OR MORE ELECTRIC MOTORS.

SPECIFICATION forming part of Letters Patent No. 786,422, dated April 4, 1905.

Application filed July 6, 1903. Serial No. 164,378.

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 of Controlling One or More 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.

This invention relates to a system of controlling one or more electric motors. As it has been especially designed to operate the apparatus for controlling electric motors from a distant point, it is particularly adapted for operating a train of cars on the multiple-unit plan from one or more points upon any one of the cars. This invention, however, may be utilized in many other ways, and it may be equally advantageously employed for operating a single car or for controlling one or more motors which are utilized for other purposes than propelling vehicles.

For the purpose of disclosing my invention I have designed the system shown in the accompanying drawings, in which the circuits and apparatus are especially arranged for operating a train of cars on the multiple-unit plan.

In said drawings, Figure 1 shows diagammatically portions of the circuits of two cars. Fig. 2 shows the complete circuit arrangement and apparatus for a single car, and Fig. 3 illustrates diagrammatically one form of interlocking lever for the series-parallel switch.

This system employs a circuit, which I term a "controlling" or "car" circuit to distinguish it from the power-circuit, which supplies the motors with their operating-current. Within this controlling-circuit are arranged a plurality of electromagnetic windings, which preferably actuate the elements of apparatus for controlling the operation of the motors; but manifestly they may be employed in different relations. These windings are so wound that they respond to different voltages, and therefore the actuation of the instrumentalities operated by said magnetic windings is dependent upon the voltage impressed upon the car or controlling circuit. The current is supplied to the controlling-circuit from a generator, and means are provided for varying the speed of the armature of said generator, so that the voltage impressed upon the controlling-circuit may be varied at will.

For the present I shall not refer to the windings on the controlling-circuit or the instrumentalities controlled thereby, but only to the generator for supplying the current to the controlling-circuit and the devices for varying the speed and direction of rotation of the armature which control the voltage impressed upon the car or controlling circuit and the direction of the current therein. First I shall direct attention to Fig. 1. Therein are represented portions of the equipment for two cars A and B. As the equipment for each car is the same, I shall refer to the car A at the left-hand side of Fig. 1 only.

The car A is provided with a motor-generator, which has the motor part m and the generator part g. The motor-field m' and generator-field g' are constantly connected in parallel between the trolley T and ground G by wires 15 and 16, to which the terminals of said field are connected. At each end of the car is situated a controller k, which has segments k' k^2 k^3 k^4 and two sets of contacts k^5. Between the contacts of one set are connected the sections of the resistance k^6, while between the contacts of the other set are connected the sections of the resistance k^7. In practice only a single resistance would be employed; but two are shown for the purpose of convenience in following the circuits.

The controller-arm k^8, having handle k^9, is preferably pivoted so as to be movable over the contacts and segments, and when it is in its initial position, as shown, the segments k' and k^2 and the contacts of resistance k^6 are arranged on one side of the arm, while the segments k^3 and k^4 and the contacts of resistance k^7 on the other side thereof. The arm carries brushes k^{10} and k^{11}, which are situated in

such positions that they engage the segments and contacts when the arm is moved from its initial position. If the arm of the controller at the left be moved in the direction indicated by the arrow, the brush k^{10} will connect the segment k' and the contacts of the resistance k^6 and the brush k^{11} will connect segments k^3 and k^4; but if the arm be moved in the reverse direction then the brush k^{10} will connect the segment k^3 with the contacts of the resistance k^7, and the brush k^{11} will bridge segments k' and k^2. The two controllers in the car are connected with each other by four wires 20 21 22 23, which under commercial conditions would preferably be formed into a single cable. The segments k' of the two controllers are connected with each other by wire 20. The wire 21 joins segments k^3. The segments k^2 and k^4 are all connected with each other by wire 22, and the last contact k^5 of each resistance is connected with the same contact of each of the other resistances by wire 23.

The last contact of each resistance is connected with the trolley T through wires 15 and 23, and the segments k^2 and k^4 are connected with the ground G by wires 16 and 22. The motor-armature m^2 has its terminal m^3 connected with the segments k^3 through wires 24 and 21 and its terminal m^4 with segments k' by wires 25 and 20.

The circuits which are established by the manipulation of the controller-arm will now be traced by referring to the controller at the left-hand side of the figure. When the circuit is first made by movement of the arm in either direction, the whole of one or the other of the resistances is included in the circuit, and as the arm is moved farther from its initial position the section of the resistances are cut out of circuit one by one until finally all the resistance is removed from circuit. Let it be assumed that the arm of the controller at the left be moved in the direction of the arrow. In this movement of the arm the contacts of resistance k^6 will be connected with segments k' by brush k^{10} and segments k^3 and k^4 will be connected by brush k^{11}. The circuit of the current through the motor-armature may now be traced from the trolley T over wire 15 to the resistance k^6, thence through the sections of resistance k^6 and across the brush k^{10} to the segment k'. From here the current will flow over wires 20 and 25 to motor-terminal m^4. The current after traversing the motor-armature will then pass from terminal m^3 over wires 24 and 21 to segment k^3. It will then be conducted by brush k^{11} to segment k^4 and flow by wire 16 to the ground G. If the controller-arm be moved in the reverse direction, so that brush k^{10} will bridge the contacts of the resistance k^7 and the brush k^{11} will connect segments k' and k^2, the current will flow through the motor-armature in the opposite direction to that which it did when the controller-arm was moved in the other direction. In the downward movement of the controller-arm the current will flow from trolley T, over wires 15, resistance k^6, brush k^{10}, segment k^3, and wires 21 and 24 to armature-terminal m^3. Then after passing through the armature in a reverse direction to that which it did before it will flow from armature-terminal m^4, over wires 25 and 20, segment k', brush k^{11}, segment k^2, and wire 16 to the ground G. The strength of the current which traverses the armature may therefore be regulated by varying the resistance included in the circuit by the controller, and the direction of the flow of current through the armature will depend upon the direction in which the controller-arm is moved. As the speed of the armature depends upon the strength of the current with which it is supplied, its speed may be regulated by adjusting the resistance in its circuit through the agency of the controller. Also as the direction of the rotation of the armature depends upon the direction of the flow of the current in the armature the armature may be caused to revolve in either direction, as desired.

The generator-armature g^2 is operated from the armature of the motor part of the motor-generator, and therefore its speed and direction of rotation will depend upon that of the armature of the motor. If the speed of the armature of the generator be increased, the voltage of the current developed thereby will be correspondingly increased at its terminals g^3 and g^4, and the polarity of the current will depend upon the direction of rotation of the armature. The strength and polarity of the motor and generator field are constant, as they are connected in parallel directly between the trolley and ground. Therefore the direction of the flow of the current developed by the generator-armature and the voltage thereof may be regulated at will from either of the controllers, as the direction of rotation of the armatures of the motor-generators will depend upon the direction in which the controller-arm is moved, and the speed of said armatures will be increased as the strength of the current flowing through the motor-armature is increased by removing the section of the resistance from the circuit thereof.

In the car is arranged a car or controlling circuit which is supplied with current from the generator part of the motor-generator.

The direction of the flow of the current in said circuit and the voltage or strength thereof may be regulated at will from the controller, as before described. This circuit preferably has two wires 26 and 27, which are connected with the armature-terminals g^3 and g^4 of the generator, and a switch 28 is preferably arranged in said circuit for opening and closing the same, so that in operating a train of cars on the multiple-unit plan the propelling-motors of each car may be controlled from the controller at the forward end of the front car. Each car

is provided with a train-line which comprises wires 29 and 30, preferably formed in practice into a single cable. The train-line of each car has at its ends suitable couplings for connecting it with the train-line of the next car, and this coupling is preferably of such construction that it will connect the wires of the train-lines symmetrically throughout the train, so that similar relations between the circuits of the several cars will always exist and the proper operation of the system will be insured. The train-line of each car is connected with the car or controlling circuit by a wire 31, which connects wires 30 and 27, and a wire 32, which connects wires 29 and 26, and suitable switches 33 are preferably arranged between the train-lines and the controlling-circuit in order that the train-line and the controlling-circuit may be disconnected, if desired.

By reference to Fig. 1 it will be observed that the generator of car A will not only supply current to the controlling-circuit of car A, but also to the similar circuit of car B through the train-line, and in this way the controlling-circuits of any number of cars may be supplied with current from one of the cars. The current on each of the controlling-circuits may of course be varied in strength and polarity, as before described, in connection with a single car. This is only one way of supplying each of the controlling-circuits with current, the strength and polarity of which may be varied at will from a single controller. Another way would be to control the operation of each motor-generator from a single motor-controller.

The manner of supplying each controlling-circuit with current and the means for varying the direction of said current and the voltage impressed upon said controlling-circuit 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 such 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; but 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 for other purposes than operating a train of cars, and other forms of the system which I am about to describe for operating the controlling apparatus for the electric motors may be employed.

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 the 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 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 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 section r^8 of the resistance from the circuit of the 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 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 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 increased sufficiently by cutting out the resistance to produce the required potential to energize the resistance-solenoids said solenoids will respond and 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 car-circuit; but in the other windings, w' and x', of said solenoid 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 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 produces 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 previous 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 96 to the opposite side of the 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 sufficiently to produce such a voltage upon the controlling-circuit. Also suppose in this instance that the direction of the flow of 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 the 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, 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 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 remove 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. Thence forward 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. It will then pass over conductor 105, through fields c' and d', and to 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 armature in the opposite direction and cause the 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 the opposte 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 to 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 before the latter releases its core. 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 car-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 the 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 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 consider 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 resistance 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 instead of going to the motors of the other set it will pass through terminal 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'*, 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 the motors may be perfectly controlled by varying the voltage impressed upon the controlling-circuit and regulating the direction of the flow of the current. Of course other forms of my system may be conceived, and other instrumentalities than the elements of an electromotor-controller may be employed with the electromagnetic windings. By arranging a controller at each end of each car a controller will always be situated at the forward end of the front car of the train, from which the motors of all the cars may be controlled. The controllers of each car are preferably connected in the circuit in such a manner that corresponding movements of the controller-arm will produce a similar operation of the car or train—that is, the controllers are so connected that no matter which of the controllers on any car is at the front end of the forward car movement of the controller-arm, say, to the right will cause the train to move forward, while movement of the arm to the left will cause the train to move rearward.

It is manifest that my invention may have many other forms than that herein illustrated, and I therefore do not desire to limit myself

to any of the features of the system shown, except as hereinafter particularly specified, and pointed out in the claims.

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

1. The combination with a controlling-circuit, of a plurality of electromagnetic windings suitably associated therewith, a generator supplying current to said controlling-circuit, and means for varying the speed of said generator to selectively actuate said electromagnetic windings.

2. The combination with a controlling-circuit, of a plurality of electromagnetic windings suitably associated therewith, a generator supplying current to said controlling-circuit, means for varying the speed of said generator to selectively actuate said electromagnetic windings, and the elements of an electric-motor controller adapted to be actuated by said windings.

3. The combination with a controlling-circuit, of a plurality of electromagnetic windings suitably associated therewith, a generator supplying current to said controlling-circuit, and means for varying the direction and speed of operation of said generator to selectively actuate said electromagnetic windings.

4. The combination with a controlling-circuit, of a plurality of electromagnetic windings suitably associated therewith, a generator supplying current to said controlling-circuit, means for varying the direction and speed of operation of said generator to selectively actuate said electromagnetic windings, and suitable instrumentalities controlled by said windings.

5. The combination with a controlling-circuit, of a plurality of electromagnetic windings suitably associated therewith, a generator supplying current to said controlling-circuit, means for varying the direction and speed of operation of said generator to selectively actuate said electromagnetic windings, suitable instrumentalities controlled by said windings, and the elements of an electric-motor controller arranged to be actuated by said windings.

6. The combination with a car or controlling circuit, of a generator for supplying current thereto, a plurality of electromagnetic windings arranged in said controlling-circuit and adapted to respond to different voltages, and means for varying at will the speed of the armature of said generator, whereby the voltage impressed upon said controlling-circuit may be varied.

7. The combination with a car or controlling circuit, of a generator for supplying current thereto, a plurality of electromagnetic windings connected in parallel across said circuit, and adapted to respond to different voltages, and means for varying at will the speed of the armature of said generator, whereby the voltage impressed upon said circuit may be varied at will.

8. The combination with a car or controlling circuit, of a generator for supplying current thereto, a plurality of electromagnetic windings arranged in said circuit and adapted to respond to variations in voltage, suitable devices controlled by said electromagnetic windings, and means for varying at will the speed of the armature of said generator whereby by the voltage impressed upon said controlling-circuit may be varied.

9. The combination with a controlling-circuit, of a generator for supplying current thereto, a plurality of electromagnetic windings connected in said circuit and wound to respond to different voltages, elements of an electric-motor controller associated with said windings and actuated thereby, and means for varying at will the speed of the armature of said generator, whereby the voltage impressed upon said controlling-circuit may be varied at will.

10. The combination with a controlling-circuit, of a generator for supplying current thereto, a plurality of electromagnetic windings connected in said controlling-circuit and wound to respond to different voltages, an armature resistance controlled by said windings, and means for varying at will the speed of the armature of said generator, whereby the voltage impressed upon said controlling-circuit may be varied.

11. The combination with a controlling-circuit, of a generator for supplying current thereto, a plurality of electromagnetic windings connected in said circuit and wound to respond successively as the voltage upon the controlling-circuit is increased, and means for varying at will the speed of the armature of said generator, whereby the voltage impressed upon said controlling-circuit may be regulated.

12. The combination with a controlling-circuit, of a generator for supplying current thereto, a plurality of electromagnetic windings connected in said circuit and wound to respond to variations in voltage, and means for varying at will the speed and direction of rotation of said armature whereby the voltage impressed upon said controlling-circuit and the polarity thereof may be regulated.

13. The combination with a car or controlling circuit, of a generator for supplying current thereto, a plurality of electromagnetic windings, arranged within said circuit and wound to respond to different voltages, suitable instrumentalities controlled by said windings, means for operating said generator, and means for varying at will the speed of the armature of said generator, whereby the voltage impressed upon said controlling-circuit may be varied.

14. The combination with a controlling-circuit, of a generator for supplying current

thereto, a plurality of electromagnetic windings for controlling suitable instrumentalities, said windings being connected in said circuit and wound to respond to different voltages, a motor for operating said generator, and means for varying the speed of said motor.

15. The combination with a controlling-circuit, of a generator for supplying current thereto, a plurality of electromagnetic windings connected in said circuit and wound to respond to different voltages, suitable devices controlled by said windings, a motor for operating said generator, and means for regulating the relative strength of the motor field and armature, whereby the speed of the armature may be varied at will so as to increase or decrease the voltage impressed upon the controlling-circuit.

16. The combination with a controlling-circuit, of a motor-generator having the generator part connected to said circuit so as to supply current thereto, a plurality of electromagnetic windings connected in said circuit and wound to respond to different voltages, suitable devices arranged to be controlled by said windings, and means for varying at will the speed of said motor-generator whereby the voltage impressed upon said circuit may be varied.

17. The combination with a suitable controlling-circuit, of a motor-generator having the generator part thereof connected to said circuit so as to supply current thereto, a plurality of electromagnetic windings connected in said circuit and wound to respond to variations in voltage, and a rheostat for varying the speed of said motor-generator, whereby the voltage impressed upon said car-circuit may be varied.

18. The combination with a controlling-circuit, of a motor-generator having the generator part thereof connected to said circuit so as to supply current thereto, a plurality of electromagnetic windings connected in said circuit and wound to respond to different voltages, suitable instrumentalities controlled by said windings, and a rheostat for varying at will the speed of the motor-generator, whereby the voltage impressed upon said controlling-circuit may be increased or decreased as desired to effect the proper actuation of said instrumentalities through said windings.

19. The combination with a suitable supply-circuit, of a motor-generator having the field of the generator part connected across said circuit so that the strength and polarity will be constant, a controlling-circuit supplied with current from said generator, a plurality of electromagnetic windings connected in said controlling-circuit and wound to respond to variations in voltage, and means for varying at will the speed of said motor-generator, whereby the potential of the current upon said controlling-circuit may be increased or decreased as desired.

20. The combination of a motor-generator, a suitable source of supply for the motor part thereof, a controlling-circuit supplied with current from the generator part of said motor-generator, a plurality of electromagnetic windings connected in said controlling-circuit and wound to respond to different voltages, suitable instrumentalities controlled by said windings, and means for varying at will the strength of the armature-current of said motor, whereby the voltage upon the controlling-circuit may be varied as desired.

21. The combination with a controlling-circuit, of a generator for supplying current thereto, a plurality of electromagnetic windings connected in said circuit and wound to respond to variations in voltage, an armature resistance controlled by said windings, a reversing-switch also controlled by said windings, and means for varying at will the speed of the armature of said generator, whereby the voltage impressed upon said circuit may be increased or decreased as desired.

22. The combination with a controlling-circuit, of a generator for supplying current thereto, a plurality of electromagnetic windings connected in said circuit and wound to respond to different voltages, a reversing-switch controlled by pairs of said windings, and means for varying at will the speed of the armature of said generator, whereby the voltage impressed upon said controlling-circuit may be increased or decreased as desired.

23. The combination with a suitable controlling-circuit, of a generator for supplying current thereto, a plurality of electromagnetic windings connected in said circuit and wound to respond to different voltages, a reversing-switch actuated by pairs of said windings and depending for its operation upon the direction of the flow of current upon the car-circuit, and means for varying at will the speed and direction of rotation of the armature of said generator, whereby the voltage and polarity of the current upon said controlling-circuit may be varied as desired.

24. The combination with a suitable circuit, of a generator for supplying current thereto, a plurality of electromagnetic windings connected with said circuit and wound to respond to variations in voltage, a motor or power circuit, a switch for directing the flow of the current upon said power-circuit, electromagnetic windings in said controlling-circuit for actuating said switch, the operation of said switch being dependent upon the direction of the flow of current upon said controlling-circuit, and means for varying at will the speed and direction of rotation of the armature of said generator, whereby the voltage and polarity of the current upon said controlling-circuit may be regulated according to the circumstances.

25. The combination with a controlling-circuit, of a generator for supplying current thereto, a plurality of electromagnetic wind-

ings connected in said circuit, and wound to respond to variations in voltage, a series-parallel switch, and means for varying at will the speed of the armature of said generator, whereby the voltage impressed upon said controlling-circuit may be increased or decreased, as desired.

26. The combination of a plurality of car or controlling circuits, a generator for supplying current to said circuits, a plurality of electromagnetic windings connected in each of said circuits and wound to respond to variations in voltage, an electric-motor controller associated with the set of windings upon each controlling-circuit and having its elements arranged to be actuated by said windings, and means for varying at will the speed of the armature of said generator whereby the voltage impressed upon said controlling-circuit may be regulated as desired.

27. The combination with a motor, of a suitable supply-circuit, a controlling-circuit having a plurality of electromagnetic windings connected therewith and adapted to respond to different voltages, a controller for said motor actuated by said windings, a generator for supplying current to said controlling-circuit, means for varying at will the speed and direction of rotation of the armature of said generator whereby the voltage and polarity of the current upon said controlling-circuit may be regulated as desired, and a switch for making the direction of rotation of the armature of the motor dependent upon the polarity of the current on the controlling-circuit.

28. The combination with a suitable controlling-circuit, of a plurality of electromagnetic windings associated therewith, a generator supplying current to said controlling-circuit, means for varying the operation of said generator to selectively actuate said windings, and an armature resistance and a reversing-switch controlled by said windings.

29. The combination with one or more electric motors, of suitable instrumentalities controlling the operation thereof, a controlling-circuit, a plurality of electromagnetic windings associated with said circuit and operating said instrumentalities, a generator supplying current to said controlling-circuit, and means for varying the operation of said generator to selectively actuate said windings.

30. The combination with a plurality of controlling-circuits, of a plurality of electromagnetic windings suitably associated with each of said controlling-circuits, a motor-generator supplying current to said plurality of controlling-circuits, and means for varying the speed of said motor-generator to selectively actuate said electromagnetic windings.

31. The combination with a plurality of controlling-circuits, of a plurality of electromagnetic windings suitably associated with each of said controlling-circuits, a motor-generator supplying current to said plurality of controlling-circuits, means for varying the speed of said motor-generator to selectively actuate said electromagnetic windings, and the elements of electric-motor controllers arranged to be operated by said windings.

32. The combination with a plurality of controlling-circuits, of a plurality of electromagnetic windings suitably associated with each of said controlling-circuits, a train-circuit, a motor-generator adapted to be connected with said plurality of controlling-circuits through the agency of said train-circuit, means for varying the speed of said motor-generator to selectively actuate said electromagnetic windings, and the elements of electric-motor controllers arranged to be operated by said windings.

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.