H. H. CUTLER.

SYSTEM FOR CONTROLLING ONE OR MORE ELECTRIC MOTORS

APPLICATION FILED AUG. 11, 1905.

903,178.

Patented Nov. 10, 1908.

2 SHEETS—SHEET 1.

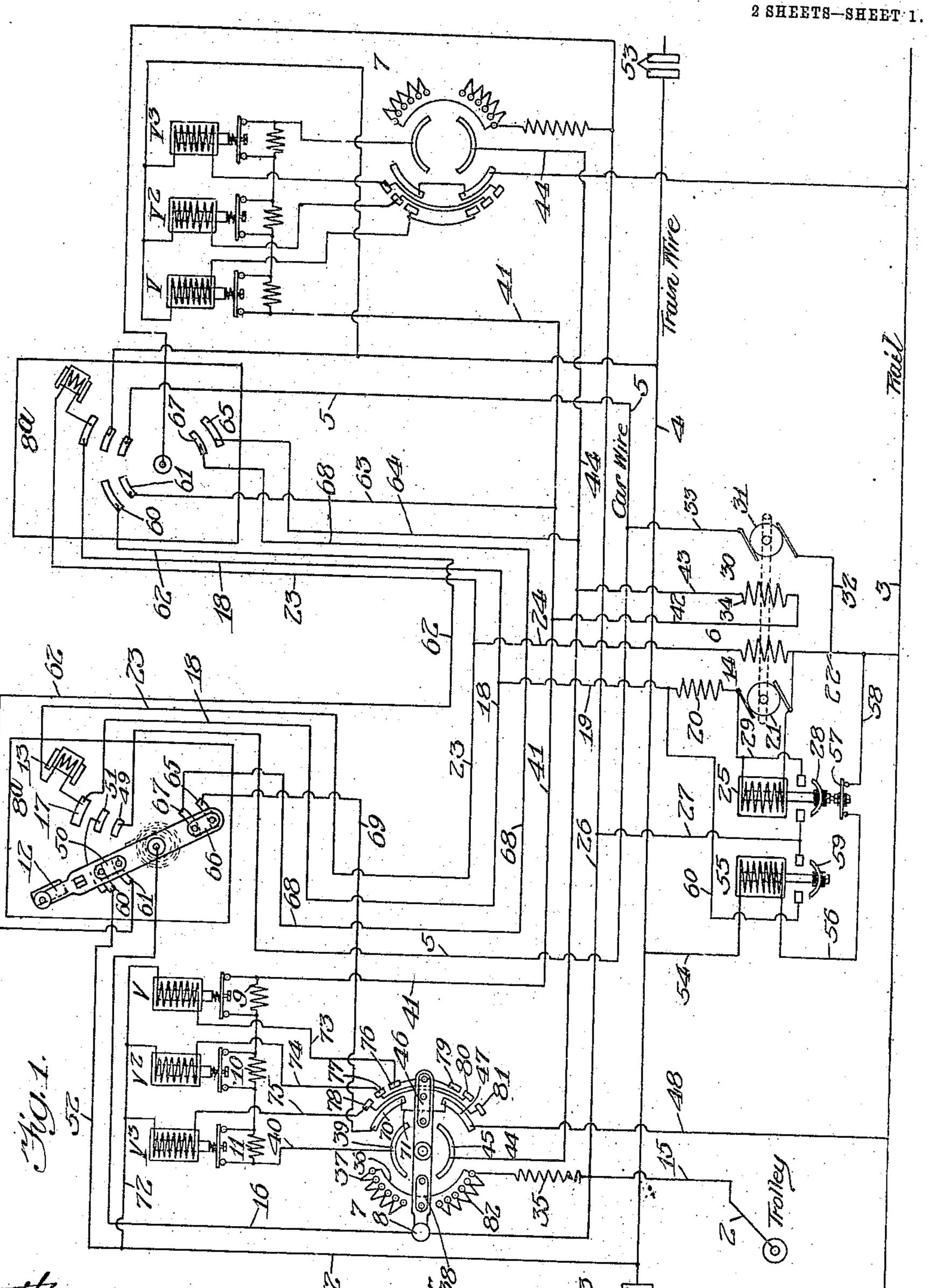


Fig. 1.

Witnesses:
Robert N. Weir
M. R. Rockford

Inventor:
Henry H. Cutler
By: Jones & Addington
Att'ys:

H. H. CUTLER.

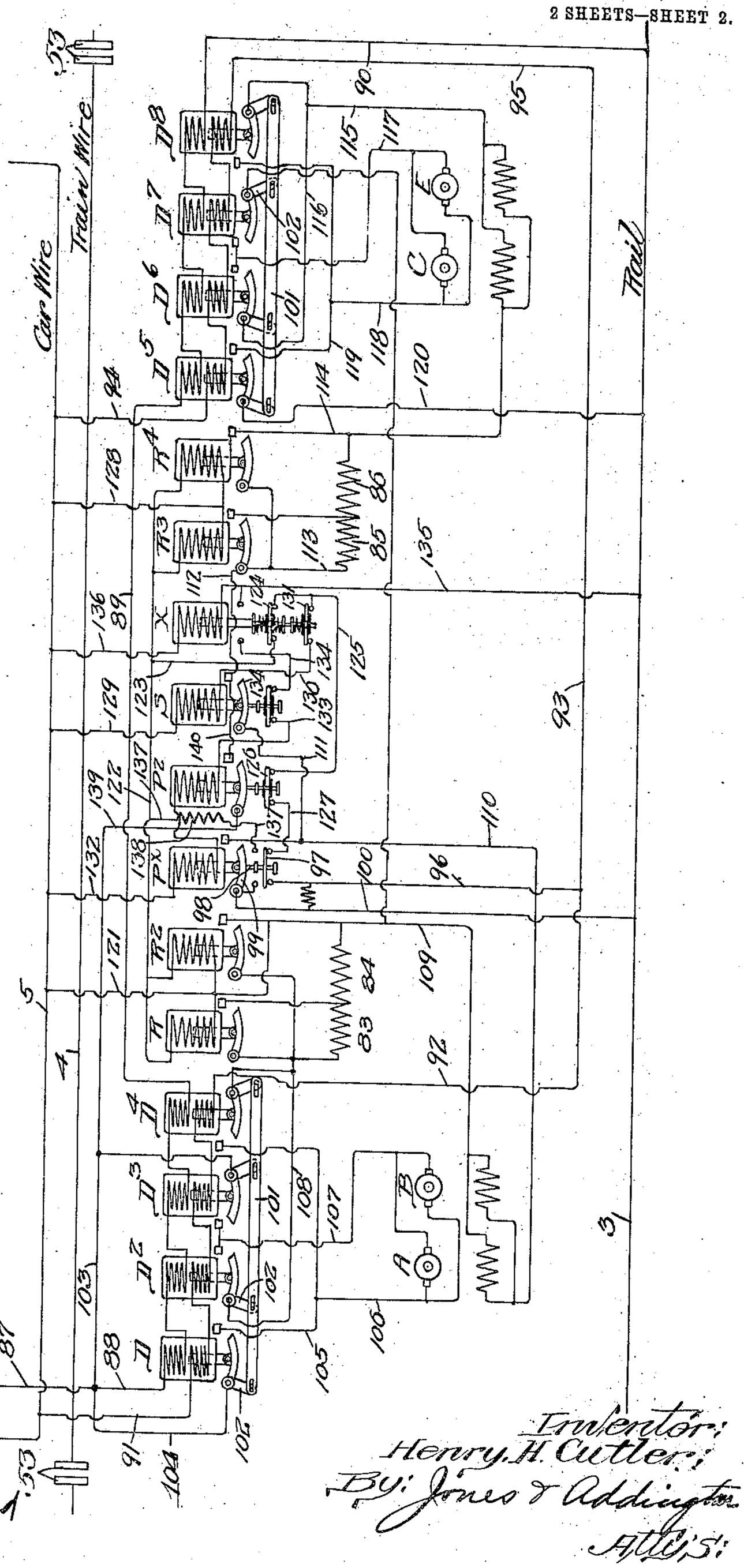
SYSTEM FOR CONTROLLING ONE OR MORE ELECTRIC MOTORS.

APPLICATION FILED AUG. 11, 1905.

903,178. **Patented Nov. 10, 1908.**

2 SHEETS—SHEET 2.

Fig. 2.



Witnesses:
Robert F. Ellis
M. R. Rochford.

Inventor:
Henry H. Cutler.
By: Jones & Addington
Atty's.

UNITED STATES PATENT OFFICE.

HENRY H. CUTLER, OF MILWAUKEE, WISCONSIN, ASSIGNOR TO THE CUTLER-HAMMER MFG. CO., OF MILWAUKEE, WISCONSIN, A CORPORATION OF WISCONSIN.

SYSTEM FOR CONTROLLING ONE OR MORE ELECTRIC MOTORS.

No. 903,178. Specification of Letters Patent. Patented Nov. 10, 1908.

Application filed August 11, 1905. Serial No. 273,838.

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 new and useful Improvements in Systems for Controlling One or More Electric Motors, of which the following is a full, clear, concise, and exact description, reference being had to the accompanying drawing, forming a part of this specification.

My invention relates to improvements in systems for controlling the operation of one or more motors, particularly in connection with a multiple-unit-train-control system.

In a companion application, Serial No. 273,837, filed August 11, 1905, I have shown and described a system of controlling one or more electric motors, particularly designed for multiple-unit-train-control, in which the operation of the various electro-magnetic-switches employed to directly control the driving motors are themselves suitably controlled by variations of voltage impressed upon the train wire, or controlling circuit of the train. In such system, each car of the train is preferably equipped with a complete apparatus, so that any car may be employed as the operator's car of the train, although when the train is made up, the motor generator set, which forms a part of the car equipment, upon the operator's car only is used, and this is required to furnish current for the various devices upon all of the cars of the train. It is thus apparent that each motor generator, although idle except in the first car in the train, must be of sufficient size and capacity to furnish current for the control of all the cars of the train, and also for the greatest number of cars that may ever be included in a train. In the present system, each car is also preferably equipped as before, with identical apparatus, and the motor generator set is preferably included as a part of such apparatus; but the arrangement is such, that each such set furnishes current for the operation of the switches, etc., upon its own car, thereby permitting the use of smaller and cheaper generator sets, since not so much work is required of them, and the amount of current that they are required to develop is a practically fixed and known quantity no matter what the length of the train. With this arrangement, the operator's motor generator set is preferably arranged to supply current to the train wire or equivalent circuit, but only for the energization of the field windings of the generators of the other sets of the train, and of course this is only a small fraction of that required where all devices are to be operated by current from the train wire. The control of the train is thus obtained by variations of voltage upon the train wire as in the system of my companion application, but through the intermediation of the motor generator sets upon each car. As will be shown hereinafter, these motor generator sets are subject to a still further reduction in size and capacity due to the fact that they are required to supply their maximum output for only an instant of time, and may therefore be overloaded with safety for such short time.

The present system, like the system of my said companion application secures the control of the various devices necessary to obtain the various speeds of the train and its direction of travel, by checking the rise in voltage of current upon the train wire at predetermined amounts, whereby the control of the train is rendered entirely independent of any fluctuations of current upon the trolley circuit, which fluctuations may be reproduced in the train wire or controlling circuit. As soon as the desired limit of voltage upon the train wire is secured and the proper devices throughout the train have operated, the voltage is automatically reduced to prevent any further possible rise in voltage beyond the desired amount, to economize current, and to permit the use of smaller magnetic devices throughout, as well as to eliminate all lamp safety switches and similar devices. This feature I broadly claim in my said application, the present invention bearing the relation to that of the said application, of species to genus.

Other features and advantages of the present invention will appear from the detailed description of the drawings and the claims.

In the accompanying drawings, Figure 1 is a diagram of a portion of the apparatus upon each car, said apparatus including that involved in the control of the voltage upon the train and car wires, as well as the direction of current flow in said wires, and by means of

which the speed and direction of movement of the train is controlled, and Fig. 2 is also a diagram showing the remainder of the apparatus for each car, and which serves to control the operation of the driving motors.

Referring to Fig. 1, the trolley is indicated at 2, the rail which forms the return circuit for most of the apparatus at 3, the train wire at 4, and the car wire at 5. The latter terms are applied to these wires for convenience, the train wire being the only one extending between the cars and throughout the train, while the car wire is that to which the solenoid switches of Fig. 2 are directly connected. A motor-generator set 6 is mounted upon each car, the motor being operated from the trolley circuit and the generator portion thereof has its armature connected with the said car wire 5 in order to supply current thereto and in the case of the operator's car as will be hereinafter pointed out, to the train wire also. The field windings of the generator portion of this motor generator 6 is adapted to be suitably magnetized at the will of the operator to control the output of the said generator and thereby to control the voltage upon the train wire, from which the corresponding motor generator sets upon the other cars of the train are actuated or controlled, and which in turn control the voltages upon the car wires of the other cars. At each end of the car is located a master controller 7, a starting switch 8^a and a plurality of voltage controllers V, V^2 and V^3, which check and secure the automatic reduction of voltage upon the train wire 4 and therefore upon the car wires 5, to suitably control and operate the various solenoid switches shown in Fig. 2 to secure the proper speed and operation of the driving motors.

The master controller is provided with an operating-lever 8, carrying a plurality of brushes adapted to be engaged with the various contacts disposed in the path of movement of the said brushes when the lever is rotated in either direction. The direction of rotation of the lever controls the direction of travel of the train. The voltage regulators V, V^2 and V^3 control short circuiting switches of resistances 9, 10 and 11, said resistances being of sufficient amount to secure the automatic reduction of voltage upon the train wire when they are included in the circuit. The starting-switch 8^a is provided with a lever 12, adapted to be returned to its normal position at which it stands in the drawings by means of a suitable spring, and which is held in its "on" position by a retaining magnet 13 suitably energized at such time. Any failure of current in the said retaining magnet permits the lever to return to its normal position.

In order to start the train, the operator closes the starting switch upon his car, thereby furnishing current to the motor 14 of the motor generator set 6. This closes a path for current from the trolley 2, via conductors 15 and 16 to the lever 12 of the starting switch 8^a, thence to contact 17, wires 18 and 19, the motor starting resistance 20, armature 21 and wire 22 to the rail 3. Current is also supplied through a parallel connection upon the contact 17 of the starting-switch through the retaining-magnet 13, wires 23 and 24 to the shunt field winding of the motor 14, and thence by wire 22 to the rail 3. The current in these paths suffices to start the motor-generator operating, and as soon as its counter electro-motive force builds up the solenoid switch 25, which has its winding connected across the brushes of the armature 21, is operated thereby closing a path for current from the trolley 2 over conductors 15 and 26, wire 27, bridging contact 28 of switch 25, wire 29 and thence directly through the armature 21 and wire 22 to the rail 3. This path for current does not include the starting-resistance 20 which therefore permits the full trolley current to flow through the armature of the motor, and thus operates the motor generator upon the operator's car at full speed. At this time, the generator 30 of the motor generator 6 has its armature 31 connected upon one side by conductor 32 and wire 22 with the rail 3 and upon the other side by conductor 33 with the car wire 5, but is not delivering current to the car wire for the reason that its field winding 34 is not yet energized.

In order to start the car, the operator now moves the lever 8 of the master controller 7 in one direction or the other. Assuming that it is moved clockwise, a path for current is immediately provided from the trolley 2 through the field winding of the generator 30, via conductor 15, resistance 35, wire 36 in the master controller, the resistance 37 of the master controller, contact 38 upon the controller lever, segmental contact 39, conductor 40, short-circuiting contacts of the voltage controllers V^3, V^2 and V, wire 41, conductor 42, thence through the field winding 34, conductor 43, wire 44, segment 45 of master-controller 7, contact 46 of the lever 8, segmental contact 47, and wire 48 to the rail 3. The current in this path therefore causes the magnetism of the field winding of the generator 30 to build up, thus causing the armature 31 to deliver current to the car wire 5, and also to the train wire 4, since with the lever of the starting-switch 8^a in the running position, said car wire 5 is connected by contacts 49, 50 upon the lever and 51 and by wire 52, with the said train wire 4, and therefore the latter receives current upon the operator's car as soon as current is delivered to its car wire.

The delivery of current to the train wire upon the operator's car furnishes current to the corresponding wires of the other cars of

the train since said wires are connected together preferably by automatic couplers 53. As a result of this, the motor generators located upon the various cars of the train are operated. This may be seen by considering for the moment that the apparatus of Fig. 1 belongs to one of the other cars of the train. Current immediately flows from train wire 4 over conductor 54, through the winding of solenoid switch 55, thence by conductor 56, insulated contact 57, upon the stem of switch 25, and conductors 58 and 22 to the rail 3. This switch 55 for each car of the train is therefore operated and closes a path for current directly from the trolley 2, over wires 15, 26 and 27, contact 59, wire 60 thence through starting resistance 20, armature 21 of motor 14 and conductor 22 to the rail. At the same time, current divides before passing through the resistance 20, and takes the parallel path over conductors 19 and 18, contact 17 of starting-switch 8[a], retaining-magnet 13, wires 23 and 24, and thence through the field winding of the motor 14. Thus the motor upon each train is started, and as soon as the counter electromotive force builds up sufficiently, switch 25 is operated to close the circuit directly from the trolley over conductors 15, 26 and 27, contact 28 and conductor 29 through the armature of the motor, thereby cutting out the resistance 20 and permitting the motor to attain full speed. In this operation of switch 25, contact 57 is lifted to break the circuit of switch 55, thus deënergizing the same, and protecting its windings from the fluctuations of voltage constantly occurring on the train wire.

The field windings of the generators 30 upon the cars of the train other than the operator's car are now connected between the train wire and the rail. This connection may be traced from the train wire 4 over conductor 52, contact 60 of starting box 8[a], contact 50 upon the lever 12, contact 61, conductor 62, contacts 60, 50 and 61 of the starting-switch 8[a] at the opposite end of the car, conductor 63, wires 41 and 42, thence through the field winding 34 of generator 30, conductor 43, wire 44, conductor 64, contact 65 of starting-switch 8[a] at the right end of the car, insulated contact 66 upon the lower end of the lever 12 of said starting switch, contact 67, wire 68, contacts 67, 66 and 65 of the starting-switch 8[a] at the left hand end of the car, conductor 69, contact 70 of controller 7, wire 71, contact 47 and wire 48 to the rail 3. This path for current insures that the field of the generator upon this car shall be subjected to the same voltage as that upon the operator's car, and further that all of the motor generators throughout the train will have their field windings energized to the same extent, and that the output of the said generators and therefore the voltage of the various car wires throughout the train will be the same. It will be understood from the foregoing that the motor generator upon the operator's car furnishes current to its own car wire and to the train wire for the entire train and therefore for the energization of the field windings of the various generators throughout the train, while the motor generators upon the other cars of the train furnish current to their individual car wires only. This added effort of the motor generator upon the operator's car, however, is very slight, since but a very small amount of current is required for the magnetization of the field windings of the remaining motor generators. The number of cars in the train may therefor be increased to any extent so far as this feature of the system is concerned.

As will be hereinafter explained, certain of the solenoid switches shown in Fig. 2 are adapted to be operated at one voltage of the car wire to secure the lowest speed of the train and its direction of movement, certain other of said switches respond to a still higher voltage of the car wire to secure the second speed of the train and other solenoid switches respond to a still higher voltage of the car wire to secure the highest or maximum speed of the train. These various operations will be pointed out in connection with Fig. 2 when reached in the description of the apparatus of that figure, and are mentioned here merely to make clear the object of varying the voltage upon the train wire as will now be described.

Returning to the operator's car, it will be noted that the voltage regulators V, V[2] and V[3] are included directly between the train wire and the rail, and are therefore subjected to the voltage of the former. Thus the wire 52 leading from the train wire 4 is joined by a conductor 72 with one terminal of each of the regulators V, V[2], and V[3], whose other terminals are joined respectively by conductors 73, 74 and 75, with contacts 76, 77 and 78 of the master controller 7, which are linked by connecting wires with the similar contacts 79, 80 and 81 upon the other side of the lever 8. Thus, when the lever 8 is rotated sufficiently so that its brush engages contact 79, the path for current from the wire 73 is completed through the contact 46 of the lever 8 to contact 47, and thence by wire 48 to the rail 3. These voltage regulators are adjusted by any suitable or desired means, either mechanically or electrically to respond to the different voltages of current on the train wire and flowing through their windings; for instance, the regulator V responds to the voltage or to only a slight increase of voltage over that at which it is desired the first set of solenoid switches of Fig. 2 should respond. As soon as said solenoid switches have responded therefore and the lowest speed of the train is secured, said regulator V is operated and cuts into the circuit of the

field winding 34 of the motor generator 30 the resistance 9 controlled thereby. This resistance 9 is of sufficient amount to check and greatly cut down the output of the generator 30 and therefore checks and cuts down the voltage of the car wire upon the operator's car and upon the train wire extending throughout the train. The latter as we have just pointed out, correspondingly affects the several motor generators in the train which in turn reduce the voltages of the car wires of the several cars. The said switches of Fig. 2 are thus subjected for only an instant to the voltage necessary to operate them and consequently do not overheat, and the consumption of current is greatly reduced. Moreover, the checking of the rise of voltage upon the train wire and the car wires renders the control of said switches of Fig. 2 entirely independent of the fluctuations of current that occur in the trolley circuit and likewise on the car wires, thereby effectually preventing the undesired operation of the said switches.

The next higher speed of the train is secured by a further rotation of the controller lever 8 thereby cutting out more of the controller resistance 37 and short-circuiting the resistance 9 by deënergizing solenoid V as the brush at the end of the lever passes from the contact 79, thus permitting the stronger current to pass through the field winding of the generator 30 and thereby to increase the voltage upon the car wire of the operator's car as well as the train wire throughout the entire train. As before pointed out, the increase of voltage upon the train wire causes an increase in the magnetism of the field windings of the generators 30 throughout the train, and raises the voltage of the car wires of the various cars. In response to this increased voltage upon the car wires, the second set of solenoid switches shown in Fig. 2 are operated and cause the driving motors to operate at the next higher speed. As soon as these switches of the second series have operated and the controller lever 8 reaches the contact 80 the second voltage regulator V^2 is subjected to the voltage of the train wire and as soon as it increases sufficiently, said regulator is operated and cuts its resistance 10 into the circuit of the field windings of the generator 30, thereby automatically reducing the voltage of the car wire and the train wire, the latter in turn decreasing the output of the motor generators throughout the train and automatically checking and decreasing the voltage upon the car wires. It should be understood that when this automatic reduction of voltage occurs at any of the various stages of the operation, that sufficient current still flows to maintain in operated condition, the switches that have already been operated. It is well understood that current may be reduced to as much as one-tenth of that required to initially operate such devices and still maintain them operated.

The third and maximum speed for which I have shown my apparatus adapted, although any desired number of speeds may be obtained by increasing the various parts and employing the same principles, is secured by the further rotation of the master controller lever 8, which excludes the remainder of resistance 37 of said controller as well as the resistance 10, controlled by regulator V^2, and consequently builds up the field winding of the generator 30 to its greatest extent. As before pointed out, the various motor generators respond to the increased voltage upon the train wire, and correspondingly affect their respective car wires. When the last series of solenoid switches have responded to this higher voltage, and the rear brush of the master controller 7 has reached its contact 81 the voltage regulator V^3 operates to include its resistance 11 in the circuit of the field winding of the motor generator 30, thereby again automatically checking and reducing the voltage of the train and car wires.

Since the direction of travel of the train is controlled by the direction of current in the train wire, it will be seen that the latter may be reversed by operating the lever 8 of the controller 7 in the reverse direction, so that the current through the field winding 34 of the motor generator 30 is reversed. This circuit may be traced from trolley 2, wire 15, resistance 35, thence direct through the resistance 82, contact 38, segmental contact 45, wire 44, conductor 43, thence through the field winding 34 in the direction opposite to that before traced, thence over wires 42 and 41, short-circuiting switches of regulators V, V^2 and V^3 conductor 40, contact 39, contact 46 upon lever 8, contact 70, wire 71, contact 47, and wire 48 to the rail 3. The continued rotation of the master controller lever 8 results in imparting to the train, the three speeds before described but in the reverse direction.

It is to be noted that a slight difference exists in the manner of connecting the master controller with the motor starting switch on one end of the car from that of the same apparatus at the other end of the car, but the two sets of apparatus are connected so as to function with one another to make a complete system. Each car of the train, however, is equipped identically the same as every other and, as shown in the diagrams of Figs. 1 and 2, the only connection between the cars being confined to the couplings at the end of the single train wire 4.

Turning now to Fig. 2, the various switches which are preferably of the solenoid type are here shown as controlling the driving motors A, B, C and E at the opposite ends of the

car. The switches indicated by the characters D, D², etc., control the direction of current flow through the armatures of the motors; those marked R, R², etc., control the inclusion and exclusion of the resistances 83, 84, 85 and 86 with respect to the motor circuits; those designated as P and P² serve when energized to complete the parallel connection of the motor sets between the trolley and rail, and that marked S serves to control the series relation of said motor sets with respect to each other. The various circuits through these switches are in general controlled by the relay X. The reversing switches D, D², etc., each has an upper winding connected between the trolley 2 and the rail 3 by conductors 87 and 88 on the left, thence by conductor 89 leading to the right hand series, and thence by conductor 90 to the rail. The current in these windings, however, is insufficient to cause them to attract their plungers. Lower windings are therefore provided for each of these switches connected between the car wire 5 and the rail 3. Thus at the left the wire 91 extends between the car wire 5 and the said windings, which are then connected by wire 92 with wire 93. The similar windings of right hand reversing switches are connected by wire 94 with the car wire and upon the reverse side by wire 95 with said wire 93. From the latter wire the path for current is continued through the medium of conductor 96, non-insulated conductor 97, stem 98 of switch P, pivoted contact 99, and thence by wire 100 to the rail 3. These reversing switches are adjusted to respond to the lowest train wire voltage which is reached just before the first voltage regulator V of Fig. 1 is operated, but since the lower windings upon switches D³ and D⁴ and upon D⁷ and D⁸ are opposed to the upper windings these switches will not be operated at the present time if the current is flowing in the same direction between the trolley 2 and the rail 3 as between the car wire 5 and the rail 3, so that only the switches D, D² and D⁵, D⁶ are now operated. A mechanical interlock is provided for the reversing switches at each end of the car, said interlock comprising bars 101 having slots therein, through which pins project that are mounted upon the levers 102 permanently secured to the contact arms of the solenoid switches. It is obvious from this arrangement that when the switches D and D² are operated, switches D³ and D⁴ are prevented from operation, and likewise that if the latter pair were operated, the former could not operate. This interlock is duplicated at the other end of the train, thus serving to prevent both pair of switches operating at the same time, and thereby possibly short-circuiting the motors and likewise disarranging the circuit connections.

The series solenoid S is adjusted to respond to this same voltage. After these switches have operated the voltage upon the car wire is reduced as a result of the operation of the voltage regulator V shown in Fig. 1, but the several solenoids maintain their plungers in their uppermost positions.

The circuit through the motors may now be traced from the trolley 2 over wire 87, conductor 103, wire 104, closed contacts of switch D, conductors 105 and 106, thence through the armatures of the motors A and B, conductor 107, contacts of switch D², conductor 108, thence through resistance 83, 84, conductor 109, through the field windings of the motors A and B, conductor 110, wire 111, closed contacts of the series switch S, conductor 112, wire 113, resistance 85, 86, conductor 114, thence through the field windings of the motors C and E at the opposite end of the train, conductors 115 and 116, closed contacts of switch D⁶, conductor 117, thence through the armatures of the motors C and E, thence by conductors 118 and 119, closed contacts of the switch D⁵, and thence by way of conductor 120 to the rail 3. It is thus observed that the motor sets are in series with each other, and that the controlling resistances are in circuit. This is the slowest running speed of the train.

When the voltage of the car wire is raised to secure the next speed, the resistance controlling switches R and R², associated with the motors A and B, and the corresponding switches R³ and R⁴ at the other end of the car are operated to cut out the resistances controlled thereby. Current for this purpose passes from the car wire 5 over conductor 121, thence through the coils of switches R and R² in parallel to conductor 122, thence by way of conductor 123 insulated contact 124 carried upon the stem of the relay X, conductor 125, insulated contact 126 on the stem of switch P², wire 127, non-insulated contact 97, stem 98, contact 99, and wire 100 to the rail 3. The switches R³ and R⁴ are likewise operated from the car wire 5 over conductor 128, and thence through the windings of said switches in parallel to the wire 122, and thence over the remainder of the path just traced. The operation of these switches eliminates the resistance sections 83, 84, 85 and 86 from the motor circuits, and permits said motors to operate at a higher speed although they are still in series with each other. The resistance controlling switches preferably operate in the order named to cut out the resistance gradually. As soon as these switches have been operated, the voltage regulator V² upon the operator's car is actuated thereby automatically checking the rise of voltage upon the train wire and the car wires, and cutting it down, but at the same time permitting sufficient current to flow to maintain the switches operated.

The next higher speed of the train is se-

cured by connecting the motors in parallel between the trolley and rail. This is accomplished at the third voltage of the train wire. The relay X is the first switch to respond to this higher voltage, and accomplishes various results in so responding. In the first place, the series switch S which has been energized by current from the car wire 5, flowing over conductor 129 to one terminal of said switch winding, and thence from the other terminal over conductor 130 and contact 131, upon the stem of the relay X, and thence over wire 125, etc., to the rail 3, is now deënergized by the breaking of its circuit at contact 131 of the relay X. Similarly the path for current through the resistance controlling switches R, R^2, etc., is opened at contact 124 of said relay X. These switches are therefore deënergized and the resistance re-inserted in the motor circuit. At the present instant therefore, the motors are entirely disconnected from the circuit. The operation of the relay X however, carried its contact 124 into engagement with its upper stationary contacts, thereby completing a path for current through the paralleling switches P, P^2 from the car wire 5, over conductor 132, thence through the windings of paralleling switches P, P^2, thence by conductor 133, contact 134 carried upon the stem of the series switch S and which is now in its lowermost position, conductor 134, contact 124 of relay X, and thence by way of wire 135 to the rail 3. It should be mentioned that the relay X is energized by current from the car wire 5, flowing over conductors 136 and 135 to the rail 3, this connection being permanent, but the relay not responding to the weaker currents heretofore flowing through the same. As soon as the switch P is operated, its contact 97 is carried into engagement with upper contact, thereby completing another path for current from wire 122, over wire 137 through resistance 138 and thence by way of contact 97 and conductor 100 to the rail 3. The resistance controlling switches R, R^2, R^3 and R^4, are thus permitted to now operate over this second path, containing the resistance 138, and to cut out the resistances 83, 84, 85 and 86. The resistance 138 may be made large enough to prevent the operation of the resistance controlling switches R, R^2, etc., until a slightly higher voltage on the car wire is reached.

The circuits through the motors may now be traced as follows: Beginning at the left, current flows from the trolley 2, wires 87, 104, 105 and 106 through the armatures of motors A and B, conductors 107 and 108, short circuiting switch R^2, conductor 109, thence through the field windings of the motors, conductor 110, closed contact of switch P, and thence by way of conductor 100 to the rail 3. The motors at the other end of the car have their circuit completed from trolley 2, over wires 87, 103, 139, closed contact of switch P^2, wires 140, 112 and 113, short-circuiting contacts of switch R^4, conductor 114, the field windings of motors C and E, wires 115, 116 and 117, through the motor armatures, wires 118, 119 and 120 to the rail 3. Thus both motor sets are connected directly between the trolley and the rail 3 with the resistance cut out of circuit so that their highest speed is obtained. As before mentioned, the switches R, R^2, R^3 and R^4 are so adjusted as to cut out the resistance sections in the order named. After these changes of the circuit connections have taken place, the voltage upon the car wire 5 is automatically reduced.

When the current through the lower windings of reversing switches D, D^2, etc., is reversed in direction, the other pairs are energized and the first pairs deënergized, this serving to direct the current through the motor armatures in the reverse direction, while still flowing in the same direction through the field windings. No other change in the cycle of operations is caused by this reversal of current, except to change the direction of travel of the train.

The apparatus thus operated at the higher voltage of the car wire constitutes in effect an electrical interlocking mechanism, since it prevents the operation of the solenoid switches in any except the proper order. For instance, in changing over from the series to the parallel relation of the driving motors, it is necessary to first open the circuit of the motors, and before connecting them to the circuit in parallel relation, to interpose their starting resistance. Thus, the operation of the relay X opens both the circuit of the series solenoid S and of the resistance solenoids R, R^2, etc. Furthermore, the paralleling solenoids P and P^2 cannot become energized until the plunger of the series solenoid S has dropped and thereby closed the circuit of said paralleling solenoid. Having thus disconnected the driving motors from the circuit and re-introducing the starting resistance, it then becomes safe and only then, to energize the paralleling solenoids P and P^2. In passing from the parallel relation to the series relation of the driving motors, it is also impossible for the winding of the series solenoid to become energized until both plungers of the paralleling solenoids have dropped, and thus closed the circuit of solenoid winding S. The plunger of the relay solenoid X is also obliged to drop before the circuit can be completed through the winding of the solenoid S. Thus, the operation of the various switches in a definite order is insured.

As was explained in connection with Fig. 1 it is evident that the windings of none of the solenoids are subjected to the voltage necessary to actuate them for any appreci-

able length of time, for as soon as this voltage has been applied and the solenoids have responded thereto, the voltage regulators immediately cut down the voltage on the train wire which results in a corresponding reduction upon the car wires and leaves only a sufficient voltage on such car wires to allow the solenoids to retain their plungers in their uppermost positions. Of course, very much less current is necessary to accomplish this latter result than the amount required to actuate the solenoids when their plungers are in their initial position.

As a result of the system thus described, smaller motor generator sets may be employed than in some other systems, such for instance as that described in my pending application, since each set supplies its own car with current for operating its own solenoid switches. Moreover, since such motor generators are required to develop their maximum output for only a few seconds of time, they may be overworked or worked beyond the usual limit for that short time without danger or harm to them. It is evident also, that with this arrangement the cars may be turned end to end without affecting the direction of travel of the same, with respect to the remainder of the train since if the car is reversed, the current is through its train wire, also reversed and the direction of travel is the same as before.

Any suitable form of solenoid switches may be employed, and any type of starting switches and controlling switches may be used. The controlling switch is one preferably having a spring or other means to return the lever to normal position as shown in Fig. 1 of the drawing, when released from the hands of the operator. These various apparatus are so well known to those skilled in the art as not to require further description or illustration.

It is to be understood that the present system may be applied to the control of one or more electric motors or other instrumentalities used in other relations than herein specified or connected in either an alternating current power circuit or a direct current power circuit. Various other alterations, changes, modifications and substitutions may be made in the construction and arrangement of the various parts and circuits without departing from the spirit or scope of my invention.

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

1. In a multiple-unit-train-control system, the combination with a plurality of cars having driving motors therefor, of electro-magnetic switches on each car responsive to different voltages of current to control said motors, a separate source of current supply for the switches of ~~each~~ car, means within the control of the train operator for varying the voltage of current supplied to said switches, and means whereby the control of said switches is rendered independent of fluctuations of current that may occur in their circuits.

2. In a multiple-unit-train-control system, the combination with a plurality of cars having driving motors therefor, of electro-magnetic switches on each car responsive to different voltages of current to control said motors, a separate source of current supply for the switches of each car, means within the control of the train operator for varying the voltage of the current supplied to said switches, and means for checking the rise of voltage through the windings of said switches at the desired times to render them independent in operation of the fluctuations of current in their circuits.

3. In a multiple-unit train control system, the combination with a plurality of cars having driving motors therefor, of electro-magnetic switches on each car responsive to different voltages of current to control said motors, a separate source of current supply for the switches of each car, means within the control of the train operator for varying the voltage of current supplied to said switches, and means for checking the rise of and reducing the voltage through the windings of said switches at the desired times to render them independent of fluctuations of current in their circuits.

4. In a multiple-unit train control system, the combination with a plurality of cars having driving motors therefor, of electro-magnetic switches on each car responsive to different voltages of current to control said motors, a separate source of current supply for the switches of each car, means within the control of the train operator for varying the voltage of current supplied to said switches, and means for automatically reducing the voltage upon the circuits of said switches to the desired amounts.

5. The combination with a plurality of cars having driving motors therefor, of electro-magnetic switches for each car responsive to different voltages of current, a circuit for each car to which said switches are connected, a separate source of current supply for each car to furnish current to said circuit to control the operation of said switches, means under control of the operator for varying the voltage of current supplied to said car circuits, and means for rendering the desired operation of said switches independent of fluctuations of current upon said car circuits.

6. The combination with a plurality of cars having driving motors therefor, of electro-magnetic switches upon each car to control the motors, a circuit for each car to which said switches are connected, a source

of current supply upon each car to furnish current to said circuit for the operation of said switches, a controlling circuit extending throughout the train from which said sources of current are controlled, means whereby the operator is enabled to vary at will the voltage upon said controlling circuit and thereby the voltage supplied to the car circuits to thus suitably operate the said switches, and further means for rendering said control of the switches independent of the fluctuations of current that may occur upon said circuits.

7. The combination with a plurality of cars having driving motors, of a plurality of electro-magnetic switches upon each car to control the driving motors, a motor-generator set upon each car to supply current for the operation of the switches upon the same car, the motors of said sets being driven from the trolley circuit, means under the control of the operator, to vary the voltage supplied by the generator of the sets to said switches, and means for rendering the desired operation of said switches independent of the fluctuations of current upon the trolley circuit.

8. The combination with a plurality of cars having driving motors, of a plurality of electro-magnetic switches upon each car to control the driving motors, a motor generator set upon each car to supply current for the operation of the switches upon the same car, the motors of each set being driven from the trolley circuit, means under the control of the operator to vary the voltage supplied by the generators of the sets to said switches, and means for automatically reducing the voltage supplied to the switches after each desired operation of the same.

9. The combination with a plurality of cars having driving motors, of electro-magnetic switches upon each car to control the operation of said motors, a motor generator set upon each car to supply current to the switches for their operation, the motors of said sets being driven from the trolley circuit, a controlling circuit extending throughout the train, means to enable the operator to control through the medium of said controlling circuit the voltage of current delivered by the generators of the said sets to said switches, and means for automatically reducing the voltage supplied to the switches at each desired operation of the same.

10. The combination with a plurality of cars having driving motors, of a plurality of electro-magnetic switches upon each car to suitably control said motors, said switches being selectively operated by different voltages of current, a circuit upon each car to which said switches are connected, a motor generator set upon each car driven from the trolley circuit and arranged to furnish current to said car circuit for the operation of said switches, a controlling circuit extending throughout the train, and furnishing current for the excitation of the field windings of the generators of the several sets, means under the control of the operator for varying the voltage upon said controlling circuit and thereby the voltages impressed upon the car circuits by said generators to suitably operate said switches, and means for automatically reducing the voltage upon said controlling circuit after each desired operation of the switches.

11. The combination with a plurality of cars having driving motors, of electro-magnetic switches upon the car to suitably control the motors, a separate source of current supply upon each car to furnish current for the operation of said switches, and means to enable the train operator to control the operation of said switches, said means including a circuit extending throughout the train and consisting of one wire only.

12. The combination with a plurality of cars having driving motors, of electro-magnetic switches controlling the said motors, a separate source of current supply for each car to furnish current for the operation of the switches, a controlling circuit consisting of one wire only extending throughout the train, means to enable the operator to control through the medium of said wire the operation of said switches, and means to render the control of said switches independent of fluctuations of current.

13. The combination with a plurality of cars having driving motors, of electro-magnetic switches upon each car to suitably control the motors, a motor-generator set upon each car driven from the trolley circuit to furnish current for the operation of said switches, a controlling circuit extending throughout the train, consisting of one wire only with which said generators are connected, means to enable the train operator to vary the voltage upon said controlling circuit and thereby the voltage of current furnished to said switches and means for causing the automatic reduction of voltage supplied to said switches after each operation.

14. The combination with a plurality of circuits, of a plurality of electro-magnetic windings connected with said circuits selectively responsive to different voltages, a separate source of current supply for each said circuit, and means for rendering the operation of said devices at the desired voltages independent of undesired fluctuations of current upon the circuit.

15. The combination with a plurality of circuits, of a plurality of electro-magnetic windings connected with said circuits responsive to different voltages, a separate source of current supply for each said circuit, and means for automatically reducing the voltage upon said circuits after said windings have been subjected to the desired voltages.

16. The combination with a plurality of electric motors adapted for simultaneous and corresponding operation, of electro-magnetic switches associated with the different motors to control their operation, said switches being responsive to the different voltages of operating current, a circuit for each group of switches, a separate source of current supply for each said circuit, means for controlling from one point the voltage impressed upon said circuits from said sources of current supply, and means for reducing the voltage successively supplied to said switches after they have been suitably operated.

17. The combination with a plurality of controlling circuits, of a separate source of current supply for each of said circuits, means for simultaneously impressing like voltages upon each of said circuits, and means for automatically reducing said voltages upon each of said circuits after said voltages have been applied thereto.

18. The combination with a plurality of separate controlling circuits, of a plurality of electro-magnetic windings connected with each of said circuits adapted to respond to the variations of voltage therein, means for simultaneously impressing at will like voltages upon each of said circuits, and means for automatically reducing the said voltages after they have been applied thereto.

19. The combination with a plurality of cars having driving motors, of a plurality of switches upon each car to control the operation of said motors and adapted to be selectively operated by different voltages of current through their windings, a separate source of supply for each car operated from the trolley circuit to supply current to switches of that car, means under the control of the train operator to vary the voltage of current so supplied to the said switches, and means to render the desired operation of said switches independent of the fluctuations occurring upon the trolley circuits.

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

HENRY H. CUTLER.

Witnesses:
J. F. HAWKINS,
T. E. BARNUM.