No. 660,066. Patented Oct. 16, 1900.

F. J. SPRAGUE.

METHOD OF REGULATING MOTORS.

(No Model.) 2 Sheets—Sheet 1.

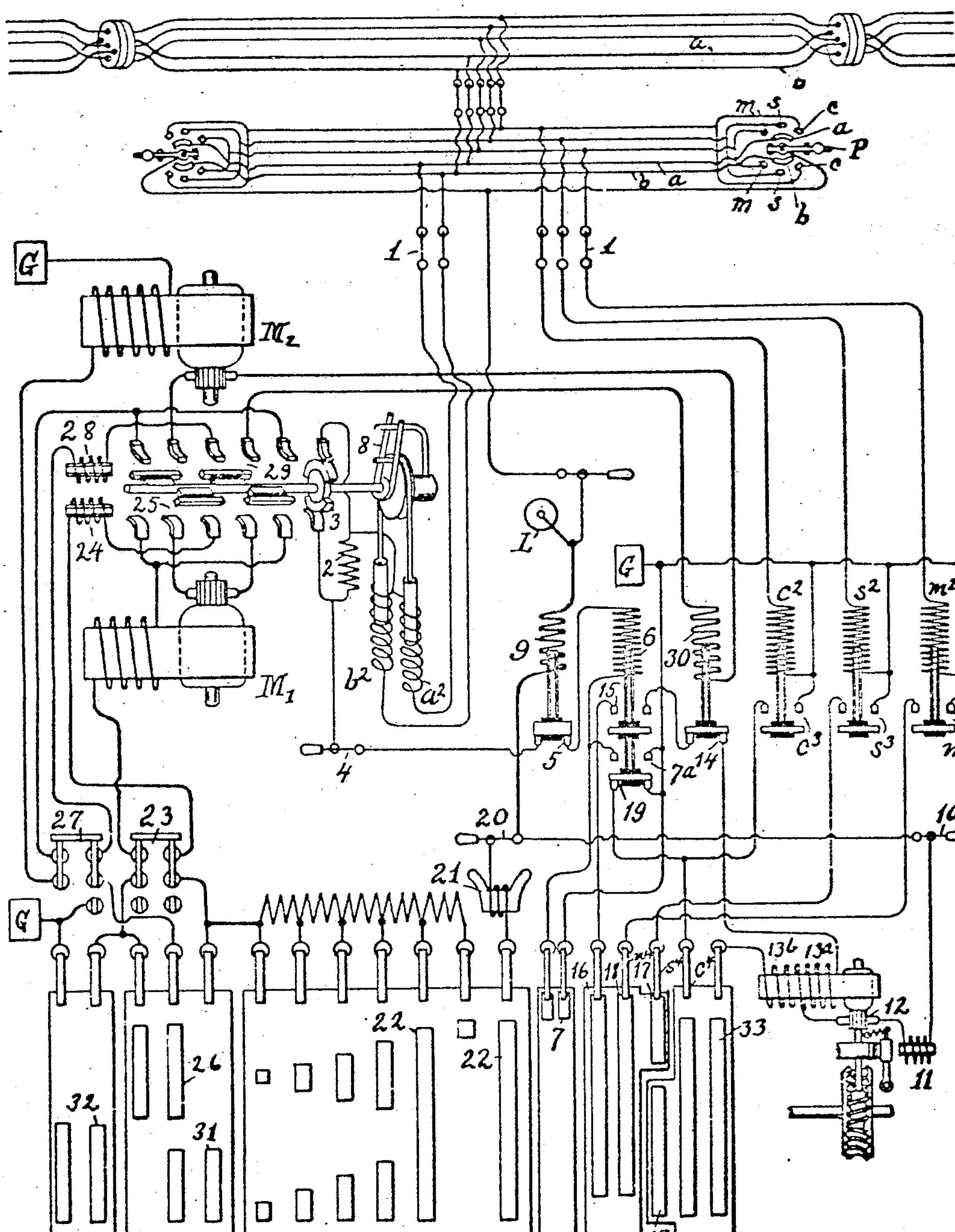

Fig. 1.

Witnesses:

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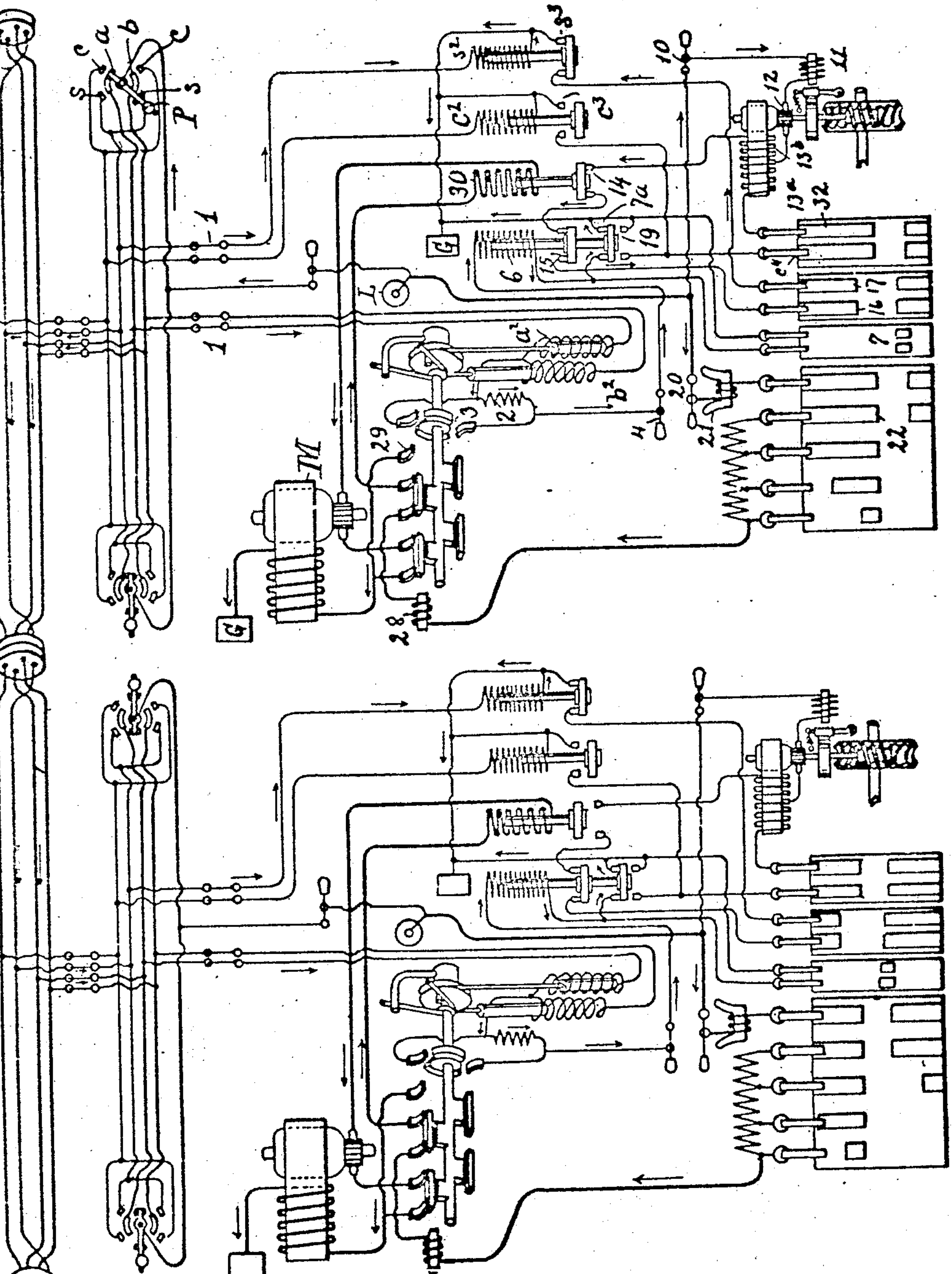

Witnesses:
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Fig. 2.

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UNITED STATES PATENT OFFICE.

FRANK J. SPRAGUE, OF NEW YORK, N. Y., ASSIGNOR TO THE SPRAGUE ELECTRIC COMPANY, OF NEW JERSEY.

METHOD OF REGULATING MOTORS.

SPECIFICATION forming part of Letters Patent No. 660,066, dated October 16, 1900.

Original application filed April 30, 1898, Serial No. 679,239. Divided and this application filed June 23, 1900. Serial No. 21,341. (No model.)

To all whom it may concern:

Be it known that I, FRANK J. SPRAGUE, a citizen of the United States of America, and a resident of the city of New York, borough of Manhattan, in the county of New York and State of New York, have invented certain new and useful Improvements in Methods of Regulating Motors, (for which I have received foreign patents in France, No. 278,105, dated May 20, 1898, and in Great Britain, No. 11,158, dated May 16, 1898, and have filed an application in Germany, dated May 24, 1898,) of which the following is a specification.

This application is filed by way of division of my former application for improvements in traction systems, Serial No. 679,239, filed April 30, 1898. The system is fully illustrated and described in my British patent, No. 11,158, of May 16, 1898.

In my earlier application there is set forth what I have called a "multiple-unit" system of operating railways. A characteristic feature of the multiple-unit system is that each fully-equipped car is a unit and that a train made up of such cars is a unit having all of the characteristics of the car without any limitations being imposed as to the number, order, or end relation of the cars going to make up the train. Of course a train can be made up of cars equipped with motors and cars not equipped with motors, but provided with the train-line and connections for transmitting control, and the train be controlled from any one of a number of points. In accordance with this system the motors distributed on the cars going to make up the train or part of a train are controlled from one or more selected points by an operator's or master's switch or controller, the controllers individual to the motor equipments being operated through a train-line and appropriate connections. Some method must be adopted which will insure that different motors, within practical limits, will do their proportionate amount of work, be limited in the amount of current which they can each take, be saved from undue rapidity of current increment, and generally operate to properly regulate and proportion the current in the motors. The method consists in regulating the operation of the controller for any motor or motor equipment constituting part of a system of motors or motor equipments all under common control or working on a common load, or, as here shown, both under common control and working on a common load, by automatically varying the operation of the controller for that motor or motor equipment under the influence of the current in the motor or motors comprised in that equipment. Thus if the controller of one motor starts ahead more rapidly than the others, or if it operates more rapidly, or if there are differences in the field strength, so that one motor or motor equipment will get more current than another in excess of the predetermined limit of safety or desirability, or if for any reason, normal or abnormal, there is an excess of current through one controller, such as might occur if some part of a circuit were grounded or were disarranged, thus threatening the controller or circuits with damage, the throttle connected with the controller of that particular motor or motor equipment will stop the progression of that controller until by reason of the speeding up of the train under the driving of the other motors the current through the motor or motor equipment in question falls to the predetermined limit. The throttle will then close and normal conditions be reëstablished, or if the controller unchecked can operate more quickly than the motor can safely take current then the throttle will check the progression of the controller. The throttle does not operate on the movement of the controller toward open position.

In the accompanying drawings, which form a part of this specification, Figure 1 is a diagrammatic representation of a complete car system with a portion of the train-line on two other cars. Fig. 2 is a diagrammatic representation of two connected car systems, showing the operation of the throttle. It is somewhat simpler than the system shown in Fig. 1. Fig. 1 is taken from my earlier application above referred to. It is Fig. 11 and a part of Fig. 22 of that application combined, without change, except that some of the reference-letters are different.

The general arrangement shown in Fig. 1 comprises a pair of motors on each of the cars, operated in accordance with what is known as the "series-multiple control," which is a convenient, but not an essential, method. This is effected through a current-varying controller consisting of a series-multiple switch and a rheostat. The combined series-multiple switch and rheostat, together with certain pilot-motor circuit-interrupter contacts, to be hereinafter described, are all combined on a single cylinder called the "controller-block" and will be referred to collectively as the "main switch." Reversal is effected through a separate reverser-switch. In case of emergency the current can be instantly cut off at the reverser without waiting for the current-varying controller to come to open position. The current-varying controller is operated in both directions by a double-field pilot-motor through a set of relays, which are in turn operated from the operator's switch or master-controller. The reverser is operated directly by solenoids connected with the operator's switch and is spring-retracted.

There are preferably two operator's switches or master-controllers, one located on each platform, like contacts of the two being connected by wires constituting an operator's-switch cable.

The various car systems are connected with the train-lines in multiple relation with each other, as indicated in Fig. 1. In this figure an entire car system and the section of the train-line located upon one of the cars are shown, together with a part of the sections of the train-line located upon two other cars. In order to complete the diagram, it would only be necessary to add for the other two cars an exact duplication of the car system shown in the figure and to connect these two car systems to the train-line in the manner shown.

Each operator's switch is provided with reverser or directional contacts and speed-contacts. The reverser-contacts a b are so placed that when the handle P is moved from the open position the switch is always closed at one or the other of these contacts. Wires a b, forming part of a reverser-circuit, lead from these contacts on each switch through a circuit-opener 1 and through two coils a^2 b^2 of solenoids which form part of the reverser. Beyond the solenoids the two wires are united and are carried to a resistance 2 or, after the reverser operates, to contacts 3 on the reverser. Thence the circuit is through a circuit-opener 4, through an overload safety-circuit opener 5, through the solenoid of an automatic safety reverser-relay 6, through a cut-out switch 7 on the controller-block, and thence to ground at G. The solenoid 6 draws up its plunger, opening the lower set of contacts controlled by it and closing the two upper sets of contacts controlled by it. Through one set of these contacts 7^a a branch to ground is closed around the cut-out switch 7. So long as the operator's switch is closed on one side the reverser is held in position to connect the armatures of the driving-motors up to the source of supply in one direction, and so long as it is closed on the other side the reverser is held in position to connect the armatures of the driving-motors up to the source of supply in the other direction. The fields of these motors are not reversed. As soon as the platform-switch is opened the reverser opens the main motor-circuit without regard to the position of the main switch and independently thereof under the influence of a centering-spring 8, which is put under tension when the reverser is thrown to either side from the open position. The details of the construction and operation of the reverser need not be described.

Each operator's switch, in addition to the reverser-contacts, is provided with three pairs of contacts for controlling the speed, the two contacts of each pair being connected together and disposed in corresponding positions on the two sides of the switch. On closing the switch to either side thereof on one of the first pair of speed-controlling contacts, which will be called hereinafter the "coast-contacts" c, no effect is produced when the system is in the normal or initial position, for the circuit, which includes the contacts c^3 of the coast-relay c^2, is open at the pilot-motor circuit-interrupter c^4, which forms a part of the main switch. If the operator's-switch handle is carried farther around and brought into contact with one of the second or intermediate pair of speed-controlling contacts, which will be called hereinafter the "series contacts" s, the corresponding speed-relay s^2 on each of the cars is energized. The series relay-contacts s^3 on all of the cars are thus closed and the pilot-motors are each connected in parallel to the line in circuit through a contact controlled by the solenoid of the throttle, above referred to, to be hereinafter fully traced. When the operator's switch is closed on one of the third pair of speed-contacts m, called the "multiple contacts," the corresponding speed-relay m^2 is energized. The multiple relay-contacts m^3 on all of the cars are thus closed, and the pilot-motors are each connected to the line in circuit through contacts controlled by the throttle, as will be hereinafter shown. As the operation of this throttle is the basis of the method claimed, the circuit will be completely described with reference to Fig. 1. It is the same on each car. It is substantially the same for Fig. 2. The circuit through the contacts controlled by the throttle when the series contacts are closed is from the trolley L through the solenoid 9 of an overload safety, through a circuit-opener 10, through the brake-magnet 11 of the pilot-motor, through the armature 12 and a field-coil 13^a of the pilot-motor, through contacts 14, controlled by the throttle, through contacts 15, controlled by the solenoid 6 of an automatic safety-reverser for the pilot-motor, through contacts 16 17 of the pilot-motor circuit-interrupter, and through the relay-contacts s^3 to ground at G. When in a similar manner closure of the operator's switch at the multiple contact m energizes the corresponding set of multiple speed-relays m^2, closes their contacts m^3, and causes operation of the pilot-motors and main switch, the circuit is as follows: from the trolley L to the overload-solenoid 9, through the circuit-opener 10, through the brake-magnet 11 of the pilot-motor, through the field-coil 13^a of the pilot-motor, through contacts 14, controlled by the throttle, through the contacts 15, controlled by the automatic safety-reverser, all as before, thence through contacts 16 18 of the pilot-motor circuit-interrupter on the main switch and through relay-contacts m^3 to ground at G. The circuits closed on the return movement of the controller are easily traced. They include the other field-coil 13^b of the pilot-motor, which is oppositely wound from the one above mentioned. They do not include the contacts controlled by the throttle. When by opening the operator's switch or by failure of the line or for any other reason the circuit is opened, the plunger of solenoid 6 drops, opening contacts 15 and 7^a and closing contacts 19 of the automatic safety-reverser on each car. This causes all of the controllers to return to open-circuit position. When the cut-out switch-contacts of the main switch are closed, control of the movement of the main switch is again restored to the operator's switch.

It is not necessary to describe more fully the operation of the controller on return to open-circuit position, as this will be clear from the drawings and is not directly involved with the operation of the throttle, which does not come into play during the return movement.

The circuit through the solenoid of the throttle is from the trolley L through the overload-solenoid 9, through a circuit-opener 20 and a blow-out magnet 21, through the rheostat-contacts 22 of the controller, through contacts of a throw-over switch 23 and the coil of the blow-out magnet 24, through reverser-contacts 25 and the armature of one of the motors M' back to reverser-contacts, thence through the field of the motor M', through contacts of the throw-over switch 23, above referred to, thence through series contacts 26 of the series-multiple switch, through contacts of another throw-over switch 27 and another magnetic blow-out coil 28, and through reverser-contacts 29 and the armature of the other motor M^2 to the solenoid 30 of the throttle, thence back to the reverser-contacts, thence through contacts of the second throw-over switch 27, above referred to, and thence through the field of the motor M^2 to ground. When the motors M' M^2 are in multiple, the solenoid of the throttle is in series with one of the motors only, the circuit being as follows: from the trolley through the overload-solenoid 9 and the circuit-opener and blow-out, through the rheostat-contacts 22 of the controller, thence through two multiple contacts 31 of the series-multiple switch, thence through the throw-over switch 27, the coil of the blow-out magnet 28, the contacts 29 of the reverser, the armature of motor M^2, the solenoid 30 of the throttle, back to the reverser again, through contacts of the throw-over switch 27 and the field of the motor M^2 to ground. The other motor-circuit, which does not include the solenoid of the throttle, can be easily traced through motor M' and contacts 32 to ground. If the current through the two motors when they are in series or through the motor M^2 when they are in multiple exceeds the predetermined limit, the solenoid 30 of the throttle opens the throttle-contacts 14 in circuit with the pilot-motor and suspends movement of the main switch until the current drops to the predetermined limit, when the throttle-contacts 14 will be again closed and the main switch will move ahead, provided the circuit has been maintained at the operator's switch. If no change has occurred in any other part of the system, the operation of the throttle has no effect excepting to check the advance movement of the controller.

Fig. 2 shows two abutting cars. Only one motor is shown in each car. The series-paralleling feature is omitted throughout the system. A master-controller on the right-hand car is shown as closed to operate the controllers. Both controllers are shown as partially operated, the controller on the left-hand car being shown somewhat in advance of the other and its operation checked by the opening of the throttle-contacts. Like parts are indicated by the same reference-letters as in Fig. 1, and the circuits can be traced from the foregoing description and are indicated by arrows.

It will be seen from the foregoing statement that all the operator has to do when he wants to bring the motors from rest into operation in any arrangement is to close the operator's switch at the proper contact. The various controllers will then progress from the open position to the series if the series contact of the operator's switch be closed, or to the multiple if the multiple contact of the operator's switch be closed, or to the series first and then to the multiple if the series contact of the operator's switch be closed first and held closed and then the multiple contact of the operator's switch be closed. It is all a question of the operator permitting the handle to rest long enough on the particular point to bring the controllers to the proper position. If the series or multiple contact of the operator's switch is opened before the main switch has progressed to the full-series or the full-multiple position, a portion of the resistance of the rheostat is left in the circuit. When the main switch has reached the full-series or full-multiple position—that is, the positions where none of the resistance of the rheostat is in circuit—the controller is stopped automatically by the opening of the pilot-motor circuit at contact s^4 if it is to be brought to the full-series position or at contact m^4 if it is to be brought to the full-multiple position. On the return the circuit is automatically opened at contacts s^4 or c^4 and 33. In progressing from open position to the full-series or full-multiple position the controller is under the control of the throttle, as above explained, which automatically takes care of the system by stopping or retarding movement of any controller whenever the current in the motor or motor equipment controlled thereby rises beyond the predetermined limit, thus preventing the further increase of current. By thus independently regulating the movement of the main switch on each car the throttle renders it impossible to overload the driving-motors M′ M². Simultaneous movement and equal work on each motor equipment are thus insured without regard to how the operator handles his switch or to the position of any of the controllers at the time the switch is operated.

The importance of the throttle will be made further apparent from the following additional considerations, among others. The controllers, even though all made alike, may operate with different degrees of promptness, because of differences in the conditions of the bearings and the like arising from use. One controller might start off so much more promptly than the others that some motors would get a large current before the others had started. Besides the controllers, the relays on some of the cars might stick or the apparatus otherwise be out of order. Again, car-wheels are allowed to vary ten per cent. in diameter because of the wear of the steel tires. This variation would not be found on the wheels of a single truck on any well-organized road, but may be found on the wheels on the different cars. There may therefore be, for example, thirty-inch wheels on one car and thirty-three-inch wheels on another car. Again, trains may be made up of cars equipped with motors of different sizes, makes, and types having different characteristics and maximum capacities, and consequently showing differences in current input, or the cars may be equipped with controllers having unequal numbers of steps, or with motors operating through different ratios of gearing. It should be perfectly possible on a railroad to make up a train of cars which are equipped with motors having different characteristics, or with controllers having different characteristics, or the wheels of which are of different diameters.

Broadly speaking, the function of the throttle is to get automatically the same practical result in operating a number of controllers as can be effected by a careful motorman with an ampere-meter, watching the current input in a single equipment and arresting the movement of the main controller by opening the master-controller whenever the current rises to the predetermined limit. In general, with the throttle as I prefer to use it, so long as the current does not reach the predetermined limit set for safe operation the movement of the controller is independent of the throttle. Since for any specific conditions the characteristics of a motor can be plotted in terms of current and speed, it may be said that the activity of the throttle is affected by the speed of the motor—the less the variation in operation with any given equipment the less the throttle is brought into play. This automatic response of the throttles to the actual needs of the motors not only affords greater freedom in manipulating the controllers, but insures greater safety and facility of train operation.

In starting, the throttle automatically takes care of the rate of acceleration for different loads, stopping the pilot-motor whenever the current is too large, and thus insuring quick acceleration of light loads and slower acceleration of heavier loads. During the time of acceleration, also, there may be slight differences in the time of making controller-contacts, and because of these differences the increase of current on the different cars is not absolutely simultaneous, the result in this case being simply that the maximum flux of current required on the train is something less than the aggregate of the maximums on all of the cars, and there would therefore be less disturbance of potential, less drop on the line, and less sudden changes in demand on the central station. Furthermore, since during the time of acceleration a series-motor operates on a highly-saturated field, and therefore has almost the characteristics of the shunt-motor, if the resistance-divisions are arbitrarily made alike in the controllers on the different cars and changes are made on all cars exactly simultaneously it is quite possible to have differences during acceleration of fully thirty per cent. of the current on different cars. It is true that the resistance is finally cut out entirely; but the motors then have less-saturated fields, and differences of resistance in the circuit make less differences of current.

I do not limit myself to having the throttle open the pilot-motor circuit directly, for it can equally well be made to operate indirectly through the relays controlling the pilot-motor; nor do I limit myself to having the throttle in circuit with one motor only when the two are in multiple, because the throttle can be operated by two coils, one in each motor-circuit, or there can be two throttles, one for each motor-circuit, controlling-contacts in the pilot-motor or relay-circuits in series with each other; nor do I limit myself to any specific type or construction of controller.

I do not claim the apparatus herein described and illustrated, since it is claimed in the aforesaid application of which this application is a division; nor do I limit myself to the details of the apparatus. Neither do I limit myself to having motors forming a motor equipment. It is plain that the throttle would operate if there were only one motor in each equipment. In my claims I treat each pair of motors as a single motor, the statement that the motors are connected in multiple or that each motor is supplied with a controller being intended to cover the case of a single motor or of a plurality of motors which may be connected up in series or multiple or otherwise, as desired.

Generally, I do not limit myself to the details shown, as many changes can be made without departing from the spirit of my invention.

What I claim, and desire to secure by Letters Patent of the United States, is—

1. The method of regulating and equalizing the operation of a number of motors in a system, each provided with a controller, which consists in varying the operation of each of the controllers with the current in the motor controlled thereby, substantially as described.

2. The method of preventing any motor of a system of motors connected in multiple, each provided with a controller, from consuming more than its due proportion of the energy delivered to the system, which consists in checking the operation of any controller when the current in the motor controlled thereby exceeds a predetermined limit, substantially as described.

3. The method of regulating and equalizing the operation of a number of motors in a system, under common control or working on a common load, and each provided with a controller, which consists in varying the operation of each of the controllers with the current in the motor controlled thereby, substantially as described.

4. The method of preventing any motor of a system of motors connected in multiple, and under common control or working on a common load, and each provided with a controller, from consuming more than its due proportion of the energy delivered to the system, which consists in checking the operation of any controller when the current in the motor controlled thereby exceeds a predetermined limit, substantially as described.

5. The method of regulating and preventing undue excess of current in the individual motors or motor equipments of a system under common control, or working on a common load, each motor or motor equipment being provided with a controller, which consists in varying the operation of each of the controllers with the current in the motor controlled thereby, substantially as described.

6. The method of governing the operation of each controller of a number of motors in a system in which each motor is provided with a controller, and all the controllers are governed by a master-controller, which consists in retarding the operation of each of the controllers by the current in the motor controlled thereby, substantially as described.

7. The method of regulating and equalizing the operation of a number of motors in a system under common control and working on a common load, where each motor is provided with a controller, which consists in varying the operation of each of the controllers with the current in the motor controlled thereby, substantially as described.

8. The method of preventing any motor of a system of motors connected in multiple and under common control and working under a common load, where each is provided with a controller, from consuming more than its due proportion of the energy delivered to the system, which consists in checking the operation of any controller when the current in the motor controlled thereby exceeds the predetermined limit, substantially as described.

Signed by me in New York city, New York, this 22d day of June, 1900.

FRANK J. SPRAGUE.

Witnesses:
A. M. DIEMER,
PAULINE STRENGER.