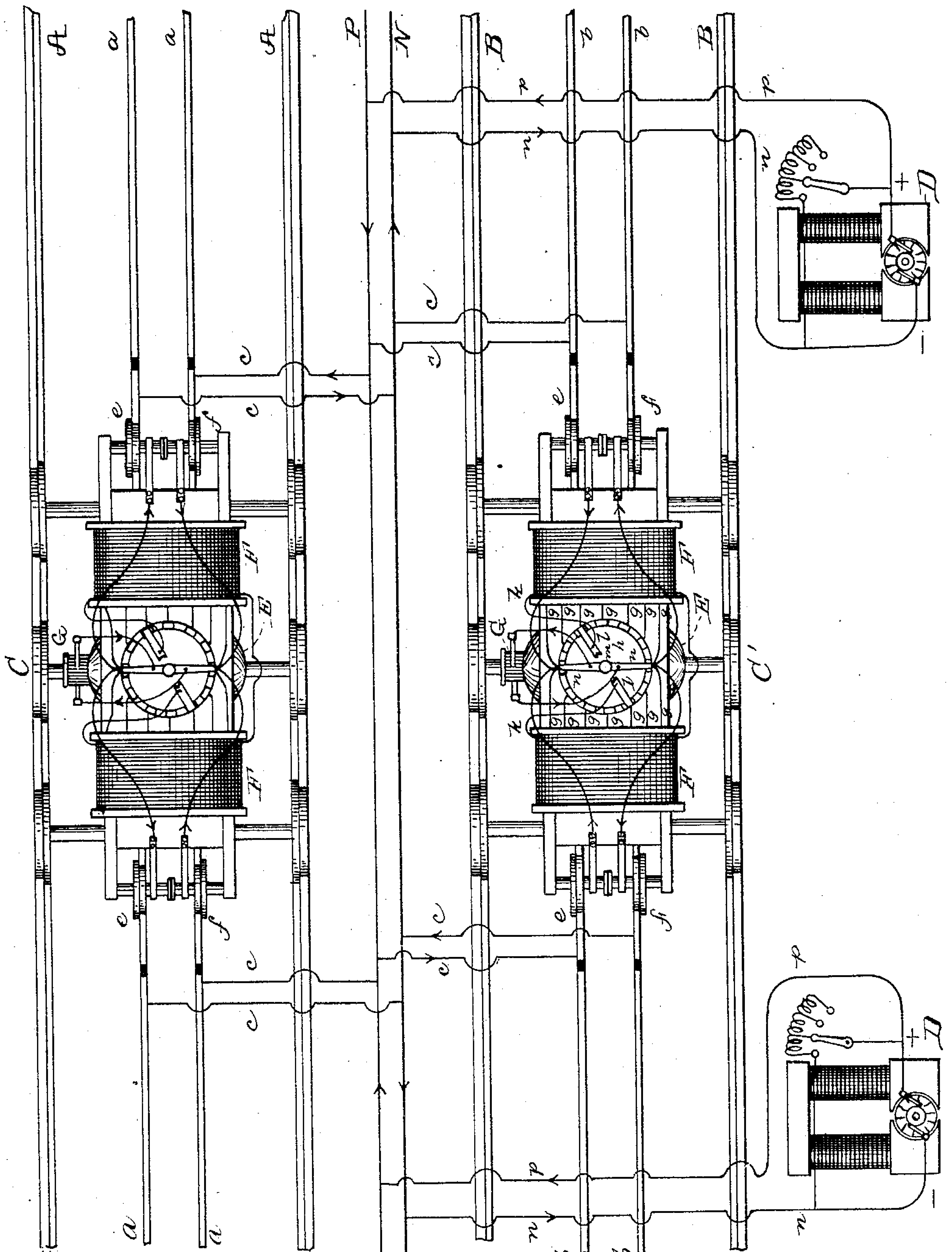
(No Model.)

F. J. SPRAGUE.

METHOD OF OPERATING ELECTRIC RAILWAY TRAINS.

No. 318,668. Patented May 26, 1885.



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METHOD OF OPERATING ELECTRIC-RAILWAY TRAINS.

SPECIFICATION forming part of Letters Patent No. 318,668, dated May 26, 1885.

Application filed December 22, 1884. (No model.)

To all whom it may concern:

Be it known that I, FRANK J. SPRAGUE, of New York, in the county and State of New York, have invented a certain new and useful Improvement in Methods of Operating Electric-Railway Trains, of which the following is a specification.

The object of my invention is to provide an effective method of braking or slowing down a train on an electric railway, which shall not entail that loss of energy incurred in the methods of braking which have heretofore been used or proposed both in steam and electric railways. This method consists in changing the electro-dynamic motor which receives current from the line and propels the train into a dynamo-electric generator receiving energy from the momentum of the train and giving current to the line, and under perfect control to vary the braking-power. Therefore instead, as in the case of a mechanical brake, of using energy to stop or slow down the train, by my invention such act of stopping or slowing down gives current to the line and relieves the generating-stations by furnishing additional power to the motors of other trains.

In my application Serial No. 121,487 is set forth a method of varying the mechanical effects in an electro-dynamic motor by an inverse varying of the strength of the field-magnets of the motor. My method of changing the railway-motor into a generator is based upon the same principle. By a continued increase of field strength I decrease, and finally reverse, the mechanical effects of the motor. When the machine is running as a motor, it develops a certain counter electro-motive force, which, taken with the initial electro-motive force, determines the effective electro-motive force, and hence the armature-current. This counter electro-motive force depends upon the strength of field and the velocity of the armature, and is independent of everything else. It is evident, therefore, that if the strength of the field-magnet is increased the counter electro-motive force is also increased, and if the increase of field is continued the initial and counter electro-motive forces will become equal, and then the counter electro-motive force will predominate. The machine has now become a generator and gives current to the line and its mechanical effects are reversed, so that it brakes the train instead of propelling it, and the current generated by it and the braking-power or reversed mechanical effect are now controllable by further increasing or by rediminishing the strength of field.

It will be seen that mechanical energy is received by the reversed motor according to the mass of the train and its velocity. If a train should start on a downgrade unprovided with a brake, the energy of falling would tend to increase its speed; but when my method of braking is used this mechanical energy is transformed in the machine into electrical energy delivered to the line, and augmenting that supplied from the generating-stations to the other trains, which may be moving upon upgrades or on levels.

When it is desired to slow down a train on a level grade, the field is increased, as before, until the counter electro-motive force predominates over the initial, and the energy stored up in the moving train is exerted to run the machine as a braking-dynamo. As the train slows, however, the diminution of speed of the armature will tend to diminish the counter electro-motive force, and the increase of field strength must therefore be continued, so as to still maintain the counter electro-motive force above the initial and keep the machine running as a generator as long as practicable when other methods of breaking, to be set forth in another application, may be used if necessary.

I will give an instance to show how effectively my invention may be employed, premising that when large masses of iron are used in the field-magnets the strength of the field can be varied within effective limits four or five hundred per cent., and also that a well constructed armature can carry for a short time fifty, seventy-five, or perhaps even one hundred per cent. more current than it can stand for any long run. Suppose the armature of the motor in question to have a resistance of three-tenths of an ohm, with its field-magnet in shunt relation to its armature (which is always the preferable manner of connection) and provided with suitable means for varying its strength. Suppose the initial electro-motive force to be five hundred volts, and forty horse-power to be required from the motor when running at its maximum. Allowing for losses in conversion this forty horse-power would be about thirty-two thousand watts. The counter electro-motive force would be four hundred and eighty volts, the effective electro-motive force twenty volts, and the current sixty-seven ampères. The electrical efficiency of the armature would be ninety-six per cent. Suppose the strength of the field to be increased about four per cent., the speed remaining the same, the motor running on a downgrade, the counter electro-motive will be increased to five hundred volts, and the motor-armature will then be perfectly passive electrically, neither taking from or giving to the line. Let the field strength be increased again one per cent., and let the increase be continued in the same ratio. The result is shown in the following table:

Total field increase.	Current to line.	Approximate energy required from train, allowing for losses.
5 per cent.	13.3 ampères.	9.5 horse-power.
6 "	29.3 "	20.9 "
7 "	45.3 "	32.7 "
8 "	61.3 "	44.7 "
9 "	77.3 "	56.9 "
10 "	93.3 "	69.3 "

From the above it will be seen that by simply increasing the field strength one twenty-fifth part, the machine is converted from a motor driving a train with forty horse-power of effective work to a perfectly passive machine, allowing the train to run absolutely free. Then by increasing the field one one-hundredth part the motor at once exerts a positive braking force, and on an increase of about eight and one-half per cent. above its original strength it will give back to the line-current equal to that which was originally taken from it sufficient, evidently, to run some other motor of the system which may at that time require that amount of current, and by increasing the original field ten per cent. the machine acts as a dynamo, requiring more than fifty per cent. more energy than is demanded to run it as a motor developing forty horse-power.

This method of braking, it will be seen, is under perfect control, and it is the most economical system possible for an electric railway, since whenever a train descends a grade and whenever a train stops the energy stored up in the moving train is delivered in the form of electrical energy upon the line. This advantage is most readily appreciable by comparing the action of my invention with that which occurs on a steam-railway train. Suppose it to be ascending a grade, then the engine exerts more than its average amount of power. When it reaches the top and enters upon a downgrade steam is shut off, and when the train begins to run faster than is desired steam is admitted to the vacuum-brake ejector, pressure is applied to the trucks, and the energy of the train is then converted into heat on the rims of the wheels and on the brake-shoes. In other words, all the energy in excess of that necessary to run the train on a level which has been required to climb the grade is now thrown away in going down the grade, instead of being utilized, as in my system; and, furthermore, additional steam is actually required to check the tendency to augmented speed. Then when the train approaches a stopping-place, or wherever it is necessary to slow the train down quickly, steam has to be employed to actuate the brakes, and all this additional power is simply thrown away. By my method of working the greater part of this loss is entirely obviated.

It is true that not all of the energy will be converted into electricity; but a large proportion of it will be.

On a double-track road with both tracks supplied from the same main circuit, as set forth in other applications made by me, the energy given to one track is also communicated to the other. The upgrades on one track being always balanced by the downgrades on the other track, it is evident that the total upgrade of the whole system is equal to the total downgrade thereof. Therefore, energy being expended on the upgrades and given out to nearly the same extent on the downgrades, the energy required in the system is that sufficient to move a train upon a level with a slight percentage added; but on a steam-railway the energy required is not only that sufficient to run a train on a level, but, in addition, that necessary to raise it from the lower to the higher grades on both tracks, no matter how many of such grades there may be.

I may employ any effective method for varying the strength of the field. I may employ adjustable resistance, or may cut in and out sections of the field-coils, or reverse the current in a greater or less number of said coils. I prefer, however, to employ such methods as have been set forth in my prior applications relating to the regulation of electro-dynamic motors.

The accompanying drawing represents an electric-railway system in which my invention is employed.

A A and B B are respectively the two tracks of an electric railway. There are two sets of working-conductors, *a a* and *b b*, preferably divided into sections, from which the motors C and C' derive current, and such working-conductors are connected by branch conductors *c c* with the continuous main conductors P N, which extend the whole length of the line and receive current from the generating-stations at D D by supply-conductors *p n*. The working-conductors, instead of being intermediate rails of the track, may be wires placed overhead or by the side of the track, or in any position where the motor can receive current from them; or the main rails of the track may form one or both sides of the working-circuit.

The main conductors may be placed overhead or underground, or in any convenient position.

In the form shown the motors have contact-wheels *e e* on one side and *f f* on the other, which travel on and take current from the working-conductors.

E is the armature, F F the field-magnet, and G the commutator, of each motor. Each motor which travels upon the line is provided with suitable means for regulating its field-magnet strength.

As shown, connections *g g* from different points of the main field-coils extend to contact-blocks of a circular commutator, *h*. From one limb of the magnet they extend to one side of the commutator and from the other limb to the other. An independent field-coil, *k k*, has its terminals connected to the arms *l l*, which are insulated from each other, and are pivoted at *m*. Portions of these arms are broken away in the drawing.

It will be seen that the independent coil is thus in a shunt between the two sets of main coils, and by moving the arms *l l* said independent coil is shunted around a greater or less number of the sections of main field-coils, and thereby the magnetizing effect of said independent coil and the strength of the field is varied, or by a continued movement of the arms the current of the independent coil is reversed, so that it opposes the main field-coils with a strength variable at will.

The terminals of the armature are preferably connected to arms *n n* on commutator *h*, whereby the armature-current may be varied or reversed in the same manner as the independent field-coils when so desired.

It is evident that the use of my invention is not confined to a double-track road or to a road in which main conductors are used to supply working-conductors, for my method of braking is applicable to any electric-railway system which has been used or proposed.

What I claim is—

1. The method herein described of braking an electric-railway train, which consists in increasing the counter electro-motive force of the motor propelling the train until it exceeds the initial electro-motive force on the line.

2. The method herein described of braking an electric-railway train, consisting in increasing the strength of the field-magnet of the motor propelling the train until the counter electro-motive force developed by its armature exceeds the initial electro-motive force on the line.

3. The method of operating electric railways herein described, which consists in increasing the counter electro-motive force of each motor when slowing down until it exceeds the initial electro-motive force on the line.

4. The method of operating electric railways herein described, which consists in increasing the counter electro-motive force of each motor when running on a downgrade until it exceeds the initial electro-motive force on the line.

5. The method herein described of maintaining the counter electro-motive force of an electric-railway motor above the initial when the train is slowing down, which consists in increasing the strength of the field-magnet of the motor as the speed of the train slackens.

6. The method herein described of slowing down or stopping an electric-railway train, which consists in increasing the strength of the field-magnet of the motor propelling the train until the counter electro-motive force of the armature exceeds the initial electro-motive force on the line, and then further increasing the said field-magnet strength to maintain the counter electro-motive force above the initial as the speed of the train slackens.

This specification signed and witnessed this 12th day of December, 1884.

FRANK J. SPRAGUE.

Witnesses:
T. G. GREENE, Jr.,
E. C. ROWLAND.