No. 776,374. PATENTED NOV. 29, 1904.

B. J. ARNOLD.

SYSTEM OF ELECTRICAL DISTRIBUTION.

APPLICATION FILED DEC. 17, 1901. RENEWED JAN. 8, 1904.

NO MODEL. 4 SHEETS—SHEET 1.

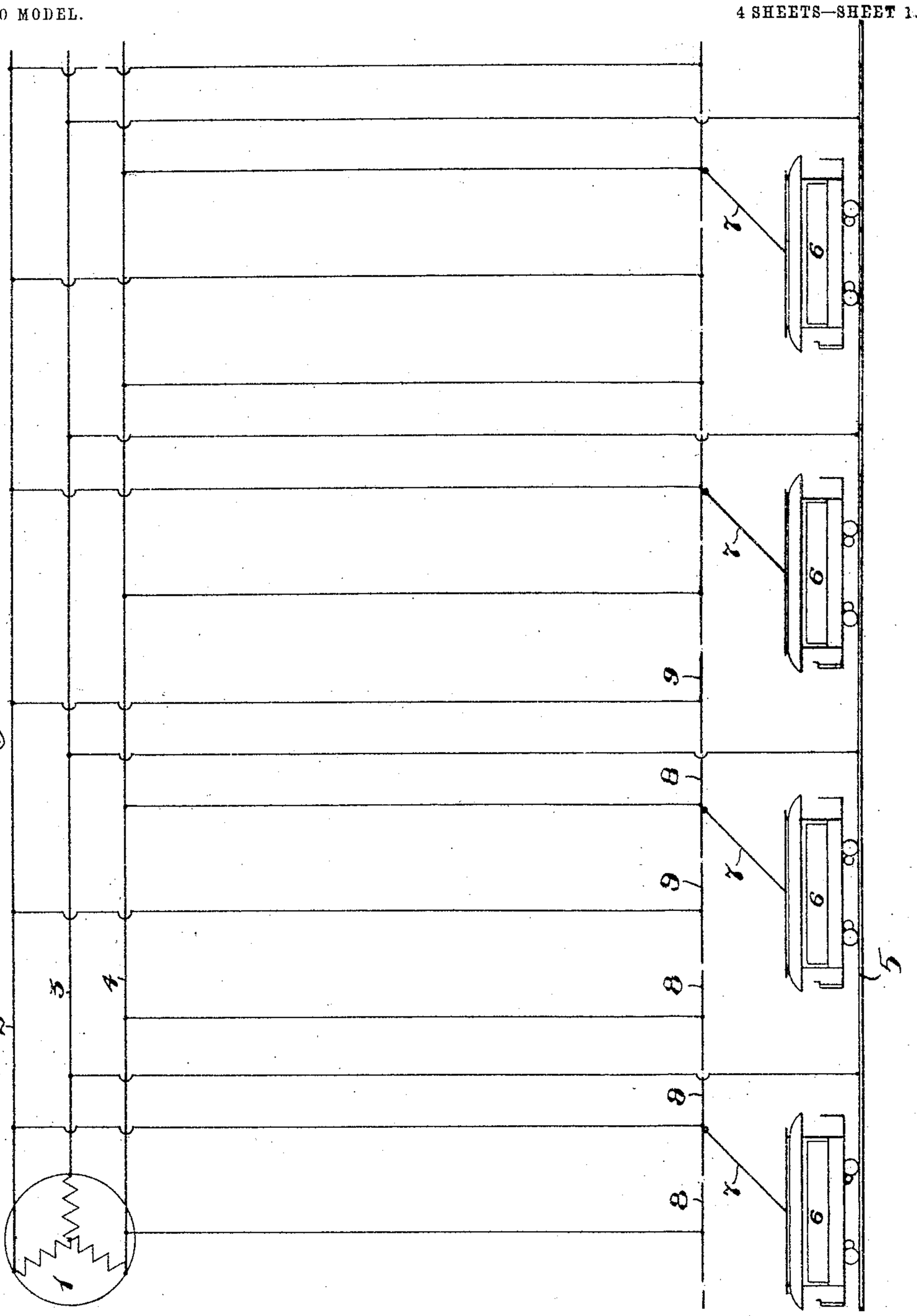

Fig. 1.

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Wilay W. Label

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NO MODEL. 4 SHEETS—SHEET 2.

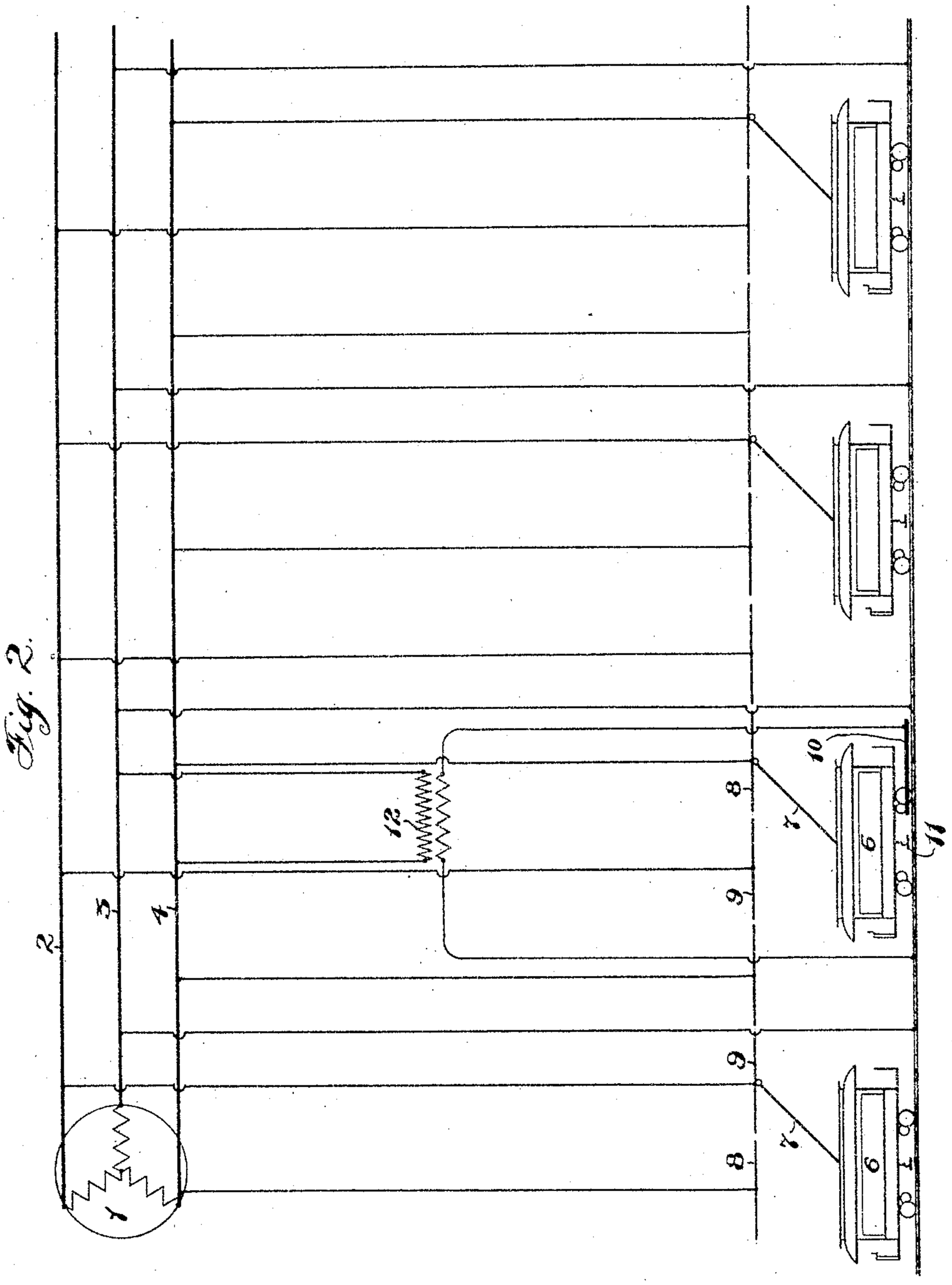

Fig. 2.

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NO MODEL. 4 SHEETS—SHEET 3.

Fig. 4.

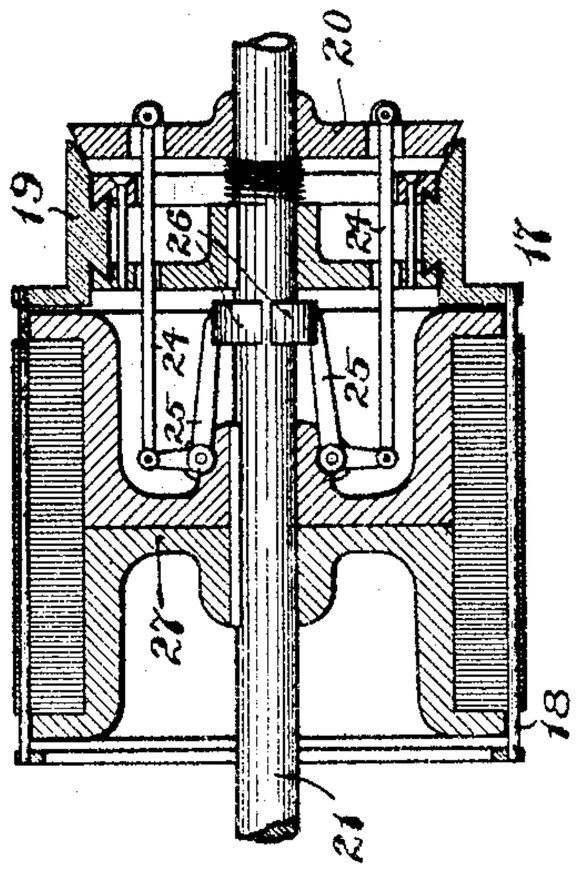


Fig. 5.

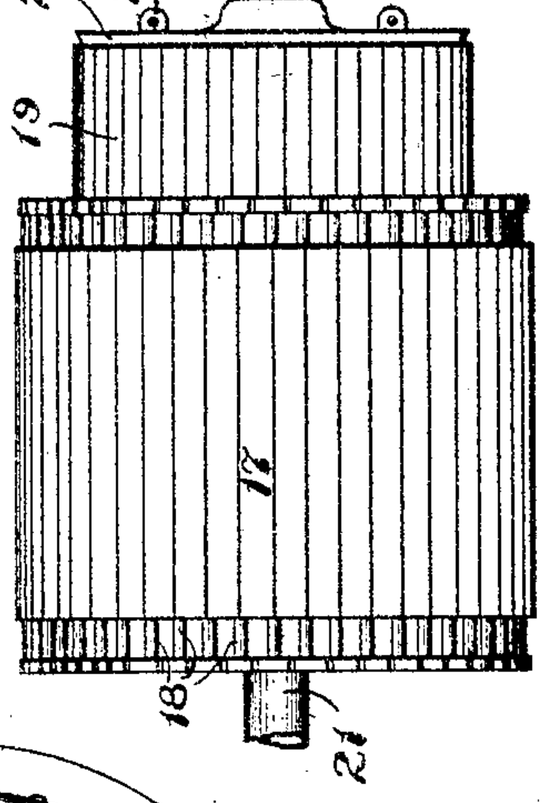
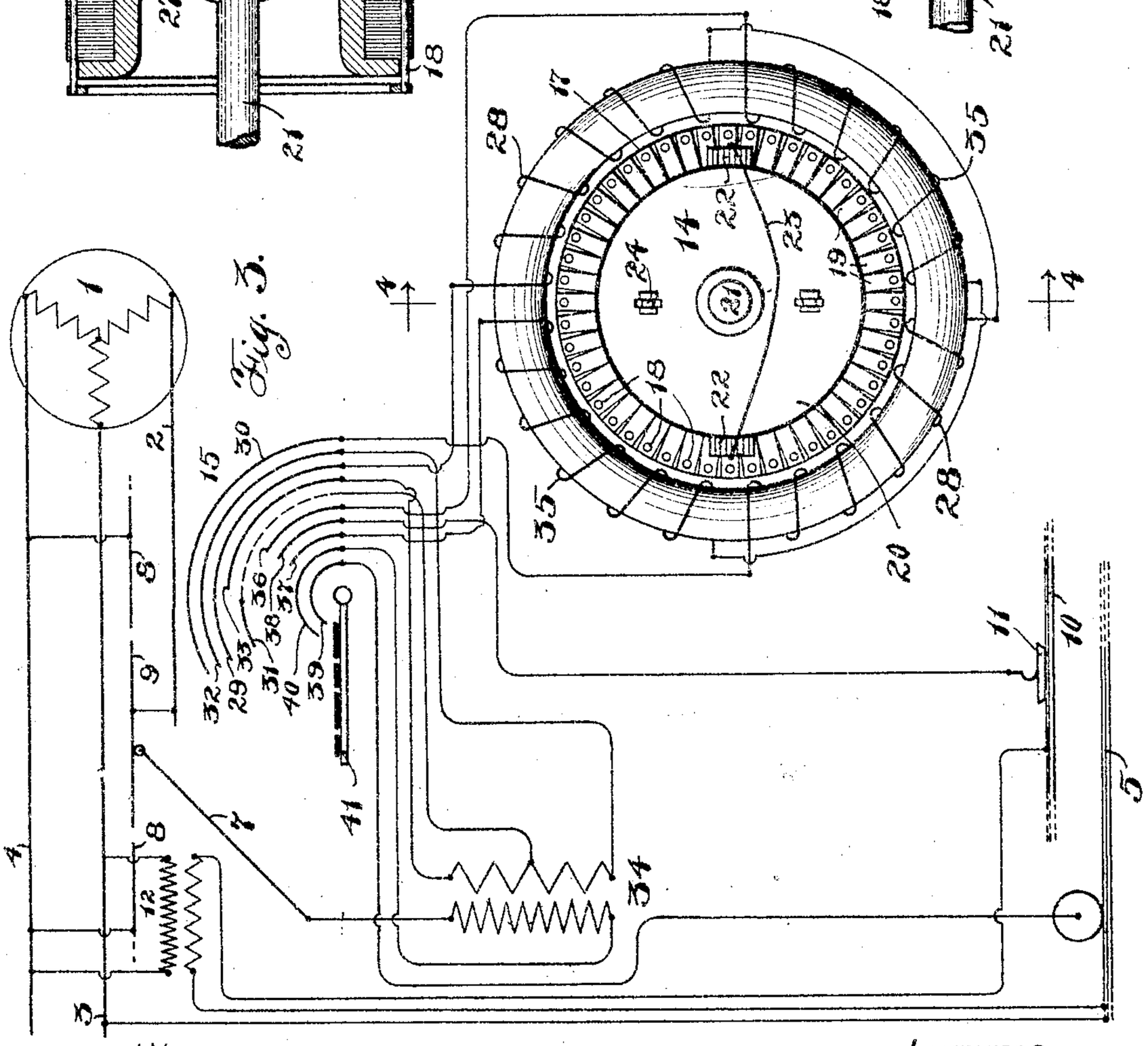


Fig. 3.



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SYSTEM OF ELECTRICAL DISTRIBUTION.

APPLICATION FILED DEC. 17, 1901. RENEWED JAN. 8, 1904.

NO MODEL. 4 SHEETS—SHEET 4.

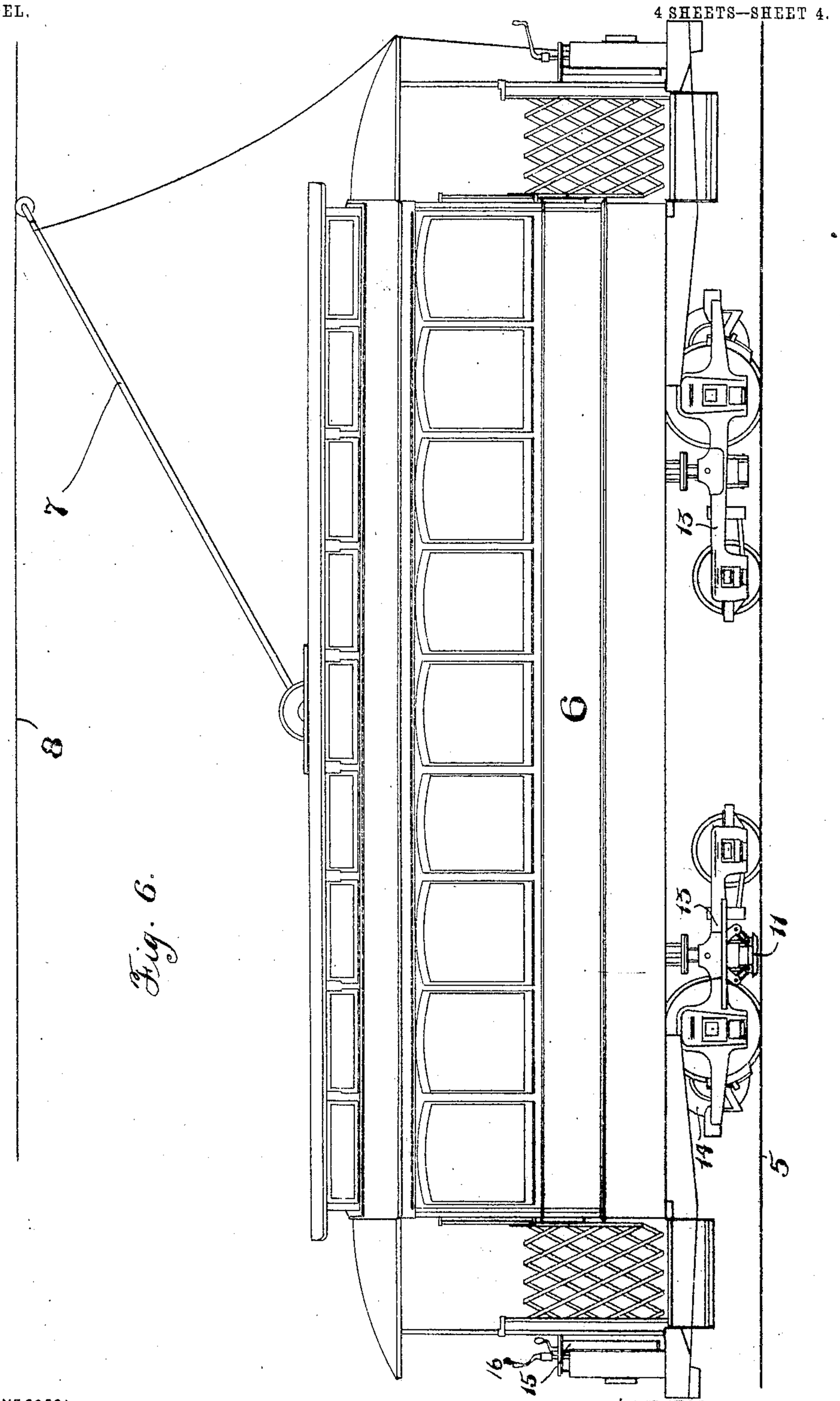

Fig. 6.

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BY Charles A. Brown, Cragg & Bedford ATTORNEYS.

No. 776,374. Patented November 29, 1904.

UNITED STATES PATENT OFFICE.

BION J. ARNOLD, OF CHICAGO, ILLINOIS.

SYSTEM OF ELECTRICAL DISTRIBUTION.

SPECIFICATION forming part of Letters Patent No. 776,374, dated November 29, 1904.

Application filed December 17, 1901. Renewed January 8, 1904. Serial No. 188,227. (No model.)

To all whom it may concern:

Be it known that I, BION J. ARNOLD, a citizen of the United States, residing at Chicago, in the county of Cook and State of Illinois, have invented a certain new and useful Improvement in Systems of Electrical Distribution, of which the following is a full, clear, concise, and exact description, reference being had to the accompanying drawings, forming a part of this specification.

My invention relates to systems for the electrical transmission of energy, being of particular service in the operation of electric railways, and has for its object the provision of an improved system of this kind wherein a minimum amount of copper is requisite to convey the electrical energy and wherein the various circuits of the transmission system are to a great extent balanced.

As my invention has a most important use in connection with electric railways, I will describe my invention as it may be embodied in an electric-railway system, which system I prefer to supply with electrical energy from a suitable source of polyphase or multiphase current, the terms "polyphase" and "multiphase" being understood as synonymous. I prefer to employ a three-phase system of distribution, which I prefer to associate with various trolley conductors along the line of the electric railway and the ground-return in such manner that vehicles along said electric railway are supplied with single-phase alternating current when operated under normal conditions.

A further feature of my invention consists in the provision of means whereby additional power may be supplied to the motors driving the vehicles over that which could normally be obtained from a main trolley-circuit. Instrumentalities for this purpose are preferably provided at those portions of the right of way at which there is a considerable ascending grade or at such other points in the line where an especially heavy load will be placed upon the motors during their operation, as at stations to aid in starting. The motors upon the vehicles preferably are so constructed that they operate efficiently when normally running single phase with the main trolley or working conductor construction and also operate efficiently (while exerting a greater torque, however) when associated with a main trolley conductor-circuit and the means for supplying the additional power. To accomplish this result, I prefer to utilize single-phase motors upon the vehicles, which motors are preferably in some suitable manner arranged to be self-starting and to supply a reasonably strong starting torque and which motors are adapted to operate efficiently when supplied, for example, with two-phase alternating current, which additional phase is suitably conducted thereto through the agency of auxiliary trolley conductors.

The vehicle traction-motors (constituting one form of translating means that may be supplied with power according to my invention) are supplied with current alternately from the different circuits of the system, so that the energy consumed is equalized between the various circuits of the transmission system, and I accomplish this through the use of but a single-trolley mechanism. The manner in which I prefer to construct the trolley conductor system so that a balance of the transmission system may be normally attainable consists in subdividing the trolley conductors into isolated sections and connecting alternate sections to unlike transmission-conductors of the system. I electrically unite another transmission-conductor of the system permanently with a ground-return to provide a return-circuit, which, as a general proposition, includes the rails upon which the vehicle is to operate. The vehicle thus at one time receives power from two of the mains of the transmission system included in one of the circuits of the multiphase transmission system and at another time receives its current from the mains of another circuit of the system, which conduct current of a different phase. Thus the vehicle-motor while normally operating receives none but single-phase alternating currents from the transmission system. In order to accelerate the operation of the vehicle or to increase the torque of the motor actuating the same, I provide auxiliary current-conducting means or trolley, so that a vehicle at such portions of its road-bed may be supplied with additional power by re-

ceiving current simultaneously from the main and the auxiliary trolley conductors, which are preferably electrically connected to separate mains of the transmission system, so that out-of-phase currents are supplied to the vehicle-motor.

I prefer to employ an additional conducting or third rail as the auxiliary trolley conductor to supply the additional phase to operate the vehicles when under heavy load. In order to provide a safe construction for said auxiliary current-conducting rail to avoid accidents to persons or animals crossing the right of way, I interpose a transformer between said third rail and the conductors of the transmission system from which it derives its current, whereby current is supplied to the third rail at a voltage sufficiently low to preclude the possibility of any disastrous results when persons or animals accidentally form connection between said third rail and the ground-return rails. I do not wish to limit myself to the use of transformers nor to the employment of a third rail as an auxiliary trolley conductor.

I preferably so arrange the controller system by means of which the travel of the car is regulated that but one operating-handle need be employed to effect normal regulation of the speed of the driving-motor and also to regulate its speed when the additional phase is required to furnish additional power. Any suitable self-starting single-phase motor may preferably be employed, whose construction and circuit arrangement I may then vary, if necessary, in accordance with my invention by placing additional windings thereon corresponding to the additional phase, or a motor may be employed which, while not inherently self-starting, is provided with means whereby the same is brought to speed, in which case I may again reconstruct or readapt said motor for operation in my improved system.

Further objects and advantages of my system will be enumerated hereinafter.

One embodiment of my invention is shown in the accompanying drawings as applied particularly to a three-phase transmission system employing self-starting single-phase motors that may be supplied with current both from an overhead trolley-main and, if desired, a third-rail trolley.

In the drawings, Figure 1 shows diagrammatically a power-transmission system constructed in accordance with my invention. Fig. 2 shows a modification of the system disclosed in Fig. 1. Fig. 3 is a diagrammatic view illustrating the method of speed control. Fig. 4 is a cross-sectional view of a motor on line 4 4 of Fig. 3. Fig. 5 is a view in elevation of the armature which I prefer to employ in connection with my improved system, and Fig. 6 is a view of a complete car adapted to operate in my improved railway system.

Like parts are indicated by similar characters of reference throughout the different figures.

In Figs. 1, 2, and 3 I have shown a three-phase alternating-current generator 1 supplying current to the transmission-mains 2, 3, and 4, the style of generator shown being in this instance provided with an armature having the Y system of connection. One of the transmission-conductors, 3 in this particular instance, is electrically connected with a ground connection comprising a continuous rail 5 of the road-bed, along which cars 6 6 are designed to travel. The cars 6 are provided with trolley-poles 7, which are adapted to engage the trolley-wire included in the conducting-circuits of my improved construction for supplying current to the cars.

In order to so arrange the trolley conductors that the distribution of current between the various circuits of the polyphase transmission system is made as uniform as possible, I subdivide the said trolley conductors into isolated sections and connect alternate sections with the same transmission-main, thus forming two sets of trolley conductors when my invention is applied to three-phase systems of distribution, one set comprising the trolley conductors 8 8 8 and the remaining set comprising the trolley conductors 9 9 9, the various sections in combination constituting a main. I electrically associate alternate sections of the trolley-mains with the same transmission-main, as shown in the drawings, the sections 8 8 8 being connected with the transmission-main 4 and the sections 9 9 9 being connected with the transmission-main 2, while the ground return, comprising the rail-sections 5, is electrically united to the transmission-main 3. It will thus be apparent that the cars 6 6 in operating along the right of way receive current alternately from trolley-sections 8 and trolley-sections 9, so that said cars are at one time—that is, when the trolley wheel or contact is in association with a conductor-section 8—included in a circuit of the generator 1 supplied by the mains 3 4 and at another time—that is, when they receive current from the sections 9—included in another circuit of the generator supplied by the transmission-mains 2 3. When a number of cars are continuously operating along the right of way, the power derived from a polyphase generator and utilized in propelling said cars is very evenly distributed between the circuits of the transmission system, and I obtain this advantage through the use of but a single line of trolley-wire, which is adapted normally to supply current to the cars.

I find that in practice it is frequently desirable to accelerate the speed of the vehicle above the normal along some portions of the right of way or to maintain the normal speed of said vehicle even though excessive load be placed upon the motor of the vehicle, as would

be the case, for instance, when said vehicle is started or ascends a grade. In order to do this, I provide auxiliary means at these portions of the right of way, which auxiliary means are adapted to supply additional power to the driving mechanism of said vehicle over that which is normally obtainable from the main trolley-wire. The means which I prefer to employ includes an auxiliary conductor-circuit in the form of a trolley-conductor third rail 10, insulated from the ground return-circuit of the system, and I electrically energize said third rail from a transmission-main other than the one which is electrically associated with the trolley conducting-section paralleling or running alongside of said third-rail section. The length of the sections of the supplemental trolley conductors or third rail will of course depend on the local conditions—as, for instance, upon the number of cars operating in the system, their speed, and the number of grades and stops. When the car is thus being supplied with energy from the main trolley wire or conductor and also from the third rail, alternating currents of two phases may be supplied to the motor, thereby to cause the said motor to develop a torque which is in excess of that under which the motor is adapted normally to operate, but which is in conformity with the increased load which said motor is called upon to move.

I prefer to employ a third rail as the auxiliary trolley conducting-circuit, so that the cars need not be provided with double overhead-trolley pole equipment, the shoes 11 of the car 6 being so placed as to readily engage said third rail 10 without requiring the attention of any one in charge of the car. The third conductor equipment is obviously also useful where overhead trolleys are not employed. To reduce the danger which may accompany such a construction having a charged third rail in place upon the right of way alongside of the traction-rails, I may interpose a transformer 12 between said third rail and the transmission-circuit from which it receives its power, so that the said third rail may be charged with a voltage considerably below the potential of the transmission-mains with which it is associated, as shown very clearly in Fig. 2, in which the primary of the transformer 12 is connected between the transmission-mains 3 and 4 and one terminal of the secondary is connected to the third rail 10, while the remaining terminal of the secondary is connected to the return-rail 5. I may arrange the capacity of the transformer so that an amount of power may be supplied thereby to the traction-motor equivalent to that supplied to said car by the main trolley conductor-circuit that then may be associated with said motor or arrange the same so that a decreased or increased amount is supplied by the said transformer, dependent upon the proportional increase of the power necessary to operate the car under the special operating conditions assumed. This feature of my invention obviously is of service where the main trolley-wire is not divided into sections connected with separate circuits.

In Fig. 6 I have shown a car equipped in accordance with one embodiment of my invention, said car being provided with the trolley-pole 7 for engaging the trolley conducting-sections 8 or 9 and is also provided with a shoe 11, flexibly mounted upon the truck 13 of the said car. The trucks 13 of the car also carry traction-motors 14 14, which are governed by controllers 15 15 upon the platforms of the said car, a controller-handle 16 being shown in association with the controllers 15.

The form of traction-motor which I prefer to employ is shown more in detail in Figs. 3, 4, and 5, its relation with the various energizing-circuits and the controller 15 being indicated diagrammatically in Fig. 3. The motor includes an armature 17, which may have an ordinary form of squirrel-cage armature-winding comprising the conductors 18, short-circuited at one end and electrically connected to the bars 19 of a commutator, which commutator is so associated with a short-circuiting plate 20, movable longitudinally upon the armature-shaft 21, that the said plate when in one position is free of the commutator-bars and in another position serves to short-circuit them, so that the motor may normally operate as an ordinary alternating-current motor with a short-circuited armature-winding. The position of the short-circuiting plate is preferably dependent upon the speed at which the motor is operating, so that when the motor is rotating below the normal speed the commutator-bars are disengaged from said short-circuiting plate and when the motor is rotating at normal speed the commutator-bars are engaged by said short-circuiting plate 20, and thus electrically connected thereto, whereby the armature is short-circuited. Brushes 22 22 are adapted to engage the commutator-bars 19, and a conductor 23 is employed to electrically unite the same, so that when the short-circuiting plate 20 is disengaged from the commutator-bars a circuit is completed through the armature by way of the brushes, thereby establishing a circuit, so that the motor may start from a state of rest and continue to operate by having its armature-circuit completed through the brushes and the said conductor 23 until it attains the normal speed, when the short-circuiting plate 20 short-circuits all the commutator-bars, thus rendering the circuit by way of the brushes functionless. To thus automatically regulate the position of the short-circuiting plate 20, it is pivotally connected to ends of rods 24 24, which are pivotally secured at their other ends to bell-crank levers 25 25. The free ends of the bell-crank levers 25 are provided with weights 26, which tend to swing

outwardly from the shaft 21 when rotated. The bell-crank levers 25 are rotatably mounted upon the armature-spider 27. The operation of short-circuiting the armature-winding being thus automatic, the function of the controller 15 may be limited to change the flow of current supplied to the energizing-windings of the motor 14. I will now explain the manner in which I prefer to regulate the motor through the agency of said controller more particularly by reference to Fig. 3. The motor in this instance is provided with with two energizing field-windings 28 28, which are adapted normally to operate the motor and which are adapted for connection with the circuit-conductor engaged by the trolley 7. The windings 28 28 are connected to controller contact-segments 29 and 30, which segments are adapted for association with the electrical controller contact-segments 31, 32, and 33, electrically connected with terminals of the secondary of a transformer 34, whose primary is supplied through the agency of the trolley 7, connected between the trolley conductor engaging the same and the return-rail conductor 5. The motor is also provided with additional field-windings 35 35, which are normally out of circuit, but which are adapted for energization only when it is necessary that the motor develop an added torque. The energizing-windings 35 35 are connected to controller-segments 36 37, which are adapted to be associated with the contact-segments 38, connected with the contact-shoe 11 and also with the grounded contact-segment 39 of the controller 15. The grounded contact-segment 39 is connected to a contact-segment 40, connected with one terminal of the primary of the transformer 34 when the car is ready for operation. The field-windings 28 28 are supplied with current of one phase from the generator 1. The windings 35 35 may when required be supplied with current from the same generator, but of different phase, when the motor may act as a polyphase motor. Through the agency of the transformer 34 the voltage of the alternating current supplied to the windings 28 28 may also be varied. A controller-actuating bar 41 is provided with switching-contacts, which are adapted to change the electrical connections of the motor-windings. In the first position of the controller-arm contact-segments 39 and 40 are short-circuited, thus connecting the primary of the transformer 34 with the rail, so that said primary winding is energized. In the second position of the controller-arm the contact-segments 32 and 30 are closed circuited, as well as the contact-segments 29 and 31, thus supplying to the windings 28 28 of the motor alternating currents at reduced pressure from one-half of the coils of the secondary winding of the transformer 34. In the next position of the controller-arm the same is disengaged from the conducting-segment 31 and engages the conducting-segment 33, thus changing the electrical connection between the coils 28 and the transformer 34, whereby alternating current at the full pressure of the secondary of the said transformer 34 is supplied to the windings 28 28 to cause the motor to exert a greater torque. The short-circuiting of the armature-conductors, as before stated, is automatically accomplished when the motor has reached the required speed.

In order to permit the motor to exert an added torque, coils 35 35 must be energized to supply the same with alternating current of differing phase, which is accomplished by a further movement of the controller-handle 41 to close circuit between the controller-segments 36 and 38 and the controller-segments 37 and 40, thus supplying current to said coils 35 from the out-of-phase circuit including the third rail 10. The motor being thus supplied with two-phase alternating currents acquires an increased torque.

The advantages of the specific application of my invention will be apparent. I adapt multiphase systems of distribution for advantageous use in electric-traction systems by so constructing the trolley-circuits that cars or vehicles operated in said traction system are alternately supplied with current first from one of the circuits of the system and then from another circuit of said system, thereby distributing the energy requisite in operating the system between the various circuits of the multiphase system. The overhead compound trolley-main constitutes a sectional supply-main. As stated, this trolley-main may be placed elsewhere. I furthermore so associate an auxiliary trolley conducting-circuit along the right of way that current may be at intervals supplied to the said motors from a plurality of circuits of the system, whereby said motors may develop increased torque to overcome abnormal conditions.

While I have herein shown and particularly described one embodiment of my invention, I do not wish to limit myself to the precise construction and arrangement herein shown and particularly described; but,

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

1. In a traction system, the combination with a polyphase source of current, of transmission-circuits supplied therefrom, an auxiliary trolley-main divided into sections, means for connecting adjacent sections of said trolley-main to unlike transmission-conductors, a plurality of motor-cars operated in said system, and means whereby the cars when operating in said system receive current in succession from sections of said trolley-main, thereby to distribute the load between the various circuits of the polyphase system, substantially as described.

2. In a polyphase system of distribution, the combination with a polyphase source of current, of transmission-circuits supplied therefrom, a translating device, means for supplying said translating device with single-phase current from a circuit of said polyphase system to operate it, and means for supplying additional current of a different phase to said translating device, substantially as described.

3. In a traction system, the combination with a polyphase source of current, of transmission-circuits supplied therefrom, a trolley-main, cars provided with traction motors operating in said system, said motors normally receiving single-phase current from said trolley-main, an auxiliary trolley conductor receiving out-of-phase current from said source, and means whereby said auxiliary conductor is associated with said motors to supply additional current of different phase thereto, substantially as described.

4. In a traction system, the combination with a polyphase source of current, of transmission-circuits supplied therefrom, a trolley-main divided into sections, electrical connections whereby adjacent sections of said trolley conductor are electrically united with unlike transmission-conductors, cars provided with traction-motors operating in said system, said motors normally receiving single-phase current from said trolley-main, an auxiliary trolley conductor receiving out-of-phase current from said source, and means whereby said auxiliary conductor is associated with said traction-motors to supply additional current of different phase thereto, substantially as described.

5. In a traction system, the combination with a polyphase source of current, of transmission-circuits supplied therefrom, a trolley-main, cars having traction-motors operating in said system, said motors normally receiving single-phase current from said trolley-main, an auxiliary trolley conductor receiving out-of-phase current from said polyphase source, means whereby said auxiliary conductor is associated with said motors to supply additional current of different phase thereto, and a transformer interposed between said auxiliary conductor and a transmission-main to reduce the pressure supplied thereby to the translating device, substantially as described.

6. In a traction system, the combination with a polyphase source of current, of transmission-circuits supplied therefrom, a trolley-main divided into sections, electrical connections whereby adjacent sections of said trolley-main are electrically united with unlike transmission-conductors, traction-motors mounted upon cars operating in said system, means whereby said motors normally receive current of one phase from said trolley-main, an auxiliary trolley conductor also receiving current from said polyphase source, means whereby said auxiliary conductor is associated with said motors to supply additional current of different phase thereto, and a transformer interposed between said auxiliary conductor and a transmission-main to reduce the pressure supplied thereby to the motors, substantially as described.

7. In an electric-railway system, the combination with a source of polyphase current, of transmission-circuits supplied therefrom, motor-cars, and means whereby the traction-motors upon said cars may be successively connected with different transmission-circuits supplied by the source of current, substantially as described.

8. In an electric-railway system, the combination with a source of polyphase current, of transmission-circuits each receiving single-phase current from the said source, motor-cars, and means whereby the traction-motors upon the said cars may be successively connected with different single-phase circuits supplied by said polyphase source of current, substantially as described.

9. In an electric-railway system, the combination with a source of polyphase current, of transmission-circuits supplied therefrom, motor-cars, means whereby the traction-motors upon said cars may be successively connected with different transmission-circuits supplied by the source of current, and supplemental means whereby said traction-motors may each be simultaneously connected with a plurality of said circuits to subject the traction-motors to out-of-phase currents simultaneously, substantially as described.

10. In an electric-railway system, the combination with a source of polyphase current, of transmission-circuits, each receiving single-phase current from the said source, motor-cars, means whereby the traction-motors upon the said cars may be successively connected with different single-phase circuits supplied by said polyphase source of current, and supplemental means whereby said traction-motors may each be simultaneously connected with a plurality of said circuits to subject the traction-motors to out-of-phase currents, substantially as described.

11. In an electric-railway system, the combination with a polyphase source of current, of transmission-circuits supplied thereby, means whereby the traction-motors upon the cars may receive single-phase current only, and supplemental means whereby the traction-motors may be subject to an additional current out of phase with the said single-phase current and simultaneously with said single-phase current, substantially as described.

12. In an electric-railway system, the combination with a source of alternating current, of a motor-car, means whereby the traction-motor upon the said car may be subject to a single-phase current, and supplemental means for supplying additional current to the said traction-motor out of phase with the afore-

said single-phase current and simultaneously with said single-phase current, substantially as described.

13. In an electric-railway system, the combination with means for producing out-of-phase alternating currents, of a motor-car in the system, and a controller upon the motor-car governing the connections of the motor with the circuits to which the out-of-phase currents are supplied, said controller being adapted to limit the traction-motor to the action of a single-phase current or to cause the same to be subjected to polyphase currents, substantially as described.

14. The combination with a source of polyphase current, of transmission-circuits receiving current therefrom, translating devices receiving current from said circuits, and means whereby said translating devices receive current alternately from circuits of said system, substantially as described.

15. The combination with a source of polyphase current, of transmission-circuits receiving current therefrom, a translating device, and means whereby said device is successively associated with the different circuits supplied by said polyphase source of current, substantially as described.

16. The combination with a source of polyphase current, of transmission-circuits receiving current therefrom, a translating device receiving current from said circuits, and means for connecting said translating device in rotation with the circuits supplied by the source of polyphase current, substantially as described.

17. The combination with a source of polyphase current, of transmission-circuits receiving current therefrom, a supply-main subdivided into sections, which receive current from different circuits of the system, a translating device receiving its current from said main, and means whereby said translating device receives current successively from different sections of the said supply-main, substantially as described.

18. The combination with a source of polyphase current, of transmission-circuits receiving current therefrom, a supply-main subdivided into sections, means whereby adjacent sections are connected to unlike transmission-conductors, a translating device receiving its current from said main, and means whereby said translating device receives current successively from different sections of said main, substantially as described.

19. The combination with a polyphase source of current, of transmission-circuits supplied therefrom, a supply-main divided into sections, adjacent sections of the main being connected with unlike transmission-conductors, and a translating device receiving current successively from sections of the said supplemental main, thereby to distribute the load between the circuits in the system, substantially as described.

20. In a polyphase system of distribution, the combination with a polyphase source of current of transmission-circuits supplied therefrom, a translating device, means for supplying said translating device with single-phase current from a circuit of said polyphase system to operate the same, means for supplying additional current of a different phase to said translating device, and a transformer for reducing the pressure of the additional current supplied by the second aforesaid means, substantially as described.

21. The combination with a polyphase source of current, of a translating device adapted for association with said source of current, means for supplying current of one phase and a given pressure to said translating device, means for supplying additional out-of-phase current from said source to said translating device, and a transformer associated with said means to reduce the pressure of the current of the second phase supplied to the said motor, substantially as described.

22. In an electric railway, a sectional conductor adapted to be engaged by a moving car, and a polyphase transmission system, the several phases thereof supplying current to the several sections of said conductor, substantially as described.

23. In an electric railway, a sectional conductor adapted to be engaged by a moving car, a source of polyphase current, and connections from the several phases of said source to the several sections of said conductor, substantially as described.

24. In an electric railway, a polyphase transmission system, a sectional conductor adapted to be engaged by a moving car, and connections whereby the several sections of said conductor are energized from the several phases of said transmission system, substantially as described.

25. In an electric railway, a source of three-phase current, a sectional conductor adapted to be engaged by a moving car and having its several sections energized by the several phases of said source, and a return-conductor connected to the neutral point of said source, substantially as described.

26. In an electric railway, a polyphase transmission system, and a sectional conductor adapted to be engaged by a moving car, adjacent sections of said conductor being insulated from each other and energized by different phases of said transmission system, substantially as described.

In witness whereof I hereunto subscribe my name this 6th day of December, A. D. 1901.

BION J. ARNOLD.

Witnesses:

GEORGE L. CRAGG,

HARVEY L. HANSON.