(No Model.) 2 Sheets—Sheet 1.

C. E. FRITTS.

PRODUCTION, TRANSMISSION, AND DISTRIBUTION OF ELECTRIC CURRENTS.

No. 383,520. Patented May 29, 1888.

Fig. 1.

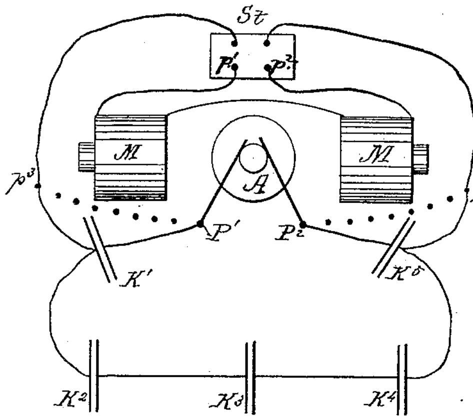


Fig. 2.

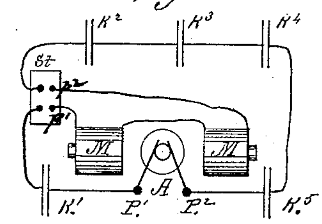


Fig. 3.

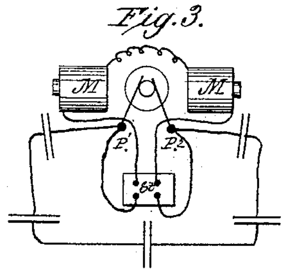


Fig. 4.

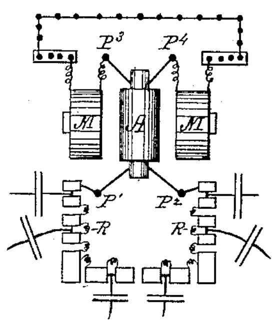


Fig. 5.

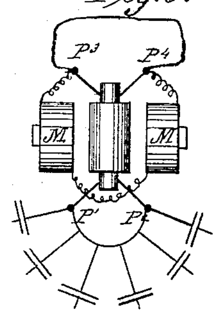


Fig. 6.

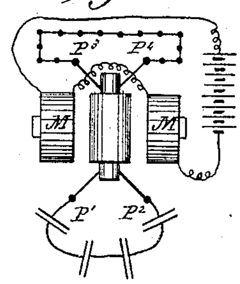


Fig. 7.

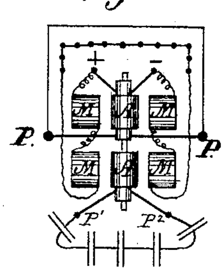
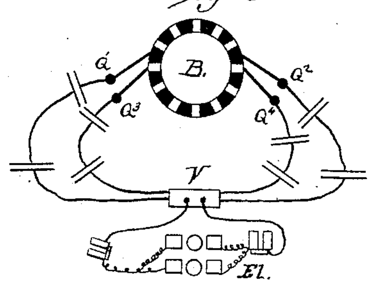


Fig. 8.



Witnesses;
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(No Model.) 2 Sheets—Sheet 2.

C. E. FRITTS.

PRODUCTION, TRANSMISSION, AND DISTRIBUTION OF ELECTRIC CURRENTS.

No. 383,520. Patented May 29, 1888.

Fig. 9.

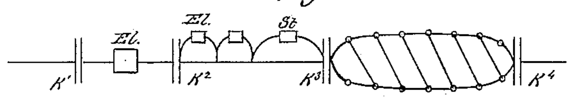


Fig. 10.

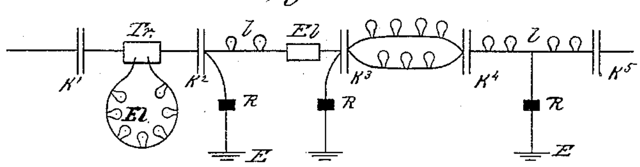
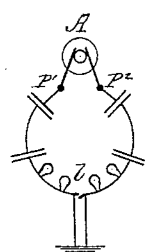
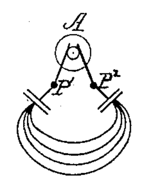
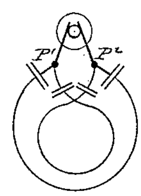


Fig. 11. *Fig. 12.* *Fig. 13.* *Fig. 14.*







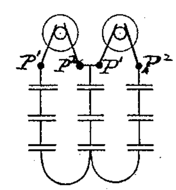
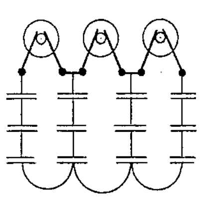
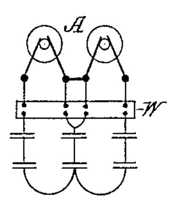
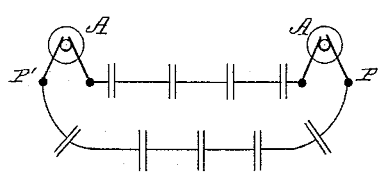


Fig. 15. *Fig. 16.* *Fig. 17.*







Witnesses;
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N. S. Faxon.

Inventor;
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UNITED STATES PATENT OFFICE.

CHARLES EDGAR FRITTS, OF NEW YORK, N. Y.

PRODUCTION, TRANSMISSION, AND DISTRIBUTION OF ELECTRIC CURRENTS.

SPECIFICATION forming part of Letters Patent No. 383,520, dated May 29, 1888.

Application filed October 7, 1885. Serial No. 179,271. (No model.)

To all whom it may concern:

Be it known that I, CHARLES EDGAR FRITTS, a citizen of the United States, residing at New York, in the county and State of New York, have invented certain new and useful Improvements in the Production, Transmission, and Distribution of Electricity, of which the following is a specification.

Heretofore currents have been produced by any suitable generator of electrical currents—as a battery or a machine—and transmitted over continuous conductors to the place of use and then returned to the generator over the continuous conductor or sent to earth; but in all cases, if the conducting-circuit is opened or broken, all the apparatus upon it become inoperative, as no current flows unless the circuit is completed. In my system, if the circuit is accidentally broken, only the apparatus near the break are disabled, all the others on the circuit continuing to operate, and even the former are not entirely useless. Another advantage is that an open circuit does not disable the generator, (if a dynamo-electric machine,) as is usually the case.

My invention also has for its object economy in the cost of producing and distributing electricity by repeated inductions, instead of sending the currents bodily over the entire length of the circuit, to render consumers independent of the original generator as regards the character of the current they use by giving them the power to take off a current of any potential or strength they require, within the capacity of the generator, without interfering with other consumers.

My invention consists in producing, by any suitable or known means, a varying current, whether alternating, undulating, or interrupted, therewith charging an electrical condenser to its own potential, and by the varying charge of said condenser inducing currents upon and over the one or more sections of the line or circuit, each of which is inductively united to the adjacent section by a condenser in like manner, and the last one to the other pole of the generator, repeating this operation fast enough to keep the electrical impulses constantly flowing over the line.

It also consists in so combining the before-mentioned sectional circuit with the generator that, even if the circuit is broken, the generator will or can furnish substantially the same current as before; that the current furnished shall be in proportion to the varying demand; that even when the circuit is broken in every section the generator does not break down; that there is not necessarily any complete circuit, in the general acceptation of the term "closed circuit," either in the generator or outside of it; that the generator is nevertheless capable, if desired, of sending out either varying or constant currents, or both, over continuous circuits, either in place of the preceding arrangements or simultaneously therewith; that electrical energy may be utilized in every section practically independent of the others as regards the character of the current used, and in other improvements, as fully hereinafter described.

Although I have improved forms of the various devices used, the invention does not depend upon them, but it is capable of satisfactory operation with such as are already known or in use, and I therefore do not herein describe them.

I do not claim the method employed in this application, reserving the same for another case, as I have, in a separate application dated January 5, 1887, prayed that Letters Patent be granted to me for that portion of my invention.

As the invention claimed in this case is simply my new arrangement and organization of elements, already well known and understood by electricians and those versed in the art, I do not give detailed descriptions or drawings of their construction further than may be needed for a full comprehension of my arrangement and use of the same.

As the simplest type of my system I will explain Figure 1 as follows:

The generator is for the moment supposed to be a dynamo-electric machine giving an alternating current.

M M are the field-magnets; A, the armature with two brushes leading the current to the poles P′ P² of the machine.

The pole-pieces and other minor parts are omitted for the sake of clearness in the drawings, not being necessary to the explanation.

To the poles are attached conductors leading to the nearest armatures of the condensers K′ and K^5, respectively. To the other armatures of the condensers are connected two circuits. One is the working or external circuit divided, we will say, into four sections by the condensers K^2 K^3 K^4, as shown, the adjacent terminals of each section being electrically connected to the respective armatures of the condenser between them. The other is the field-magnet circuit and extends between K′ and K^5, as before, passing through an apparatus, S*t*, for straightening alternating currents, the adjusted or straightened currents proceeding from binding-post *p*′ through the field-magnet coils M M of the generator, then back to post p^2, and thence through S*t* to the condenser K^5. When the generator starts running, the residual magnetism in the field-magnets gives rise to a slight electro-motive force in the armature, which charges the two condensers K′ K^5, and they send a like impulse through the field-magnet coils. By the process of cumulative effects or action and reaction between the field-magnets and armature, well understood, the current gradually becomes stronger until it reaches its normal or working strength; but this result will be reached more quickly if the poles P′ P^2 are connected directly to S*t*, as indicated by the dotted lines to p^3 p^4, until the field-magnets are fully energized and the generator working properly. Then condensers K′ K^5 are connected, as shown by the full lines, and a practically continuous straight current flows through the field-magnet coils M M, while an alternating current flows through the working-circuit. This is accomplished as follows: Let us start with a positive impulse from the armature to pole P′. It charges the inner half of condenser K′ positively to its own potential. The outer half of K′ is thereby charged negatively by induction to an equal potential, and a positive impulse is sent over the first section of the circuit and charges the nearest half of K^2 positively to a potential substantially equal to that of K′. By a similar induction in K^2 an impulse is sent from K^2 over the next section of the circuit to K^3, and in like manner over the section between K^3 and K^4, and that between K^4 and K^5, at the other end of the circuit. As the positive inductive action from the end at K′ is re-enforced by the negative inductive action from the other end at K^5, the loss of potential at the intervening condensers is very slight unless the circuit is very long and of high resistance or divided into a very large number of sections; but even then the loss is only in the middle sections, and is that due to half the length of the circuit, growing less toward either end. The next positive impulse is from pole P^2, which charges condenser K^5 positively and sends a positive impulse over the several sections of the circuit from K^5 to K′ in the manner already described. Thus there flows over the several sections of the circuit as many distinct currents, each consisting of impulses in alternately opposite directions, substantially like that which would be sent over a continuous circuit between P′ and P^2, and it acts in a like manner upon any apparatus which may be inserted in any of the sections of this circuit.

In arranging this system the condensers must be of sufficient capacity to receive and yield impulses of the required strength or volume, and the insulation capable of bearing the potential of the initial generator without injury. They are to be charged and discharged (the terminal ones by the generator) with sufficient rapidity to keep electrical impulses passing over the sections as an ordinary alternating current would do over an ordinary line, and so that if the impulses are rectified—*i. e.*, the current straightened or "adjusted"—a practically-continuous current will be obtained. For very rapid reversals condensers with air-insulation are preferable, as they discharge quickly, all of which will be well understood by those versed in the art and easily carried out and practiced without further explanations.

I hold that the currents passing over the line-sections consist of the neutral electricity residing in the sections and apparatus, (and the earth-connections, when any exist,) and that it is decomposed and separated by the inductive action of the condensers, which drives the positive and negative portions over the sections in obedience to its varying status, and that the energy required for this action is very little. Consequently there is only a small amount of energy expended beyond that transformed into useful work in the electrical receivers in the various circuits, and the system is highly economical, in addition to its other advantages pointed out herein.

Fig. 1 shows the field-magnets in shunt with the external circuit, so that the greater the resistance or the counter electro-motive force in the latter the more current goes to the field-magnet circuit, and vice versa, thus regulating the yield of current to the demand therefor, precisely analogous to the action of the like arrangement with continuous circuits. Instead of this the field-magnet coils may be arranged in series with the external circuit, as shown in Fig. 2, or they may be arranged after any of the systems of compound winding, or others, in connection with the armature, as may be deemed best for his purposes by the electrician or operator. Fig. 3 shows them in a continuous circuit between the poles, equivalent to the arrangement in Fig. 1, including the dotted lines, when the magnetic field will be stronger, other things being equal, than if the connections P′ p^3 and P^2 p^4 are omitted.

In place of the arrangements which include the current-straightener S*t*, a dynamo with two commutators or collectors may be employed, from one of which the brushes take a straight or adjusted current, and from the other an alternating one. This construction may be conveniently shown by representing the two collectors as being at the opposite ends of armature A, (although they need not be so in practice,) as shown in Fig. 4, where P′ P² are the poles for the alternating current, and P³ P⁴ those for the straight current. This may be accomplished either by devoting separate coils of the armature for each purpose, by having two armatures, or otherwise.

Fig. 4 shows the field-magnet coils in series with the external straight-current circuit; but they may be in shunt with it, as in Fig. 5, or may be separately excited, as in Fig. 6 or in Fig. 7, which latter represents two machines, both armatures being on the same shaft and both magnets energized by one of them, while the other furnishes the alternating current for the external circuit. The exciting-armature has also a second commutator at its other end, from which alternating currents may be sent by poles P P to either sectional or continuous circuits, to relieve the overtension of the machine when in full action. As the coils of the armature and the field-magnets would otherwise be in closed circuit, the intensity of the magnetic field would soon become enormous, from the absence of any external resistance and no waste of current, all being used in exciting magnetism by constant action and reaction. Consequently, with the arrangement shown in Fig. 5, a very few coils of the armature would suffice to keep up the magnetic field.

Of course, continuous-current machines may be employed and an apparatus used to change the straight into alternating currents for the condensers—such, for example, as that described by Trowbridge and Hayes in Silliman's Journal for May, 1885—or any other suitable for the purpose.

Instead of alternating currents, interrupted currents may be used in my system, produced in any suitable or well-known way.

Fig. 8 may represent a revolving circuit-breaker, B, whose surface is equally divided between conducting and non-conducting spaces, (the latter being drawn black, as indicating that they are not connected to the generator, but grounded or otherwise arranged for discharging,) with two pairs of brushes bearing thereon, having their ends one space apart. The spaces on the left are connected to the positive generator-pole, and those on the right with the negative pole. As B revolves, the current is sent first into one set of condensers, then into the other. This is not intended as a working drawing, but to show that the condensers are to be alternately charged with electrical impulses, one set being disconnected from the generator and discharging while the other is connected and charging, and each line is occupied by intermittent impulses. Any suitable circuit-breaker may be used, and with a single divided circuit instead of two, if desired. Undulating currents may also be sent and utilized in a like manner as alternating ones, with this exception, that the condensers will only send a current corresponding to the difference between the greatest and least strengths, or to the amount of the variations in the initial currents.

My system is not adapted for sending continuous or straight currents, as the condensers only act by change of charge, whereby induction is produced to that extent; but a continuous current may be sent in an indirect way, either by first converting it into an alternating current, sending it as such to the place of use and there reconverting it to a straight current, or by first dividing it into two equal interrupted ones, transmitting each over a separate line, and by any well-known means causing both to pass through the utilizing apparatus, the impulses of one filling in the intermissions in the other, and by their reunion forming a solid current, as illustrated at V in Fig. 8, which thus supplies a local circuit with a solid current.

I do not claim herein that division or part of my system which consists in starting with continuous or straight currents and converting them into interrupted, undulating, or alternating currents for transmission in the manner described, as I have another pending application therefor, together with many details of the construction and arrangement of the lines and apparatus in my system, filed October 18, 1886, and I shall claim all such matter therein.

My object in showing the foregoing different arrangements is to illustrate that my system is not limited to any particular kind or class of electrical generators, but may be used with any, and to explain how it may be done. It will therefore no longer be necessary to show the complete arrangements of the generators, but in subsequent drawings only the commutator and brushes will be given, it being understood that the field-magnet coils may be wound and connected up according to any well-known or suitable system preferred, or that any other generator may be connected to the poles shown in the drawings; also, that regulating devices may be used in either the external or the field-magnet circuit, as usual, and that in taking off currents of whatever character from the high-resistance closing-circuit between the poles of the generator any desired potential may be given to them by making the connections nearer to the poles or to the middle or point of zero-potential, as a higher or a lower potential is required. This closing-circuit is shown more fully in Fig. 4, where it is represented as divided into sections with artificial resistances R between them, so that connections can be made at any desired points by plugs or otherwise, all of which is well understood by electricians.

It will now be seen that while on an ordinary or continuous line the point of zero-potential is in the center (of resistance) of the entire line, in my system it is in the center of each section, and the points of highest and lowest potential at the ends of the line are repeated at the end of each section, so that the consumer may have virtually an entire line on his own premises, with the corresponding power to take off currents of such volume and electro-motive force as he may require. If he connects the terminals of his industrial apparatus to the condensers at each end of his section, he gets substantially the same difference of potential as if he connected at the generator itself, and if he uses but one conductor between the condensers he gets the entire volume of current passing over the circuit. On the other hand, if he divides the current between two or four conductors containing equal resistances, as between K^3 and K^4, Fig. 10, each will receive one-half or one-fourth as many ampères as the one would, and by proper adjustment of resistances he can control the difference of potential at the terminals of his apparatus. This can be done in different ways. He may insert his electrical receiver in the single wire of a section and get a difference of potential corresponding to its resistance, as shown between K' and K^2 in Fig. 9. If his receiver El has one-fourth the resistance of the entire section it will have between its terminals one-fourth the difference of potential between the condensers. Between K^2 and K^3 a conductor (preferably of high resistance) is shown, having various electrical receivers connected in shunts at different points, and receiving currents whose difference of potential will depend on the respective resistances of the various apparatus and conductors, as will be readily understood. K^4 and K^5 are connected by two branch conductors, which in their turn are connected by cross conductors, whose ends are attached at points of different potential, so that a current flows from the point of higher to that of lower potential through the cross connecting conductors, in which may be inserted any desired electrical receivers. If the branch conductors have uniform resistances, and are connected at uniform distances from their ends, as shown, I obtain a constant difference of potential between the terminals of the cross-conductors, which is uniform throughout the section. If the entire line is similarly arranged, I thus obtain a constant and uniform difference of potential at all points in the line, regardless of how near to or far from the generator the cross-conductors may be located. If he wishes to get more or less difference of potential than could be obtained as described with or without a change in the quantity or volume of the current for use in a local circuit, he may use some form of induction coils for that purpose, as the "transformers" of Gaulard and Gibbs or those of Zipernowski and Déri, as represented by Tr in Fig. 10, where a local circuit is shown containing electrical receivers fed by the transformed current El and l. The electrical receivers may be electric lamps, motors, or any other electrical apparatus. If the line breaks the ends may be grounded until repairs are made, as in Fig. 11, whereby the apparatus between the next condenser and the earth can still be used, although the difference of potential is only one-half as great as before the breakage.

Of course a number of circuits may be run between two condensers, as shown in Fig. 12, each receiving a current of the same potential, and the strength (or ampères) in inverse proportion to the respective resistances. So, also, any number of independent condensers may be charged at the same poles, either connected directly to the poles and charged to a like potential or charged to any different potentials required, as explained for Fig. 4. The number of sections in a circuit or the length of them may be largely a matter of choice.

The advantage of having an entire section under control is the great difference of potential available; but as there is a slight loss by each induction the number of condensers should not be excessive. If the potential of the initial current from the generator is very high, it may be beneficial to connect the ends or the middle of each section, or of one or more of them, to earth through a suitable resistance, as shown in Fig. 10. This resistance may, of course, be composed of any suitable electrical receivers for utilizing the current flowing through the grounded circuit. The resistance R should be sufficient to prevent this circuit from interfering with the charging of the condensers on the line proper, as K^2 and K^3.

If it should be desirable to have two conductors alongside, whose currents flow in opposite directions, Fig. 13 shows how they may be arranged and connected to the generator-poles. When independence of the currents is not required, a single condenser at each pole will answer for both circuits.

My invention is also applicable with the three-wire or multiple-wire systems of conductors, as shown by Figs. 14 and 15. If necessary, in order to insure that the two (or more) machines shall produce currents whose alternations (or interruptions) shall be exactly synchronous, straight currents may be used and led to suitable apparatus for changing them to alternating (or interrupted) currents, as already explained, and all the currents should be manipulated by the same shaft or vibrator of the apparatus, although the current from each generator may be kept isolated from the others and led to its own line. Fig. 16 illustrates this arrangement, where W is the apparatus adapted to manipulate the two currents, as described. Each current enters the apparatus straight and emerges alternating. On its return to W, at the other end of the external circuit, it is straightened again by its passage through W, and returns so to the other pole of the generator, thus completing its circuit.

For the system in Fig. 15 the apparatus should be adapted for manipulating three currents.

The arrangements drawn in Figs. 14, 15, and 16 serve to show that two lines returning to the generators may have their return-halves united into one, as there drawn, the condenser capacity of the combined portion being of course large enough for both lines. Whenever desired, however, the two return lines may be kept entirely separate, as would ordinarily be arranged. For instance, in Figs. 14 and 16 the interior or united part would then be replaced by two, thus making two complete lines, or four halves, instead of three, as shown. In Fig. 15 there would then be six halves instead of four, as shown.

If two widely-separated generators are caused to produce currents exactly coinciding in their alternations, (or interruptions,) as may be done by well-known means, they can be arranged at the two ends of the circuit or circuits, and the distant end of a circuit, instead of returning to the other pole of the same generator, will then return to the opposite pole of the twin generator, as shown in Fig. 17. The complete circuit would then include two generators instead of the one shown in Figs. 1 and 11. The principle is the same as if the two machines were together, connected up in series, for the higher electro-motive force, economy, &c. In like manner we may connect together any number of machines necessary to produce the desired strength of current or inductive action, either as one machine or apparatus or at different places in the circuit.

I will now state the general electrical laws involved in the operation of my invention or system in conventional technical terms in formulas convenient for use in working; but, first, I would observe that although there is a slight loss in the action of condensers, as before stated, it is not so large as is commonly supposed. In fact, with a properly-made condenser momentarily charged, as is done in my system, the loss is too inconsiderable to be discovered by ordinary measuring apparatus and should not in practice exceed one per cent. for each condenser.

The capacity of a condenser is expressed in farads and designated by the letter F. When a number of similar condensers are connected in series, as in my system, their working capacity is reduced in proportion to the number so connected. If ten 1-F. condensers are connected in series, as shown in the drawings, with the distant end of the line connected to earth, as in Fig. 11, the working or series capacity L-F. of each condenser will be one-tenth farad; but that does not imply any waste of energy in working. It merely limits the amount of electrical energy that can be transmitted by the given size of condensers. Although separately they have a capacity of 1-F. when so connected, they act as one-tenth farad condensers, and that capacity indicates the amount of electrical energy received and given out by them with the loss of one per cent. or less, as before stated. When both ends of the series are connected to the opposite poles of the generator, which is the normal arrangement of my system, the line so formed virtually consists of two series of equal capacity, one connected to each pole, and having their distant ends connected together. The line or series capacity L-F. is the capacity in farads of the polar or terminal condenser (or any one in the series) when so connected, and is obtained by dividing the absolute capacity of the individual condensers when alone by the number N in the series. Thus:

$$L\text{-}F = \frac{F.}{N} \quad (1.)$$

The charge or quantity of electricity which a single condenser can contain is expressed in coulombs, (coul.,) and is found by multiplying the capacity F. by the difference of potential (D. of P.) between its opposite plates or sides: Coul. = F×D. of P. of condenser; but when connected in series each one takes the same charge as the polar condenser receives from the generator, and the formula for each is then: Coul. = L-F × D. of P. of condensers. (2.)

If sufficient time is allowed for charging, the D. of P. of the condensers will be equal to E, the D. of P. between the generator poles—*i. e.*, when both ends of the line are connected to the generator-poles, which is the bipolar or normal arrangement, D. of P. of condensers = D. of P. at generator, (3;) but when one end of the series is connected to one pole, and the other end and other pole are connected to earth, which I call the "unipolar arrangement," the D. of P. of the condensers is double that at the generator, because it is the sum of +E and −E, and the formula is unipolar D. of P. of condensers = 2 × D. of P. of generator. (4.)

I transmit currents of as high electro-motive force as possible to utilize in the electrical receivers in the line, because high D. of P. increases the charge which a given size of condensers will contain, and therefore increases the work which a small condenser can do. It also causes the current to have a higher D. of P. and greater power to overcome resistance, or allows a greater volume of current through a given resistance.

The D. of P. of the current flowing between the condensers in a line on my system will be that of the condensers—*i. e.*, in an alternating current, the D. of P. (between the extreme positive and negative points of the current) will be equal to the D. of P. between the condenser-plates, and with an undulating interrupted or other like charging-current at the polar condensers the D. of P. of the line-current will be equal to the variations in the potentials of the charges of the condensers; but the D. of P. of an alternating current as measured by the usual voltmeters—such as Cardew's—does not indicate the D. of P. between the + and − extremes of the alternating impulses, but the expenditure of electrical energy by the current, and therefore gives approximately the average D. of P. of the current. It may ordinarily be considered that the D. of P. of current as measured = ½ D. of P. at condensers. (5.)

The volume of current which flows in a continuous circuit is expressed in ampères A, and is found by dividing the electro-motive force of the current by the resistance R, through which it flows; but in the case of alternating currents this rule may or may not apply, because they are not continuous and constant in either volume or electro-motive force. What their real average strength is may be different with different currents of the same type. The actual character, strength, and properties of such currents are as yet not fully understood, and many points about them are still involved in uncertainty. Sufficient exactness for a working rule will be obtained by taking one-half D. of P. at the condensers as the average D. of P. of the current, corresponding to an equal electro-motive force in a continuous current, and the volume of current which will flow through the line sections will be approximately obtained by the formula—

$$A = \frac{\tfrac{1}{2}\text{ D. of P. at condenser}}{\text{R. of the section.}} \quad (6.)$$

When the current is actually flowing, and its D. of P. can be measured, as above, the volume of the current may be adjusted by the formula—

$$A = \frac{\text{D. of P. of current as measured}}{\text{R. of individual section.}} \quad (7.)$$

Formula 6 will give the approximate strength of the alternating line-current; but when it is important to know precisely the volume of any particular current which flows or can flow over a given line, it can easily be determined by slowly increasing the resistance in one of the sections. If the measured D. of P. of the current begins to drop, it shows that the rate of flow or current, A, is being cut down, and the condensers do not become fully charged up to the proper D. of P. in the time allowed for charging, for it is obvious that if the discharge begins before the condensers are fully charged the D. of P. of the condensers will be correspondingly lower, and the D. of P. of the current will also be lowered. On the other hand, if the measured D. of P. of the current is increased by lowering the R., it shows that the resistance was too high, and that the average volume of the current is really greater than the mean value assumed in the formulas. Thus the calculated factors of a line may be readily tested and corrected to suit the peculiarities of any given current by simply increasing the normal R. of a section till the standard measured D. of P. of the current begins to drop, or vice versa, and the difference between the calculated and the allowable resistances shows the deviation of the current from the normal type of such currents, as given in formulas 5 and 7.

It is obvious that the resistance in the several condensers should be approximately the same for this reason. All the condensers charge up simultaneously and at the same rate, and the same current flows over each section, connecting the condensers to each other and to earth. An excess of resistance in any one section would lessen the rate of flow in that section and delay the charging of its condensers, and consequently of all the condensers in the line. The line-current A is therefore limited to D. of P. ÷ the highest R. in any one section. The line should evidently be arranged so that the resistances in the several sections will be approximately the same (or, at least, not above the standard R. of a section) at any particular time, although they may be very different at different times to suit the requirements of the service.

As the current is, in my system, produced by variations of charge in the condensers, each impulse can continue only so long as the charge stored in the condenser can supply the requisite electricity by discharge. The charge must then be repeated. The frequency of these charges should be such as to keep the impulses constantly flowing over the line in one direction or the other. This speed of reversing or varying the charges should be so adjusted that the condensers can be charged up to the required D. of P. in the time between the reversals or variations, and so that at the instant when they become so charged they will be caused to begin to discharge. To ascertain the speed required with a given line or series of condensers, I need only find how long the charge stored up in the condensers will sustain the current which will flow in any given case.

A coulomb of electricity will keep up a current of one ampère for one second, or a smaller current for a longer time or a larger current for a shorter time. The volume of current which will flow through a conductor connecting two condensers, as shown in the drawings, does not depend on the amount of the charge in the condensers, but is governed by the ratio of the D. of P. of the current to the resistance of the sections, as given in formulas 6 and 7. We may therefore have any current we wish by suiting the R. to the D. of P., to allow that current, A, to flow in the sections. Then the time, T, in seconds, during which the charge Coul. will furnish this current A is found by dividing the charge by the rate of flow, thus:

$$T = \frac{\text{Coul.}}{A} \quad (8.)$$

This time, T, indicates how often the charge must be repeated—*i. e.*, the speed of reversals in an alternating current, or of the breaks in an interrupted current, or of the variations in an undulating charging-current; or with current-varying apparatus for charging having a given speed and a current of a given volume and D. of P. required on the line we can calculate the line or series capacity, L-F., necessary to hold the requisite quantity of electricity for supplying that current by the formula—

$$L \cdot F = \frac{T \times A}{\text{D. of P. of condensers.}} \quad (9.)$$

And each condenser in the line should have the absolute or individual capacity—

$$F = \frac{T \times A \times N}{\text{D. of P. of condensers.}} \quad (10.)$$

In arranging a system, therefore, I proceed as follows: If I want a one-ampère current and one thousand volts D. of P., as measured, I shall require (as a general rule) one thousand ohms resistance in the sections, or in the one having the highest resistance. So, in any other case, I suit the R. to the D. of P. in formula 6 or 7 to get the current I want. A 1-F. condenser charged to one thousand volts D. of P. (formula 3) contains one thousand coulombs, which will supply a one ampère current (through five hundred ohms, formula 6) for one thousand seconds, (formula 8.) Instead of that, it would supply one thousand ampères for one second, fifty ampères for twenty seconds, one hundred thousand ampères for one one-hundredth second, or any desired modification of these quantities, provided that D. of P.÷R. (formulas 6 and 7) is in each case so adjusted as to permit the desired current to flow through the conductor.

In order to keep the impulses continuously flowing over the line in one direction or the other, I repeat the charges as rapidly as they are discharged in each case. For instance, if I want an alternating current of one ampère, and my condensers are so small that they will keep up one ampère of current for only one two-hundred-and-fiftieths second, I reverse the charging-current two hundred and fifty times per second, and the successive discharges then supply a continuous alternating current on the line.

It is commonly supposed that in order to get a current or impulse of any considerable volume a condenser of enormous size is required. The foregoing formulas prove that such is not the case. A condenser of the size commonly used in telegraphy, or of only four microfarads capacity, charged to two thousand volts D. of P. contains one one-hundred-and-twenty-fifths coulomb, which will supply a two-ampère current for one two-hundred and-fiftieths second. Thus, with a charging-generator reversing two hundred and fifty times a second, this tiny condenser will keep a two-ampère alternating current flowing through five hundred ohms resistance and transmit over two and two-thirds horse-power in electrical energy; or a 1-F. condenser, with the same speed of reversals, the same D. of P., and having one five-hundredths ohm resistance in the conductors, will keep an alternating current of five hundred thousand ampères and one thousand volts flowing with electrical energy, equivalent to 670,241 horse-power, minus one per cent. or less for loss in the condenser. The volume of current flowing in the sections being governed by the ratio of R. to D. of P. in formulas 6 and 7, any desired volume of current may be obtained by so varying the R. as to cause that current to flow, and if the generators are self-regulating, as hereinbefore explained, they will supply the current required. The method of regulating and governing dynamo-electric generators to get constant potential and varying current, constant current and varying potential, or current and potential both constant, either by electrical or mechanical arrangements, is now so well understood by all electricians that it will not be necessary to explain those points any further than has already been done, only to say that the capacity of the condensers should be sufficient for the greatest volume of current they will at any time be required to furnish.

Telegraphic and telephonic lines have been proposed consisting of sections connected together by condensers; but such a line is connected to one pole only of the generator and is intended to actuate apparatus at the other end and to deliver to the utilizing apparatus an exact reproduction of the initial current, whereas mine is adapted to actuate apparatus in every section of the line, giving in each one a current which may be quite unlike that in any other section or that which the generator produced; and the far end of the line returns to the other pole of the generator and is connected thereto, so that both poles exert an inductive action over the whole line, each assisting the other, and both poles being virtually repeated at the ends of each section. Moreover, my receiving apparatus are not connected to earth, but are in the line and without the earth connections employed by others.

My invention is not the transmission of identical or uncharged single-signaling impulses or currents over a line having one end connected to the current generating and varying apparatus, for utilization exclusively in receiving apparatus in the terminal sections of the line, but the transmission over a line having one or both ends connected to the charging apparatus and adapted for insulated electrical receivers in every section of an amount of electrical energy in current whose character may be indefinitely varied at many points between the poles of the generator, as may be required by the electrical receivers there for purposes of utilization.

Another peculiarity of my system is that there is little or no tendency of my currents to escape from the line to earth, as in all previous systems, because these currents, being produced by inductive attractions from both ends of the line, are more strongly drawn there than to the earth, and there is a greater difference of potential between any point in the circuit and its ends than between that point and the earth. Still another peculiarity is that the currents when they arrive at the condensers and become "charges" are "bound" therein and are not liable to escape even if an earth-connection is provided. These two facts largely remove the danger to attendants arising with any other kind of apparatus statically charged to a high potential. Even if the body of the attendant became an earth-connection, as R. at K^2 in Fig. 10, the currents would have only one-half the potential and about one-third of the strength of the normal currents over the line. If he touched the line at its center of resistance, as R. between K^4 and K^5, he would receive no current or shock at all; hence by my system lines with very moderate insulation may carry currents of very high potential without loss, and much higher, with safety to attendants, than by any other system.

A further advantage of my system is that by the duplicating or repeating of the inductions over sections of line the resistance of a long line in numerous sections may be no greater than that of an ordinary line having only the length of one of my sections for conveying the same amount of energy, and I can use a conductor that is very much smaller and less expensive, although my line is many times the longer. This fact will be evident on consideration of the laws governing the inductions of condensers; but the crowning peculiarity of my system is the method of and economy in the transmission of power. Supposing that we have a sectional line arranged, for example, as in Fig. 1, and a certain amount of energy is expended in charging the polar side of the terminal condenser—say K′—that energy will be expended in putting K^2 in a like condition. The energy in K^2 is then expended in putting K^3 in like condition, and so on to the end, currents being sent over the conductors connecting the several condensers, whose potential depends on the potential of the terminal condensers and their quantity or strength upon the capacities of the condensers in the line and the resistances of the conductors connecting them. A difference of potential being established between the two ends of the section-conductor, a current flows through it precisely as if the same difference were brought about by direct connection to the poles of the generator, excepting only that it is limited by the capacity of the condensers at its ends. This current may be utilized in overcoming resistances or doing work on the section like all other currents—that is to say, the original amount of energy expended by the generator is reproduced in the several sections by the inductions and electrical attractions and repulsions in the several condensers, and is consequently repeated as many times as there are sections in the line, minus the small loss at the condensers.

I do not confine myself to the exact arrangements or details described, for it is evident that they may be widely varied without departing from the principles of my invention, as will be readily understood and accomplished by those versed in the art.

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

1. An organized system for the production, transmission, and distribution of electric currents, consisting of the combination of apparatus for automatically producing a suitably-varying current and one or more external or working circuits connecting the opposite poles of the current producing and varying apparatus, said circuits being inductively connected to the poles through electrical condensers or devices which prevent the actual passage of the initial current from the poles over the lines or circuits, but which transmit a corresponding amount of electrical energy over the circuits by virtue of induction through said devices from both of said poles.

2. An organized system for the production and distribution of electrical energy, consisting in the combination of apparatus for producing a suitably-varying current, and one or more lines or circuits connecting the opposite poles of the current-producing apparatus, one or more of said lines being divided into sections by condensers, each section having substantially the same potential at its ends as the undivided line would have had and being substantially a counterpart of said undivided line.

3. The combination of apparatus for producing a suitably-varying current and one or more lines or circuits connected to the opposite poles of said apparatus, one or more of said lines being divided into sections inductively united by condensers, each such section being adapted for the utilization of the current passing over it in electrical apparatus inserted in it.

4. The combination of apparatus for producing a suitably-varying current and one or more lines or circuits connected to the opposite poles of said apparatus, one or more of said lines being divided into sections inductively united by condensers, and each of said sections being practically independent of the others as regards the character of the current passing over it or through the electrical apparatus inserted in it.

5. The combination of apparatus for producing a suitably-varying current and one or more lines or circuits connecting the opposite poles of said apparatus, one or more of said lines being divided into sections inductively united through condensers, whereby each pole acts by induction over the whole line to the other pole and each assists and sustains the inductive action of the other.

6. The combination, substantially as described, of dynamo-electric apparatus for producing a suitably-varying current, two or more lines connecting the opposite poles of said apparatus through condensers, and a circuit containing the field-magnet coils of said apparatus and means for changing the varying to a straight current.

7. The combination, substantially as described, of dynamo-electric apparatus for producing a suitably-varying current and one or more lines connecting the opposite poles of

said apparatus through condensers, and a circuit containing the field-magnet coils of said apparatus.

8. The combination of apparatus for producing a suitably-varying current, one or more lines or circuits connected to the opposite poles of said apparatus, and means in said circuit or circuits, but independent of or separate from the generating apparatus, for changing said varying to a continuous or straight current for use therein.

9. The combination of dynamo-electric apparatus for producing a suitably-varying current and a circuit containing its field-magnet coils in closed circuit with one or more coils of the armature, with one or more external or working circuits connected to its poles through condensers.

10. The combination, substantially as described, of apparatus for producing a suitably-varying current, one or more lines connected to the opposite poles of said apparatus through condensers for transmitting said current, and electrical receivers actuated by the impulses or currents induced by or between said condensers.

11. The combination of apparatus for producing a suitably-varying current, one or more lines or circuits connected to the poles of said apparatus through condensers, apparatus in said circuit for changing the character of the current flowing over it and sending it through a local circuit connected to said apparatus, then on over the line, and an electrical receiver in said local circuit for utilizing said changed current.

12. The combination, substantially as described, of apparatus for producing a suitably-varying current, one or more lines connected to the opposite poles of said apparatus through condensers for transmitting said current, means for also producing a straight current, and one or more lines connected thereto for transmitting said straight current.

13. The combination, substantially as described, of apparatus for producing a suitably-varying current, one or more lines connected to the opposite poles of said apparatus for transmitting said current bodily, one or more lines connected to the poles through condensers for transmitting said current by induction over them, means for producing a straight current, and one or more lines for transmitting said straight current.

14. The combination, substantially as described, of apparatus for producing a suitably-varying current, one or more lines connected to the opposite poles of said apparatus through condensers, and means for giving any desired potential (within the capacity of the said apparatus) to the current sent over each individual line.

15. The combination, substantially as described, of apparatus for producing a suitably-varying current, one or more lines connected to the opposite poles of said apparatus through condensers, and means for sending a current of the same potential over each of said lines.

16. The combination of apparatus for producing a suitably-varying current, one or more lines connected to the opposite poles of said apparatus through condensers, means for giving any desired potential to the current sent over each individual line, one or more lines connected to the opposite poles of said apparatus for transmitting said varying current bodily, and means for giving any desired potential to the current sent over each of said lines.

17. The combination of apparatus for producing a suitably-varying current, one or more lines connected to the opposite poles of said apparatus through condensers, means for giving any desired potential to the current sent over each individual line, means for producing a continuous current, one or more lines for transmitting said current, and means for giving any desired potential to the current sent over each of said lines.

18. The combination of apparatus for producing a suitably-varying current, one or more lines connected to the opposite poles of said apparatus through condensers, means for giving any desired potential to the current sent over each individual line, one or more lines connected to the opposite poles of said apparatus for transmitting said varying current bodily, means for giving any desired potential to the current sent over each of said lines, means for producing a continuous current, one or more lines for transmitting said current, and means for giving any desired potential to the current sent over each of said lines.

19. The combination, substantially as set forth, of apparatus for producing a suitably-varying current, one or more lines or circuits connected to the poles of said apparatus and divided into sections inductively connected through condensers, and a conductor connecting one of said sections to earth through a suitable resistance.

20. The combination, substantially as described, of apparatus for producing a suitably-varying current, one or more lines or circuits connected to the poles of said apparatus and consisting of sections inductively connected through condensers, and an electrical receiver inserted in one of said sections, whose resistance bears the same ratio to the resistance of said section as the desired difference of potential between its terminals bears to the difference of potential between the ends of said section.

21. The combination, substantially as described, of apparatus for producing a suitably-varying current, one or more lines or circuits connected to the poles of said apparatus and consisting of sections inductively connected through condensers, each section being divided into as many derived circuits and with such

resistances as may be necessary to secure for the electrical receivers in them the proper strength or tension of current.

22. The combination of two or more apparatus for producing a suitably-varying current, with a suitable number of sectional lines, such as described, arranged on the multiple-wire system of conductors, substantially as set forth.

23. The combination, substantially as described, of apparatus for producing a suitably-varying current, one or more lines or circuits connecting the opposite poles through condensers, one of the sections of such wire or line being broken or open, and a conductor connecting the broken wire to earth.

24. The combination of a line consisting of a conductor whose ends terminate in the contiguous sides or armatures of condensers, generating apparatus for producing suitably-varying electro-motive force, and connections from the two poles of said apparatus to the opposite sides or armatures of the said condensers, enabling the generating apparatus to give them correspondingly-varying electric charges, and thereby inducing currents or impulses over the conductor connecting their opposing sides or armatures.

25. The combination, substantially as set forth, of a line consisting of a suitable conductor, two condensers, each having one of its sides or armatures connected to the contiguous end of said conductor, generating apparatus for producing suitably-varying electro-motive force, and connections from the two poles of said apparatus to the other sides or armatures of said condensers, enabling said apparatus to decompose or separate the electricity of the conductor and its connections and to attract the same to the condenser-plates attached to its ends by simultaneous induction from both poles of said apparatus, the whole arranged and operating to lessen or prevent the tendency of the said electricity to escape from said conductor to earth.

26. In a system such as herein described, the combination of a line terminating in condensers and consisting of two or more sections connected by condensers, and electrical receivers in one or more of said sections and between the condensers, actuated by the currents or impulses induced by said condensers.

27. In a system such as described, the combination of an electric generator charging condensers connected to its poles, a line connected to said condensers and divided into sections, and condensers inductively uniting said sections into a sectional line and caused by the terminal condensers to reproduce the changes occurring therein, the whole arranged and operating to substitute, in place of the sending of a current over the whole distance or length of the line, the production of corresponding but separate and independent currents in and over the several sections by the simultaneous inductions of the section-condensers, whereby the electrical resistance of said line is practically reduced to a minimum.

28. In a system such as described, the combination of apparatus furnishing suitably-varying currents, electro-motive force or potential, a sectional main line conveying varying currents therefrom, a local circuit distinct from the circuit containing the generator, an induction-coil having primary coil or coils acted upon by the currents of said sectional line and secondary coil or coils in the local circuit, and one or more electrical receivers in the local circuit.

29. In a system such as described, the combination of a sectional main line, a conductor therein conveying line-currents, a local circuit distinct from the generator-circuit, and an induction-coil having primary coil or coils acted upon by the line-currents, and secondary coil or coils in the local circuit.

30. In an organized system for the production and transmission of electrical energy by repeated inductions, the combination of a generator expending a certain amount of energy in charging condensers connected to its poles, two or more sections of conductors arranged in series, condensers inductively uniting said sections into a line whose ends are connected to the terminal condensers and having capacities suitable for discharging over the sections connected to them currents having the stated amount of electrical energy, and devices properly reversing or varying the charges of said terminal condensers, the whole arranged and operating to reproduce the original amount of energy in each of the sections by the repeated inductions and electrical attractions and repulsions at the several condensers.

31. The combination of one or more sectional lines consisting of sections inductively connected through condensers, self-regulating apparatus for automatically supplying suitably-varying currents as needed on said line or lines, and connected to said line or lines through suitable polar condensers, and electrical apparatus in said line or lines utilizing said currents.

32. The combination of a sectional line consisting of sections inductively connected through condensers, self-regulating apparatus for automatically supplying suitably-varying currents as needed on said line and properly connected thereto, and suitable resistances in the sections, having the maximum section resistance properly adjusted to determine the volume of current flowing over the line.

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