(No Model.) 3 Sheets—Sheet 1.

F. J. SPRAGUE.

SYSTEM OF ELECTRICAL DISTRIBUTION.

No. 335,045. Patented Jan. 26, 1886.

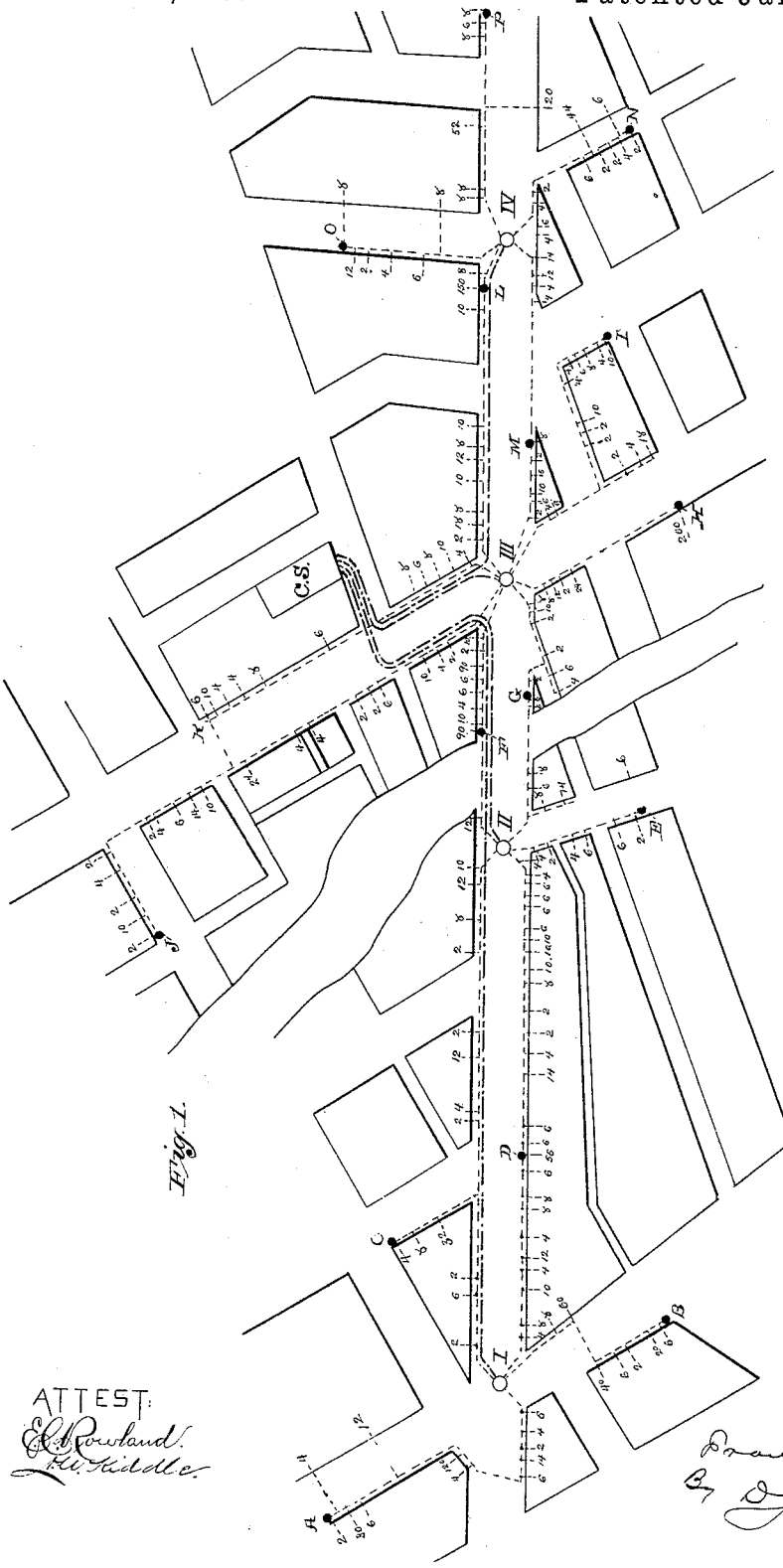


Fig. 1.

ATTEST:
E. C. Rowland.
R. H. Liddle.

INVENTOR:
Frank J. Sprague
By Dyer & Duell
Att'ys.

N. PETERS. Photo-Lithographer, Washington, D. C.

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F. J. SPRAGUE.

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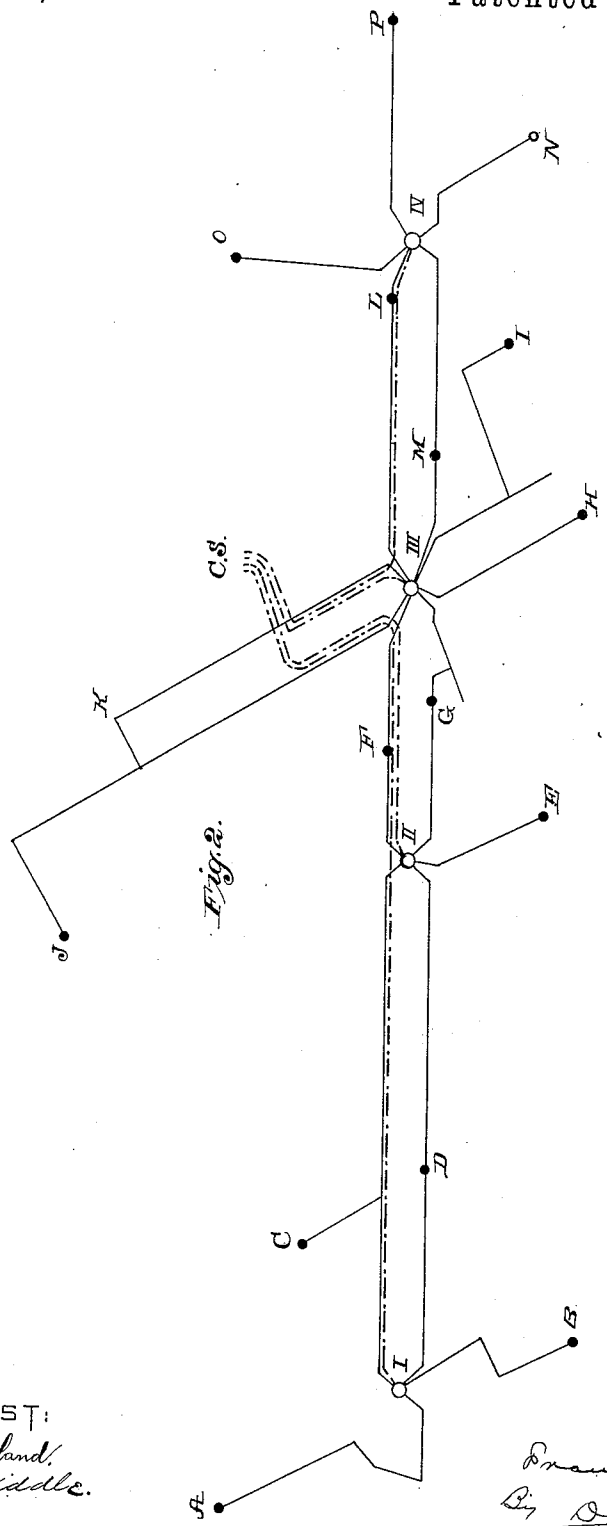


Fig. 2.

ATTEST:
E. C. Rowland.
A. L. Riddle.

INVENTOR:
Frank J. Sprague
By Dyer & Seely
Atty's

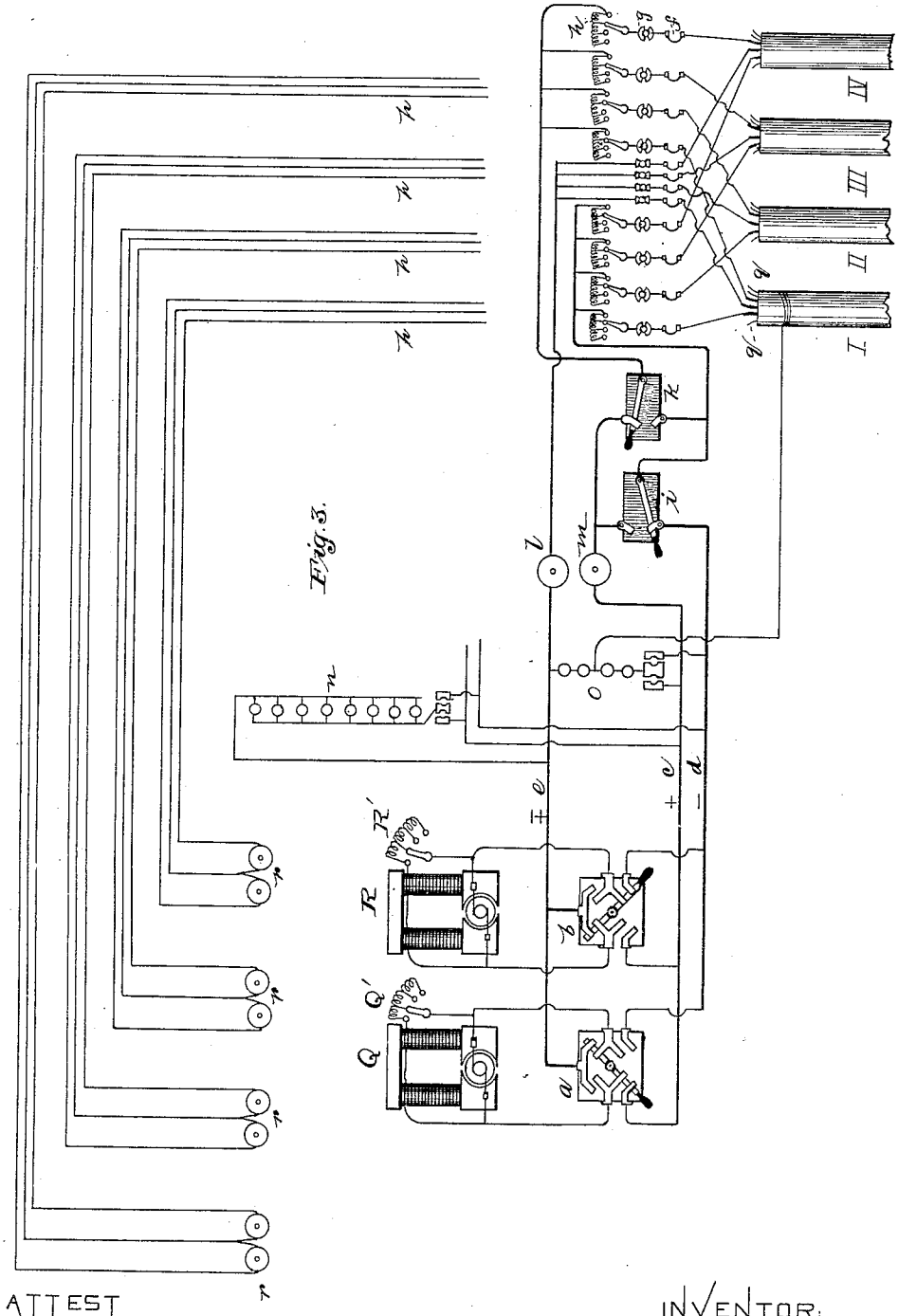
N. PETERS. Photo-Lithographer, Washington, D. C.

(No Model.) 3 Sheets—Sheet 3.

F. J. SPRAGUE.

SYSTEM OF ELECTRICAL DISTRIBUTION.

No. 335,045. Patented Jan. 26, 1886.



ATTEST

E. L. Rowland

H. W. Biddle.

INVENTOR:

Frank J. Sprague

By Dyer & Duffy

attys.

N. PETERS, Photo-Lithographer, Washington, D. C.

UNITED STATES PATENT OFFICE.

FRANK J. SPRAGUE, OF NEW YORK, N. Y., ASSIGNOR TO THE EDISON ELECTRIC LIGHT COMPANY, OF SAME PLACE.

SYSTEM OF ELECTRICAL DISTRIBUTION.

SPECIFICATION forming part of Letters Patent No. 335,045, dated January 26, 1886.

Application filed September 19, 1885. Serial No. 177,631. (No model.)

To all whom it may concern:

Be it known that I, FRANK J. SPRAGUE, of New York city, in the county and State of New York, have invented a certain new and useful Improvement in Systems of Electrical Distribution, of which the following is a specification.

Heretofore in the placing of conductors for multiple arc or multiple-series systems of electrical distribution for light and power the plan followed has been to consider the district to be supplied with current as divided into a number of smaller or sub districts, all of equal normal consumption, but varying in area accordingly as the locality was thickly or sparsely settled. The entire district has been provided with a connected system of main conductors, (or street-mains,) and to the electrical center or center of consumption of each of the sub-districts feeding-conductors from the central station or source of supply have been run to such street mains. The entire current of the system was intended to be divided equally among the feeders, which were made of the same resistance, although varying in length, and in this way it was proposed to maintain the same difference in potential at the outer ends of all the feeders. This system is described in patents of T. A. Edison, Nos. 264,642 and 266,793. I have found that this method of constructing the feeders has radical defects, which it is the principal object of my invention to overcome. As the more substantial of these defects, it may be stated that an unnecessarily large amount of copper was required for the feeders, and even by the use of an excessive amount of copper in conductors it was found impossible to secure an equal distribution of current. This resulted in producing greater heating effects upon some feeders and mains than upon others, in an unequal potential at the ends of the several feeders, in an unequal drop on mains between ends of feeders, in bringing the lamps up to different degrees of incandescence in different portions of the district, and in producing an excessive breakage of lamps. These defects I remedy by arranging the feeders of such a system to carry different quantities of current. Since the drop in electro-motive force is proportional to the current and resistance of conductor, I provide for the same difference in potential at the outer ends of all the feeders by making them of different resistances, so that they will be relatively inversely proportional to the ampères of current that they carry. While the total resistance of the feeders from end to end will be governed by one condition, (the current,) the size or cross-section of the feeders will also depend upon the length of the feeders, which are different in this respect, as well as in the current they carry. In the preferred system of electrical distribution, the dynamos in the central station feed into omnibus conductors, with which all the feeders are connected as a common source of supply, and it is in connection with a system of this character that my invention is hereinafter particularly explained; but it may also be employed in a system wherein two or more separately-regulated sources of electrical supply are used, as described in patent of C. S. Bradley, No. 291,141.

As one character of multiple-arc systems of electrical distribution I desire to be understood as including the compensating or three-wire system described in principle in patent of T. A. Edison, No. 274,290.

In carrying out my invention I provide a central-station plant with an appropriate number of feeders, the number and location of the feeders being determined arbitrarily upon a consideration of the total consumption and its distribution, it being desirable as a matter of practice that feeders should not be larger or smaller than certain maximum and minimum sizes, which can be readily produced by conductors that it will be found convenient to use. To determine the load which each feeder will carry under normal conditions, the points of lowest difference in potential upon the mains are first determined, since toward such points the current from feeders on opposite sides thereof will flow. The location of the feeders being fixed upon a plan, (which also shows the number of lights and their location, and the mains from which the lights are supplied,) each main connecting two feeders will be considered separately. The difference in potential at the outer ends of the two feeders being the same, and the main connecting the two feeders being of uniform size (not yet determined upon) from one feeder to the other, the point of lowest difference in potential upon the main can be readily fixed. The location of this point will depend not

only upon the number of lights, but their distribution along the main. The current from the two feeders will flow from opposite ends of this main toward the point of lowest drop, so that if the normal conditions were always preserved the main could be severed at that point without effect upon the distribution of current. The mains will be made of such definite sizes, as hereinafter explained, that there will be a certain drop in electro-motive force from ends of feeders to points of lowest difference in potential. This is preferably from three to five per cent. If a main connecting two feeders has branch mains taken therefrom, as is often the case, the point of lowest drop upon the main may not be one of the points of lowest difference of potential of the system, since the main and branches will be constructed to give the lowest permitted drop at the ends of the branches. There are other or open-ended mains which do not connect two feeders, but are connected each to one feeder only. These will also be made of definite sizes, so that at their outer ends, or at the outer ends of all branch mains therefrom, there will be the lowest difference in potential that is allowed for the system. The points of lowest drop being determined upon as to all mains connecting feeders, and the mains not connecting feeders, but running off each from one feeder, being also taken into consideration, the load which each feeder will carry under normal conditions can be accurately determined. This may result in a change in the position of the feeders from the positions first arbitrarily fixed, or a change in their number, to secure the best arrangement; but whatever changes are made the normal load of each feeder will be finally determined in the manner stated. This being fixed upon, the proper size of each feeder can be determined by a consideration of their load and of the loss it is desired there should be upon the feeders (usually from ten to fifteen per cent.) and the length of each feeder. Since the load upon the feeders will differ, it will be seen, as before stated, that the feeders by my method will be made of different resistances, which resistances shall be inversely proportional to the current each has to carry. At the central station or source of supply the feeders will be provided with adjustable resistances or other suitable devices for regulating to compensate for changes from the normal conditions in the distribution of the translating devices in the district. Suitable pressure-indicators will also be provided, which may be such as described in Patent No. 266,793, to show the electro-motive force at the outer ends of the feeders and give the indications required for performing the regulation of the feeders. The dynamo-machines supplying the current will also be capable of regulation to compensate for changes in the total number of translating devices, and ampère meters will be used to give proper indications for performing this regulation. The central station will further be provided with the other necessary indicating, regulating, and switching devices, which are usual in systems of electrical distribution.

Another feature of invention is the peculiar construction of the mains in a system of the character contemplated by this application. These I make each of the same size or cross-section throughout its length from end to end, but proportional to the load, so that the several mains differ in cross-section and resistance. Each single-end main is of uniform size throughout its length, and if there are branch mains these are each of uniform size from the point of junction with the main to the outer end of the branch main. The branch mains are preferably of the same size as the mains from which they are taken; but they may be smaller. The size of each single-end main will be determined by its length and the number of lights it will carry, so as to give the lowest permitted drop (say, from three to five per cent.) at its outer end, or at the outer ends of the branch mains therefrom, if there are any. Each main connecting two feeders is also of uniform cross-section throughout its length, and this size is determined by its length and the number of lights fed from it, so that at the point of lowest drop upon the main the lowest permitted difference of potential will exist, or at the ends of its branch mains, if there are any. Each branch main from a main connecting two feeders will be uniform in size throughout its length, and preferably of the same size as the main from which it runs, although it may be of smaller size than the main. If the system includes branch mains which connect two mains, so as to receive current from each, these branch mains will be treated the same as mains connecting two feeders.

A system embodying my invention is illustrated in the accompanying drawings, in which Figure 1 is a plan of feeders and mains, showing location of lamps, the plan being on a scale of two hundred and twenty feet to the inch; Fig. 2, a plan of feeders and mains on same scale as Fig. 1; and Fig. 3 a view, principally in diagram, of the arrangement for a station.

The system illustrated is the three-wire or compensating system of Patent No. 274,290, before referred to, each feeder and main being composed of three conductors. The lamps indicated on plan, Fig. 1, by numbers at ends of short lines are divided equally between the two sides of the system. The single lines for feeders and mains in Figs. 1 and 2 indicate each three conductors, which are all of the same size, and the size on cross-section hereinafter given for a feeder or main is the size of each of the three conductors of the feeder or main. The central stations in Figs. 1 and 2 is at the point C S. Four feeders are shown, their outer ends being indicated in Figs. 1 and 2 by open circles, I, II, III, IV. In Figs. 1 and 2 these feeders are shown by lines composed of dots and dash-

es. The mains are shown in Fig. 1 by lines composed wholly of dots, and in Fig. 2 by full lines. The loss upon feeders is ten per cent. The maximum loss on mains is three per cent. The initial potential on both sides of system is, at station, 233.3 volts, and at feeder-terminals, 210 volts. The system illustrated has 2074 ten-candle incandescent electric lamps. The solid circles lettered in capitals indicate the points of lowest difference of potential of the system.

The following is a table of the feeders:

Number.	Length in feet.	No. of lights.	Current in ampères.	Circular mills.	
				True size.	Commercial size.
I	1,654 4	513.4	123.2	182,008	No. 000 B. W. G.
II	792.0	338.6	81.3	57,465	" 4 "
III	391 6	790.5	189.7	66,334	" 3 "
IV	904.2	431.7	103.6	83,645	" 2 "

The following is a table of the mains, showing sizes:

Number.	Circular mills.	
	True size.	Commercial size.
I A	55,304	No. 4 B. W. G.
I B	24,739	" 8 "
I C II	15,349	" 11 "
I D II	25,498	" 8 "
II E	3,649	" 16 "
II F III	16,689	" 10 "
II G III	3,863	" 16 "
III H	54,778	" 4 "
III I	22,905	" 9 "
III J	40,376	" 6 "
III K	40,376	" 6 "
III L IV	11,162	" 12 "
III M IV	3,878	" 16 "
IV N	13,956	" 11 "
IV O	6,664	" 14 "
IV P	19,611	" 9 "

These sizes are determined in the manner already explained. The commercial sizes nearest the true theoretical sizes will be used in practice, as shown by the tables.

In Fig. 3 is shown the station arrangement for the system. Two dynamo-machines, Q R, are shown regulated separately by adjustable resistances Q′ R′, and connected with opposite sides of the system through shifting-switches *a b*. The regulation of dynamos by resistances Q′ R′ is performed to compensate for changes in total number of translating devices in circuit. The positive, negative, and neutral omnibus conductors are shown at *c d e*. The conductors of the feeders I, II, III, and IV are connected with the omnibus conductors through safety-catches *f*, switches *g*, and adjustable resistances *h*, the adjustable resistances not being used in the neutral conductors. The adjustable resistances *h* are used to regulate the feeders to compensate for changes from the normal in the distribution of the translating devices. Break-down switches are shown at *i k* and ampère-meters at *l m*, to give indications for adjustment of resistances Q′ R′. A bank of test-lamps is shown at *n*, and an arrangement for testing for grounds and insulation at *o*. For clearness the station pressure-wires *p* are shown as disconnected from the pressure-wires *q* in feeder-pipes. At the ends of wires *p* are the pressure-indicators *r*, to give indications for adjustment of feeder-resistances *h*.

What I claim is—

1. In a system of electrical distribution, the combination, with the main conductors, of two or more feeders connecting such main conductors with the source of electrical supply, said feeders carrying different normal loads and constructed of different resistance inversely proportional to the loads they carry, so as to produce the same difference in potential at the terminals of the two or more feeders, substantially as set forth.

2. In a system of electrical distribution, the combination, with main conductors and two or more feeders, such feeders carrying different normal loads and constructed of different resistance, connecting the mains with the source of electrical supply, of means for regulating such feeders to compensate for variations from the normal distribution of the translating devices, substantially as set forth.

3. In a system of electrical distribution, the combination, with main conductors and two or more feeders, such feeders carrying different normal loads and constructed of different resistance, connecting the mains with the source of electrical supply, of means for regulating such feeders to compensate for variations from the normal distribution of the translating devices, and means for regulating to compensate for changes in the total number of translating devices, substantially as set forth.

4. In a system of electrical distribution, the combination, with two or more feeders from the source of electrical supply, of main conductors connected with such feeders, and constructed of different resistance inversely proportional to the loads they carry, each main conductor being of uniform size throughout its length, substantially as set forth.

5. In a system of electrical distribution, the combination, with a source of electrical supply, of two or more feeders therefrom carrying different normal loads and constructed of different resistance inversely proportional to their normal loads, and main conductors connected with and supplied by such feeders, said mains being constructed of different resistance inversely proportional to their loads and of uniform size throughout their length, substantially as set forth.

This specification signed and witnessed this 2d day of September, 1885.

FRANK J. SPRAGUE.

Witnesses:
R. W. KIDDLE,
E. C. ROWLAND.