No. 876,979. PATENTED JAN. 21, 1908.

E. LEHR.

POTENTIAL REGULATOR.

APPLICATION FILED NOV. 13, 1905.

Fig. 1.

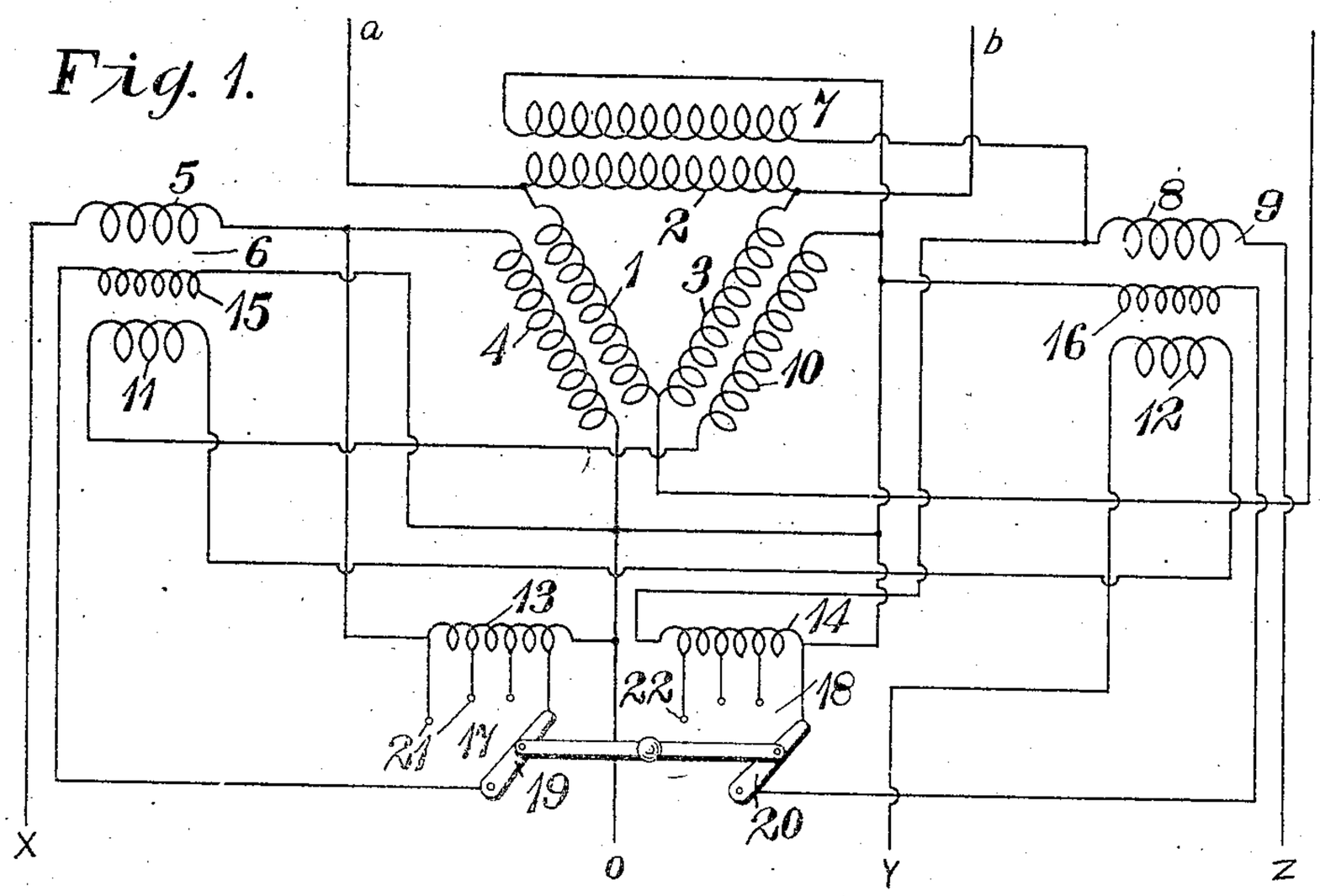


Fig. 2.

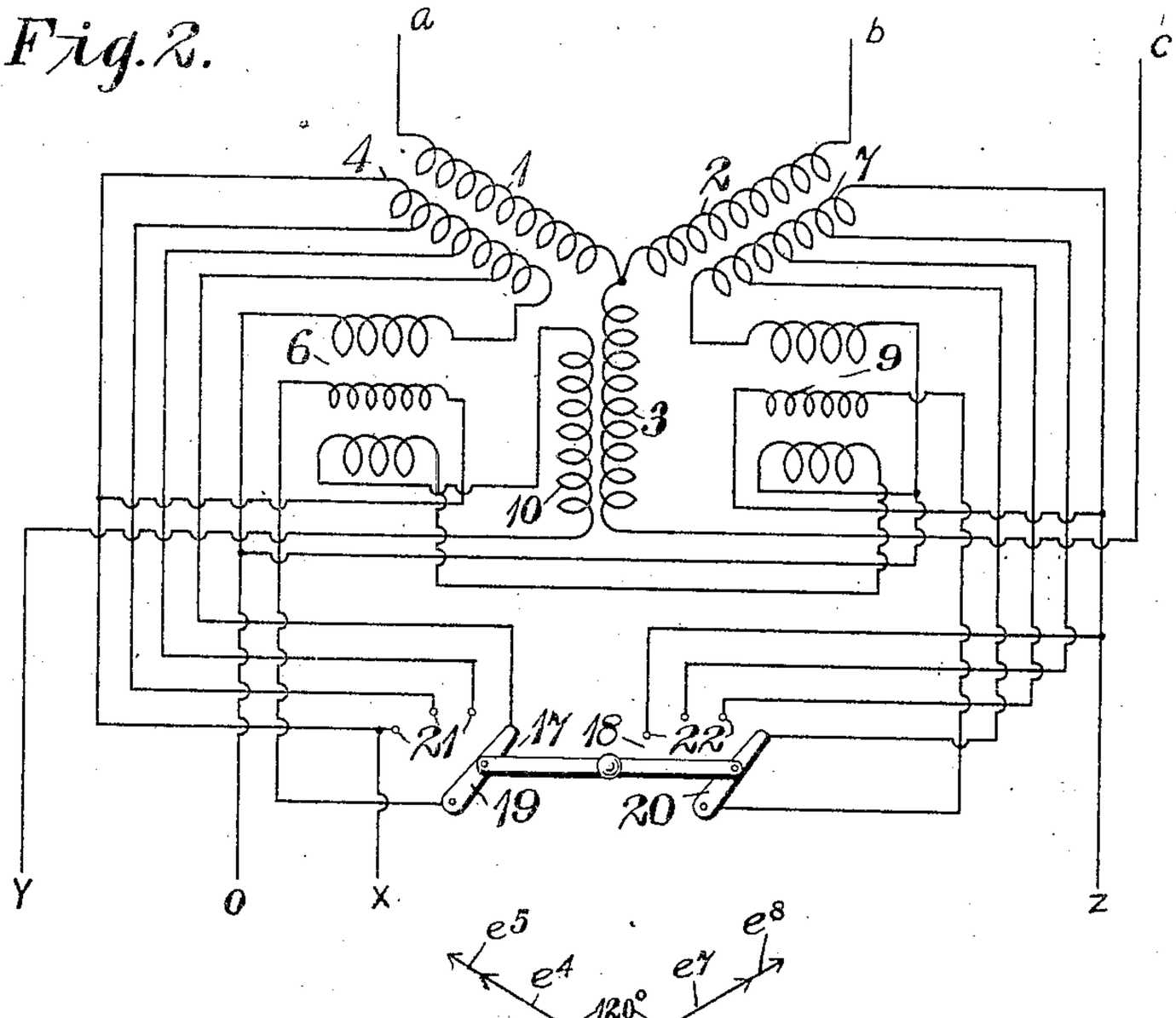
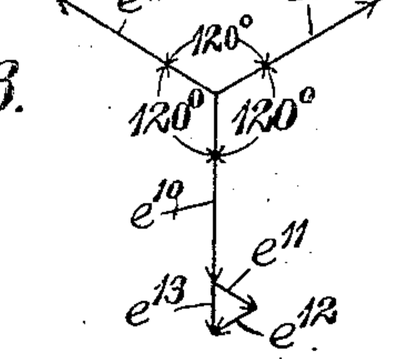


Fig. 3.



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POTENTIAL-REGULATOR.

No. 876,979. Specification of Letters Patent. Patented Jan. 21, 1908.

Application filed November 13, 1905. Serial No. 287,168.

To all whom it may concern:

Be it known that I, EDWIN LEHR, a citizen of the United States, and a resident of Wilkinsburg, in the county of Allegheny and State of Pennsylvania, have invented a new and useful Improvement in Potential-Regulators, of which the following is a specification.

My invention relates to systems of electric feeder regulation and particularly to the regulation of three-phase alternating current systems of distribution.

The object of my invention is to provide a system of the aforesaid class that shall adequately and simultaneously regulate the potential between lines and that shall preserve the relative phase relations of the electromotive forces imposed upon the outgoing circuits.

A further object of my invention is to eliminate a considerable portion of the electrical apparatus formerly employed in systems of this character.

In three-phase alternating current systems of distribution, it has been found desirable to provide regulation which, although relatively inconsiderable in its range, shall maintain suitable phase relations between the lines supplied and also produce such regulation simultaneously. This has been accomplished in the prior art in combination with an ordinary reducing system of transformers, which were either delta or star connected in accordance with well known principles. When three transformers were star connected for this purpose, the outer terminals of their secondary windings were connected to the outgoing circuit conductors through the windings of series transformers, these three series transformers being energized by independent primary windings, which were supplied with variable voltages that were in phase with the electromotive forces induced in the secondary winding of the power transformer to which the series transformer was connected. These variable voltages were either supplied by auto-transformers which were connected across each phase of the line and were provided with a plurality of taps, or from the secondary winding of the power transformer, in which case this winding was provided with numerous intermediate taps, the three voltages being simultaneously varied by interlocking a plurality of regulator switches which determined the connections between the primary of the series transformer and the variable voltage winding. By connecting the series transformers in this way to the secondaries of the power transformers, the voltage impressed upon the external circuits is varied at the will of the operator and the regulated voltage always remains in phase with the voltage in the secondary winding to which the circuit is connected.

I have provided two series transformers each having two secondary windings in place of the three series transformers of the prior art, regulation being obtained by the use of two auto-transformers and two regulating switches, which obviously simplifies the system and considerably reduces the amount of auxiliary apparatus employed.

My invention is illustrated in the accompanying drawings, in which

Figure 1 is a diagrammatic view of a system arranged in accordance therwith. Fig. 2 is a similar view of a modified arrangement which may perform the same functions, and Fig. 3 is a vector diagram showing the phase relations between the electromotive forces induced in the various windings of Figs. 1 and 2.

Referring to Fig. 1, alternating current electrical energy is supplied from a three-phase circuit *a*, *b* and *c* to an outgoing feeder circuit *x*, *y* and *z*. The primary windings of transformers 1, 2 and 3 are delta connected in the usual manner and are completely insulated from the feeder and regulating systems. The secondary winding 4 of the transformer 1 is connected through a secondary winding 5 of a series transformer 6 to the conductor *x* of the feeder circuit. The secondary winding 7 of the transformer 2 is similarly connected through a secondary winding 8 of a series transformer 9 to the conductor *z* of the feeder circuit, while the secondary winding 10 of the tsansformer 3 is connected, through a secondary winding 11 of the series transformer 6 and a secondary winding 12 of the series transformer 9, connected in series, to the feeder conductor *y*. A pair of similar auto-transformers 13 and 14 are respectively connected between the outer terminals of the secondary windings 4 and 7 and the neutral conductor *o* of the three secondary windings 4, 7 and 10, which are Y-connected. In this way, the neutral point of the distributing system is accessible irrespective of the primary

connections, which may be either delta or Y-connected.

The series transformers 6 and 9 are respectively energized by primary windings 15 and 16, which are supplied with variable voltages from the auto-transformers 13 and 14 through a pair of mechanically interlocked regulating switches 17 and 18. The switches 17 and 18 comprise conducting arms 19 and 20 which may engage a plurality of contact terminals 21 and 22 that are connected to intermediate taps in the windings of the auto-transformers 13 and 14. The simultaneous regulation of the several lines is insured by interlocking the regulator switches 17 and 18, since the electromotive forces impressed upon the conductors x and z of the feeder circuits are obviously in phase with the electromotive forces induced in the secondary windings 4 and 7, while the electromotive force impressed upon the feeder conductor y is substantially in phase with the electromotive force induced in the secondary winding 10, since the resultant of the component electromotive forces which are induced in the windings 11 and 12 of the series transformers 6 and 9 is in phase with the electromotive forces induced in the secondary winding 10.

In order to demonstrate the relations above specified, reference may be had to Fig. 3, in which the electromotive force vectors are shown in their existing relations, vector e^4 representing the electromotive force induced in the secondary winding 4 and electromotive force vectors e^{10} and e^7 representing, respectively, the electromotive forces which are induced in the secondary windings 10 and 7. The electromotive force e^5 induced in the secondary winding 5 of the series transformer 6 is added to the electromotive force induced in the secondary winding 4 and is in phase therewith, since this series transformer is energized from the auto-transformer 13, which is energized directly from the secondary winding 4. The voltage induced in the winding 8 of the series transformer 6, which is represented by e^8 in the vector diagram, is added to and is in phase with the electromotive force e^7 which is induced in the winding 7 for the same reason. Vector e^{11} is shown parallel to the vectors e^4 and e^5 and represents the voltage induced in the winding 11 of the series transformer 6, which is added to the electromotive force induced in the secondary winding 10. Line e^{12} is drawn parallel to the vectors e^7 and e^8 and represents the voltage induced in the winding 12 of the series transformer 9, which is added to the electromotive force represented by e^{10} and e^{11}. Since the supply circuit a, b and c is a three-phase circuit, the vectors e^4, e^7 and e^{10} will be one hundred and twenty degrees apart, and consequently the resultant e^{13} of the components e^{11} and e^{12} will be equal to these vectors and form an equilateral triangle therewith, and since vectors e^{11} and e^{12} are respectively parallel to the vectors e^4 and e^7, the resultant e^{13} will form a continuation of the vector e^{10}.

Referring to Fig. 2, in which similar numerals refer to the same parts as in Fig. 1, the outer terminals of the secondary windings 4, 7 and 10 are respectively connected directly to the feeder circuit conductors x, y and z, regulation in this instance being obtained through series transformers 6 and 9, the secondary windings of which are respectively connected between the inner terminals of the secondaries 4, 7 and 10 and the neutral conductor o instead of between the outer terminals of these windings and the feeder circuit conductors. The primary windings 15 and 16 of the series transformers are energized directly from the secondary windings 4 and 7, which are provided with a plurality of taps for this purpose that are connected to contact terminals 21 and 22 which are engaged by mechanically interlocking contact arms 19 and 20. The simultaneous regulation of the electromotive forces and their proper phase relations are secured in this as in preceding instance.

It will be seen that many variations in the circuit connections may be made without departing materially from my invention, and I desire that such variations shall be included in its scope.

I claim as my invention:

1. The combination with a three-phase alternating current source of electrical energy and three transformers having their primary windings connected thereto and their secondary windings Y-connected to a supply line, of a pair of series transformers each having a primary winding and two secondary windings arranged and connected to preserve the neutral point of the system and to give simultaneous potential regulation between the several supply lines.

2. The combination with a three-phase alternating current feeder system, of means for regulating the voltage between lines that comprises a pair of series transformers and means for simultaneously regulating the exciting voltages applied thereto.

3. The combination with a three-phase alternating current feeder system, of two series transformer and two regulating switches for simultaneously regulating the voltage between the lines.

4. The combination with three power transformer secondary windings, one terminal of each of which is connected to a supply line, two series transformer secondary windings connected to corresponding terminals of two of the power windings, and two secondary windings for said series transformers connected in series with each other

to the free terminal of the power transformer, of means for simultaneously varying the exciting voltage applied to said series transformers.

5. The combination with three power transformer secondary windings, one terminal of each of which is connected to a supply line, two series transformer secondary windings connected to corresponding terminals of two of the power windings, and two secondary windings for said series transformers connected in series with each other to the free terminal of the power transformer, of means for simultaneously varying the exciting voltage applied to said series transformers, said means comprising exciting windings therefor, auto-transformers having intermediate taps, and switches for connecting said taps to said exciting windings.

6. The combination with three Y-connected transformer windings, auto-transformers connected between the outer terminals and the common terminal of said power transformer windings, and two series transformers having secondary windings connected to corresponding terminals of the auto-transformers and to a pair of supply line conductors, and secondary windings connected, in series, to the free power transformer winding terminal and to a third supply line conductor, of means for varying the exciting voltage applied to the series transformers.

7. The combination with three Y-connected power transformer windings, auto-transformers connected between two outer terminals and the common terminal of said power transformer windings, and two series transformers having secondary windings connected to corresponding terminals of the auto-transformers and to a pair of supply line conductors, and secondary windings connected, in series, to the free power transformer winding terminal and to a third supply line conductor, of means for simultaneously varying the exciting voltage applied to said series transformers, said means comprising exciting windings therefor which are supplied with variable voltages from said auto-transformers.

8. The combination with three Y-connected power transformer windings, auto-transformers connected between two outer terminals and the common terminal of said power transformer windings, and two series transformers having secondary windings connected to corresponding terminals of the auto-transformers and to a pair of supply line conductors, and secondary windings connected, in series, to the free power transformer winding terminal and to a third supply line conductor, of switches coöperating with said auto-transformers for simultaneously varying the exciting voltages applied to the series transformers.

9. The combination with three Y-connected power transformer windings, auto-transformers connected between two of the outer terminals and the common terminal of said windings, and two series transformers having primary windings that are energized from said auto-transformers and having secondary windings which are connected in series and to the free terminal of the power transformer.

10. In a three-phase feeder system, the combination with three wire transformer secondary windings, of means for varying the voltage of the three lines simultaneously and for maintaining the proper phase relation between said voltages, said means comprising two interlocked regulator switches and two series transformers.

11. In a three-phase feeder system, the combination with three wire transformer secondary windings, of means for varying the voltage of the three lines simultaneously and for maintaining the proper phase relation between said voltages said means comprising two series transformers having separate exciting coils, two auto-transformers, and switches for varying the voltages supplied thereby.

12. The combination with a three-phase power circuit, three primary transformer windings severally connected to said circuit conductors and interconnected at their opposite ends, three interconnected secondary windings, auto-transformers connected between two outer terminals of the secondary windings and their common terminals, two series transformers having primary windings which are energized from said auto-transformers and two secondary windings one of each of which is connected in series between the outer terminal of one of said interconnected secondary windings and a feeder circuit and one secondary of each being connected respectively to the remaining two outer terminals of the interconnected secondary windings, of means for simultaneously varying the electromotive force impressed upon the primaries of said series transformers.

In testimony whereof, I have hereunto subscribed my name this 9th day of November, 1905.

EDWIN LEHR.

Witnesses:
HENRY D. JAMES,
BIRNEY HINES.