No. 620,144. Patented Feb. 28, 1899.

E. L. K. F. KAHLENBERG.

MULTIPHASE CURRENT TRANSFORMER.

(Application filed Aug. 8, 1898.)

(No Model.)

Fig. 4.

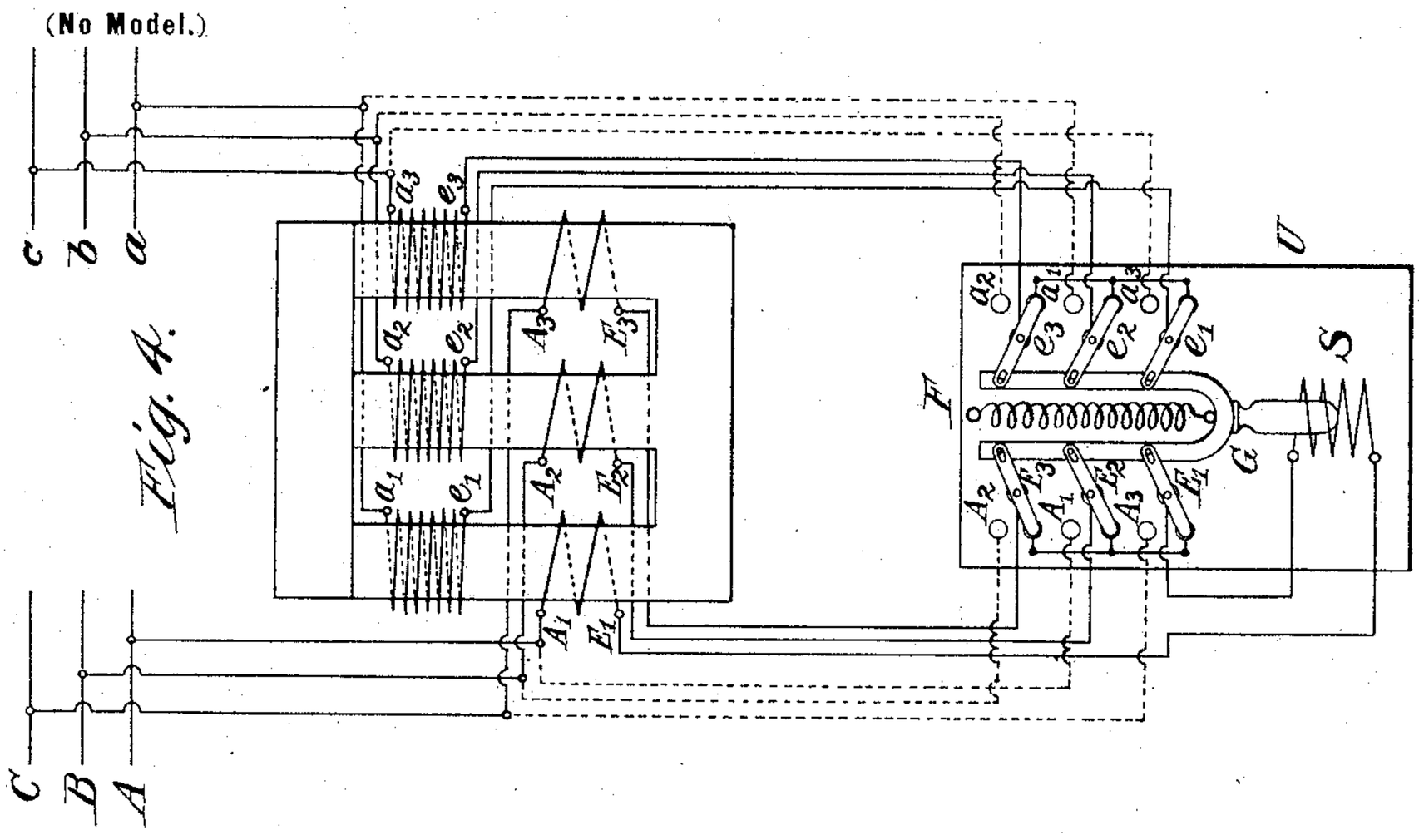


Fig. 1.

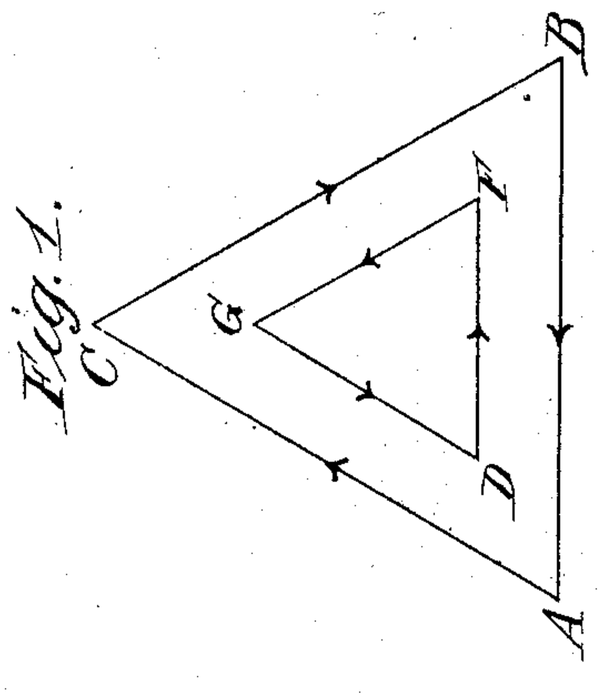


Fig. 2.

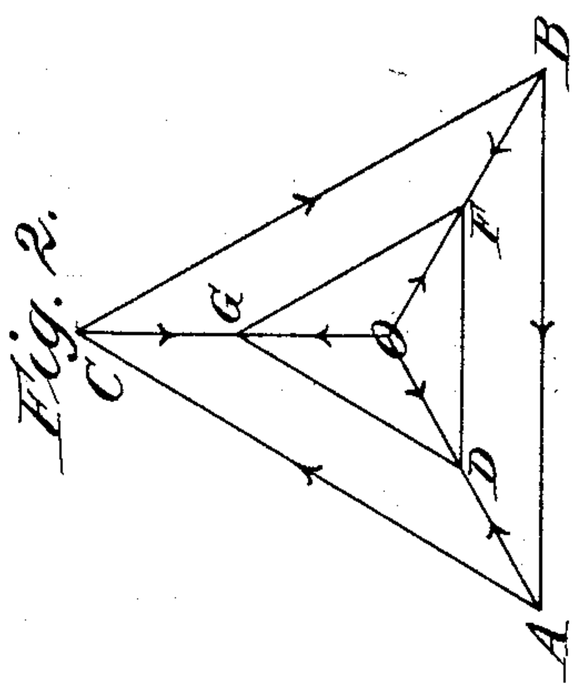
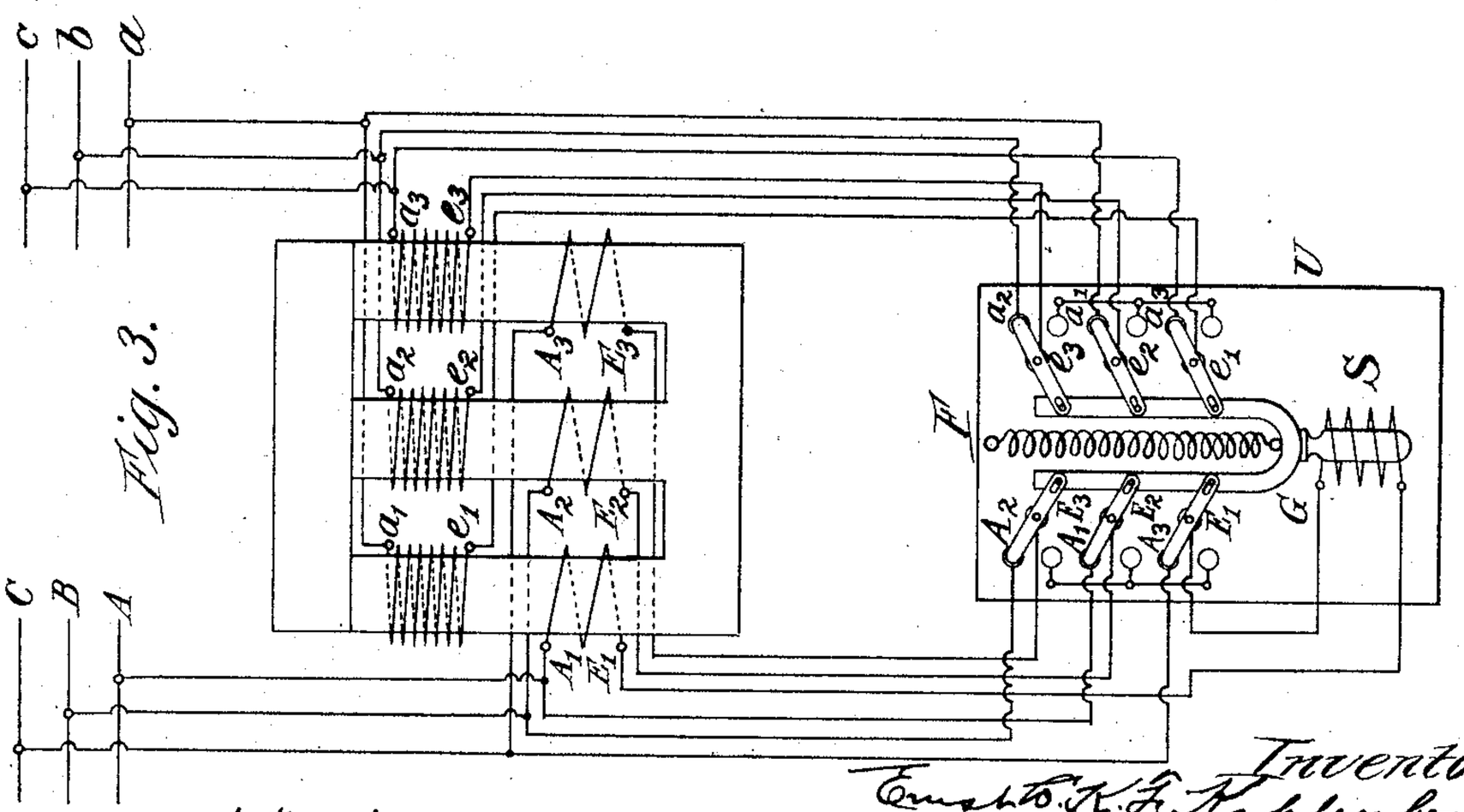


Fig. 3.



Witnesses: D. W. C. Danner, A. D. Cairnes.

Inventor: Ernst L. K. F. Kahlenberg, By Burton Brown, Attorneys.

UNITED STATES PATENT OFFICE.

ERNST LUDWIG KARL FRIEDRICH KAHLENBERG, OF BERLIN, GERMANY, ASSIGNOR TO THE SIEMENS & HALSKE ELECTRIC COMPANY OF AMERICA, OF CHICAGO, ILLINOIS.

MULTIPHASE-CURRENT TRANSFORMER.

SPECIFICATION forming part of Letters Patent No. 620,144, dated February 28, 1899.

Application filed August 8, 1898. Serial No. 688,070. (No model.)

To all whom it may concern:

Be it known that I, ERNST LUDWIG KARL FRIEDRICH KAHLENBERG, a subject of the Emperor of Germany, residing at Berlin, Germany, have invented a certain new and useful Improvement in Multiphase-Current Transformers, (Case 153,) of which the following is a full, clear, concise, and exact description.

This invention refers to multiphase-current transformers, and has for its object to adapt them to varying loads.

The invention consists in connecting the windings of the transformer with the leads by means of a switch device by which either a star connection or a triangle connection can be made.

Of the accompanying drawings, Figures 1 and 2 are diagrams illustrating the relations between the potential differences in a multiphase-current system. Fig. 3 is a diagram showing the connections which form the object of this invention; and Fig. 4 is a repetition of Fig. 3, showing the switch device in another position.

In the drawings, A, B, and C are the secondary, and *a*, *b*, and *c* the primary, leads of a multiphase-current-distributing system.

U is a switch device by which the different windings of the transformer can be differently connected together and with the leads.

G is a piece of insulating material shaped like a horseshoe and suspended from a number of metallic levers mounted on pivots and making contact with the same. The opposite ends of said levers likewise make contact with a number of buttons connected with the terminals of the windings of the transformer.

a', a^2, and a^3 and e', e^2, and e^3, respectively, are the terminals of the primary windings, and A′, A^2, and A^3 and E′, E^2, and E^3, respectively, are the terminals of the secondary windings, of the transformer. Each terminal is connected by a suitable conductor to one of the contact-buttons on the switch U, and the corresponding buttons are marked with the same letters of reference as the terminals to which they are connected.

S is a solenoid inserted in one of the secondary windings and acting upon an iron core suspended from the horseshoe-piece G. F is a spring which tends to withdraw the said iron core from the solenoid and to lift up the piece G into the position shown in Fig. 4.

The operation of my invention is as follows: In a former specification, United States Patent No. 529,152, it is set forth that a considerable reduction in the expense of energy necessary for the operation of transformers connected in parallel can be obtained by subdividing the windings and by connecting the subdivisions either in parallel or in series, accordingly as the load on the transformer is increased or diminished. As explained in the above-mentioned patent, the work of magnetization, which is constantly consumed in the iron of transformers that are connected in parallel, is diminished as the number of windings is increased. Therefore if means are provided to diminish the number of windings as the load increases the work of magnetization that has to be expended is always adapted to the actual want. The same object can be obtained with a multiphase-current transformer in even a more simple and direct way.

It is known that the windings of a multiphase-current transformer can be connected with the leads in two different ways—*i. e.*, once by placing each one of the windings between two neighboring leads, thus obtaining what is generally termed a "triangle connection," or else by connecting one terminal of each winding with one of the leads and the free ends all together at one common terminal, thus making what is generally termed a "star connection." It is likewise known that the potential difference at the terminals of a winding is greater when it is connected triangle fashion than when it is connected star fashion, the potential difference between the respective leads remaining constant. As this rule holds good whether it be applied to the primary or the secondary windings, this circumstance can be made use of to reduce the work of magnetization in a similar way, as it has been set forth with regard to ordinary alternating-current transformers in the above-mentioned former patent specification. For

this purpose it is merely necessary to insert suitable switch arrangements between the primary as well as the secondary windings of the transformer and the corresponding leads, by means of which the former can be either connected triangle or star fashion. To obtain the desired result, however, it is essential not only that the ratio of transformation will remain unaltered by such an alteration of the connections, but also that the phases of the primary and the secondary system shall not be relatively disturbed. In order to understand that this is the case, the reader is referred to the diagrams Figs. 1 and 2. In these diagrams the lengths of the single lines represent amplitudes, and the angles which are inclosed by the different lines represent differences of phase. If the primary difference of potential is E, the potential difference at the terminals of one winding is likewise E when the windings are connected triangle fashion. If the ratio of transformation between the secondary and the primary windings is n, the potential difference at the terminals of one secondary winding, and consequently likewise the potential difference between the secondary leads, is n E. If the primary winding is connected star fashion, the potential difference at the terminals of every winding is $\frac{E}{\sqrt{3}}$, and consequently the potential difference at the terminals of a secondary winding will be $n\frac{E}{\sqrt{3}}$. If, however, the secondary winding is likewise connected star fashion, the potential difference at the secondary terminals of the transformer is

$$n\frac{E}{\sqrt{3}}.\sqrt{3}=n.E$$

The ratio of transformation therefore remains unaltered.

When the triangle connection is used, the potential differences at the terminals of the single windings of the transformer are equal in phase with the corresponding potential differences between the leads. Fig. 1 diagrammatically represents this case. AC, CB, and BA signify the potential differences of the terminals of the three primary windings of the transformer and correspondingly GD, FG, and DF the potential differences at the terminals of the three secondary windings, GD being equal to n.AC, &c., respectively. If the connections are made so as to have a corresponding sense of rotation in all the windings, the secondary potential difference will lag behind the primary by the amount of one hundred and eighty degrees, as indicated in the diagram by the arrows.

When the star connection is used, the potential differences at the terminals of the windings do not coincide with the potential differences between the leads. Let AC, CB, and BA in Fig. 2 represent the three potential differences between the primary leads. Then AO, BO, and CO will be the potential differences between the terminals of the respective windings. The phase of the potential differences at the terminals of the secondary windings OD, OF, and OG lags behind the phase of the potential differences at the terminals of the primary windings to the amount of one hundred and eighty degrees. The resulting potential differences between the secondary leads are GD, GF, and FD. Therefore the lag of the phases of the secondary potential differences behind the phases of the primary potential differences amounts to one hundred and eighty degrees when the primary and secondary connections are the same. Therefore by changing the connections from the triangle fashion to the star fashion neither the ratio of transformation nor the relative phases of primary and secondary potential differences are disturbed.

By following up the connections shown in Figs. 3 and 4 it will be seen that when the switch is in the position shown in Fig. 3 both primary and secondary windings are connected triangle fashion, and when it is in the position shown in Fig. 4 both primary and secondary windings are connected star fashion. The position shown in Fig. 3 corresponds to an increased load and the position shown in Fig. 4 to a diminished load.

In the diagrams the arrangement is made in such a way that the operation of the switch U takes place automatically. The solenoid S is inserted in one of the secondary leads. When the load is small, the current in the secondary lead, and consequently in the solenoid S, is not sufficient to counterbalance the action of the spring F, and the switch will therefore remain in the position shown in Fig. 4 until the load, and consequently the current in the solenoid S, increases sufficiently to overpower the spring F and pull the piece G downward, thus connecting the transformer triangle fashion. I wish it to be understood, however, that I do not limit myself to the automatic arrangement shown in the drawings, the essence of the invention herein described not being changed if the switch is operated by hand. Likewise I consider it to be self-evident to every expert that the arrangement herein described can be combined with the arrangement described in the aforesaid Patent No. 529,152. If this is done, the work of magnetization can be reduced by applying the triangle and star connections to the amount of $\frac{1}{\sqrt{3}}$ and by employing the arrangement described in my former patent above referred to by $\frac{1}{2}$. Therefore by combining the two the work of magnetization can be reduced to $\frac{1}{2\sqrt{3}}$ of its original value.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is—

1. The combination with a source of multiphase current of a transformer for supplying secondary circuits and having multiphase windings and switching apparatus for connecting windings of the transformer either in star or triangle fashion, substantially as described.

2. The combination with a multiphase-current system consisting of a set of primary and a set of secondary leads, the latter being fed from the former by means of suitable multiphase-current transformers of switches inserted between the said transformers and the said systems of primary and secondary leads said switches being connected up with the single windings of said transformers in such a way as to allow the latter to be connected to the leads either star fashion or triangle fashion, substantially as and for the purpose set forth.

3. The combination with a multiphase-current-distributing system consisting of a set of primary and a set of secondary leads and of transformers by means of which the latter are fed from the former, of switches inserted between the single windings of the said transformers in such a way as to allow the connections of said transformers to be changed from the star fashion to the triangle fashion or vice versa by a movement of the said switches and of means for operating said switches automatically when the load on the transformer increases or diminishes, substantially as and for the purpose set forth.

4. The combination with a multiphase-current-distributing system consisting of a set of primary and a set of secondary leads the latter being fed from the former by means of transformers of switches being inserted between the single windings of said transformers in such a way that the connections of the latter can be changed from the star fashion to the triangle fashion and vice versa and of a solenoid traversed by one of the currents passing through the leads of said distributing system and automatically controlling said switches in such a way as to put the transformers into the triangle connection, when the load increases and vice versa, substantially as and for the purpose set forth.

5. The combination with a source of multiphase current of a transformer for supplying secondary circuits and having multiphase windings and automatic means for connecting windings of the transformer either in star or triangle fashion, substantially as described.

6. The combination with a source of multiphase current of a transformer having primary and secondary multiphase windings and switching apparatus for connecting the primary and secondary windings of the transformer either in star or triangle fashion, substantially as described.

7. The combination with a source of multiphase current of a transformer for supplying secondary circuits and having primary and secondary multiphase windings, and automatic means for connecting the primary and secondary windings of the transformer either in star or triangle fashion, substantially as described.

In witness whereof I have hereunto subscribed my name this 23d day of July, A. D. 1898.

ERNST LUDWIG KARL FRIEDRICH KAHLENBERG.

Witnesses:

C. H. DAY,

HENRY HASPER.