J. S. PRESTON.

ELECTRICAL APPARATUS.

APPLICATION FILED DEC. 30, 1914.

1,200,233. Patented Oct. 3, 1916.

Fig. 1.

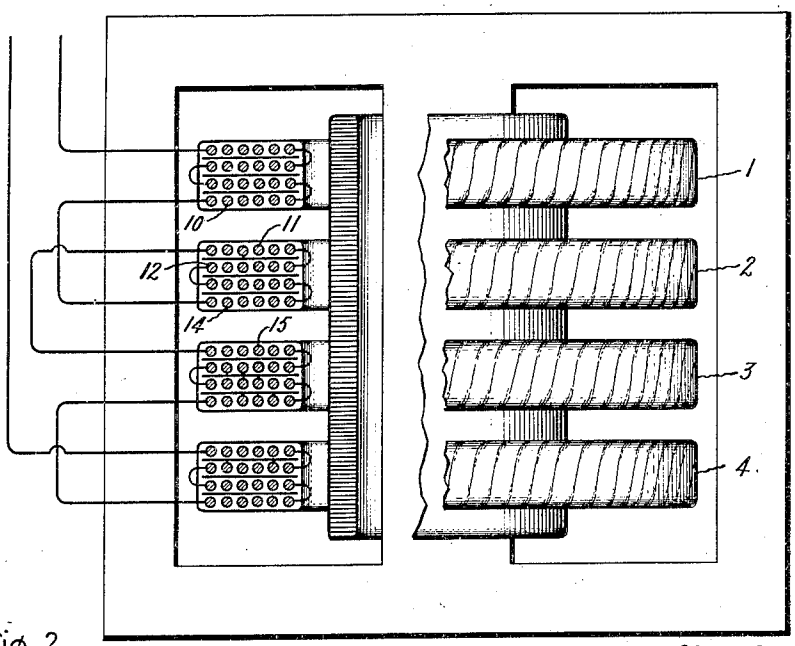



Fig. 2.

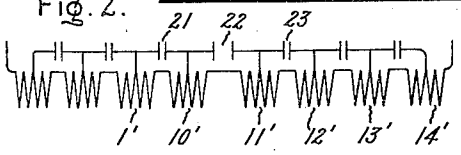



Fig. 3.

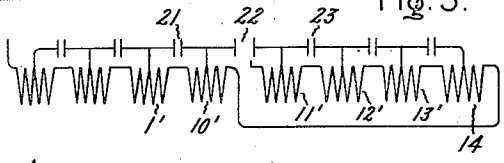



Fig. 4.

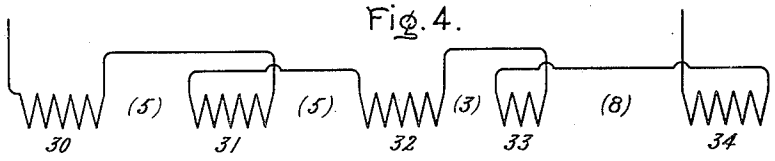
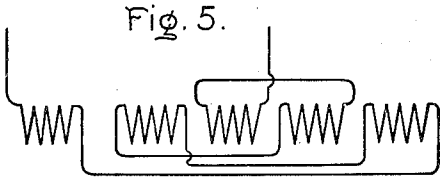



Fig. 5.



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# UNITED STATES PATENT OFFICE.

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## ELECTRICAL APPARATUS.

1,200,233. Specification of Letters Patent. Patented Oct. 3, 1916.

Application filed December 30, 1914. Serial No. 879,791.

*To all whom it may concern:*

Be it known that I, J STANLEY PRESTON, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Electrical Apparatus, of which the following is a specification.

My invention relates to a number of types of electrical apparatus likely to be damaged through resonating with abnormal frequencies; it is however, particularly applicable to transformers, and for the sake of simplicity, I shall mostly describe but its application to such apparatus. The extent of its application to other apparatus, and how such applications may be made, will be readily understood from the description of its application to transformers.

As is well known, any electrical apparatus or portion of electrical apparatus having both inductance and capacity, may oscillate or resonate at some certain frequency dependent upon the values of these features. Now for apparatus to resonate as a whole is not particularly dangerous, for protective devices as of the over-voltage type, are readily applied at the terminals of the apparatus to take care of such conditions. Such cases occur when the impedance factors of the apparatus are uniformly distributed between its terminals. When however, the electrostatic capacity of the apparatus for example, is not uniformly distributed throughout the apparatus, the continuity of the apparatus is broken. Then portions of the apparatus may resonate substantially independently of the other portions thereof and of the apparatus as a whole, and one or more of those portions may develop a dangerously high voltage without any manifestation at the terminals of the apparatus (with the possible exception of an abnormally high frequency manifestation of a value not dangerous to the apparatus as a whole, and of low voltage). Such discontinuous capacity distributions occur very frequently in transformers, wherein commonly each winding is (or may be described as) comprised of straight series connected coils assembled in groups, the groups being separated from each other for ventilation or to allow the insertion of portions of the other winding, or for other purposes. The capacity of the two coils forming the adjacent faces of two such adjacent groups of the same winding, is considerably less than the capacity of two similar coils both of which are located within a single group, and hence the electrostatic displacement between any two adjacent coils within a single group is greater than that between two adjacent face coils of different groups. These differences of capacity and displacements are due both to the difference in spacing between coils and to the difference between the specific inductive capacities of the dielectrics between the coils; between the coils of any single group, some solid dielectric is commonly used, while between groups (and hence between adjacent face coils of different groups) the principal dielectric is commonly oil or air, the specific inductive capacities of both of which are considerably lower than those of the common solid insulations. In short in transformers as commonly constructed, the energy of any winding is not uniformly distributed along its length.

The object of my invention then, is to overcome the ill effects of such arrangements of coils (or broadly, such non-uniform distribution of capacity) and to maintain the electrical continuity of the apparatus between its terminals and the uniform distribution of the energy thereof. To do this I may be said to provide for substantially equal displacements between all the faces of the internal coils (or whatever the conductors of the apparatus may be), presupposing that the coils are of the same size, or I relate the capacities of pairs of adjacent coils to inductances of values inversely proportional to the values of the respective capacities. However, since separating the groups also brings about differences in the mutual inductions of adjacent coils and other inci-

dental effects, and since the coils may sometimes be of different sizes, it may sometimes be undesirable, or even unnecessary for these or other reasons, to exactly equalize the displacements or the products of the capacities by their respective inductances to bring about the desired degree of continuity; however herein, including the claims, I shall refer to only such equalities, or substantial equalities, and similar conditions, and must be understood as including thereby all these special cases so far as may be or as indicated. These special cases are too numerous to mention, are fairly uncommon, and are unnecessary for an understanding of my invention and as they arise will be readily understood by those skilled in the art.

To equalize the displacements, I propose to impress greater voltage differences between those adjacent coils separated by the greater distances and by dielectrics of lower specific inductive capacity (as the adjacent face coils of different groups), than are impressed between other adjacent coils. Preferably, to produce exact equalities of displacements, the voltage differences between all adjacent coils are made directly proportional to the distances between the coils and inversely proportional to the specific inductive capacities of the dielectrics between them (the areas of the coils being equal and the mutual inductances sufficiently equal). Practically, for most common constructions this may be brought down to employing the usual group construction wherein the capacities and voltage differences per pair of coils are substantially equal, and to simply arranging for a greater voltage difference between the two coils adjacent each space between groups. This may be simply, and preferably is, done, by the system of coil connections which is described hereinafter in detail, this system of connections in turn brings about the hereinbefore mentioned capacity-inductance relation. The specific apparatus in which my invention may be embodied is however, subject to considerable modification.

In the following detailed description and the accompanying drawing I have described and diagrammatically illustrated various embodiments of my invention.

Figure 1 is an elevation, partly in section, of a transformer embodying my invention in one of its windings. Figs. 2 and 3 are diagrammatic representations of windings of use in explaining my invention. Figs. 4 and 5 illustrate windings with some other connections embodying my invention.

In the transformer of Fig. 1, all the coils of the outer winding are alike and are assembled in groups of four separated for ventilation; in this transformer there are four groups, 1, 2, 3 and 4. The other winding is illustrated as of the simple cylindrical type and does not here embody my invention though my invention is not limited in its application to any single type of winding or to one of a plurality of windings. The capacities of the different pairs of coils of any group, as for example of the group 1, are equal, for the coils are all alike and adjacent twos are separated by equal distances and by the same dielectric material; they are connected in straight series and therefore the voltage differences are equal; the displacement between any two adjacent coils of a group is therefore equal to that between any other two adjacent coils of that group. Also the displacement between any two adjacent coils of any single group is equal to that between any other two adjacent coils of that or any other single group, since the coils and groups and voltages are alike. According to the prior practice, all the coils of this winding would be connected in straight series. The discontinuities of the winding would occur then between each two groups of coils, for between the adjacent face coils, for example coils 10 and 11, of the different groups 1 and 2, the capacities are considerably less than between adjacent coils of any single group, for example coils 11 and 12 of group 2, while equal voltage differences would exist between each two adjacent coils, irrespective of their location; this results of course, in smaller displacements between adjacent face coils of different groups than between adjacent coils of any single group. According to my invention however, while I connect the coils of each single group in straight series and connect all the coils in straight series in effect, that is so that none buck the others, the face coil of each group is not connected to the adjacent face coil of the adjacent group, but, in this particular case, it is connected to the far face coil of that adjacent coil, so that there exists a voltage difference of a full group of coils across each space. Thus the face coil 10 of group 1 is connected to coil 14 of group 2, and coil 15 of group 3 is connected to coil 11 of group 2, and so on through the winding. In addition, the whole is so designed that the voltage of a group is sufficient to produce substantially the same displacement in the smaller capacity between each two adjacent face coils, as 10 and 11, as takes place under the smaller voltage in the greater capacity between each two adjacent coils as 11 and 12, of a single group. In accomplishing this it is necessary of course, that the voltage difference between physically adjacent coils be inversely proportional to their capacities, or directly proportional to

their distances apart and inversely proportional to the specific inductive capacity of the dielectrics between them (the areas of the coils being equal).

By some, the invention will be better understood perhaps by a consideration of Figs. 2 and 3. These figures diagrammatically illustrate the principal inductance and capacity relations of two windings each comprising two groups of coils similar in construction and location to the groups 1 and 2 of Fig. 1; they may be taken as equivalent circuits in which the inductive and capacity relations concerned by my invention are separated. The coil parts of these figures bear reference characters similar to those borne by the physically similar parts of Fig. 1. Fig. 2 illustrates all the coils connected in straight series as has been the common practice heretofore; Fig. 3 illustrates the coils connected in accordance with my invention as explained with reference to Fig. 1 and as may be understood from an inspection of Fig. 3. In both cases as well as in the case illustrated in Fig. 1, a current traversing the winding from one terminal to the other, circulates in the same direction about the core in all the coils. The condensers including 21, 22 and 23, indicate the capacity relations between the coils; the plates of the condensers are of the same size since the coils are presumed to be of the same size; the plates of condenser 22 are separated about four times the distance between the plates of condensers 21 and 23 and the others, since the capacity of the coils 10 and 11 (and likewise of 10′ and 11′), the adjacent face coils of adjacent groups, is assumed in this case to work out to be but one-fourth of the capacity of two adjacent coils of a single group, as the coils 11 and 12 and the coils 11′ and 12′. Now, as is well known, the periodic time of oscillation of any portion of electrical apparatus may be represented by

$$T=k\sqrt{LC}.$$

Assume the capacity of each condenser except condenser 22, to be C; the capacity of 22 is then C/4 by prior assumptions. Each condenser spans approximately two half coils or one complete coil; assume the inductance of each two half coils to be L. In Fig. 2, the local circuit formed by condenser 23 and one-half of coil 11′ and one-half of coil 12′, has then for its periodic time of oscillation,

$$T=k\sqrt{LC};$$

with the exception of the local circuit including condenser 22, every other local circuit of Fig. 2 has the same periodic time of oscillation since each is exactly similar to the circuit of condenser 23. The periodic time of the local circuit including condenser 22, half of coil 10′ and half of coil 11′ is however,

$$T=k\sqrt{LC/4}=\frac{k}{2}\sqrt{LC},$$

or the natural frequency of this local circuit is double that of each of the others. This winding is thus, discontinuous between the groups. In Fig. 3, every local circuit except that including condenser 22 has likewise periodic time represented by

$$T=k\sqrt{LC};$$

the local circuit including condenser 22 has a periodic time represented by

$$T=k\sqrt{4LC/4},$$

since it spans or includes in its complete local circuit, four complete coils (one half of coil 10, all of coils 14, 13 and 12, and the right hand half of coil 11) rather than one complete coil; this reduces to

$$T=k\sqrt{LC},$$

or the natural frequencies of all the local circuits of this winding are equal. The whole of the winding of Fig. 3 is therefore electrically continuous from one terminal to the other.

The winding of Fig. 4 contains certain modifications and extensions of the invention embodied in Fig. 1. Here each turn illustrated may be considered a coil, all the coils being alike; they are assembled into the groups 30, 31, 32, 33 and 34. The groups are spaced apart unequal distances and the numerals in parentheses indicate the relative distances between groups. The connections are such however, that the displacements between the groups are equal (it being presupposed that the dielectrics are alike) and designed to be equal to those between adjacent coils of any single group. Between groups 30 and 31 and between groups 31 and 32 the distances are each (5), and the voltage difference across each group is equal to that of five coils or one of the groups as indicated. Between the groups 32 and 33 the distance is (3) and the voltage across it is that of the small group 33 of three coils. Between groups 33 and 34 the distance is (8), and the voltage difference between the adjacent face coils of these two groups is that of both groups 33 and 34 or eight coils.

Fig. 5, drawn on the same plan as Fig. 2, illustrates a winding embodying my invention in which certain of the connections extend between other than the physically adjacent groups. This arrangement is par-

ticularly of use in those transformers in which a single terminal is brought out of the high voltage winding midway between its ends. The connections will be understood from the drawing. The voltage of two groups which is impressed across each space, is arranged to be substantially just sufficient to equalize the displacements between every two adjacent coils.

While I have described the principle of my invention and the best mode I have contemplated for applying this principle, other modifications will occur to those skilled in this art and I aim in the appended claims to cover all modifications which do not involve a departure from the spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:—

1. An electrical winding comprising a plurality of coils arranged in separated groups, connections extending between each two adjacent groups, the connection between each two adjacent groups extending from the far coil of one of those groups to a coil of the other group.

2. An electrical winding comprising a plurality of coils arranged in separated groups, connections extending between each two adjacent groups, the connection between each two connected groups extending between two coils of those groups other than those coils forming the adjacent faces of the groups.

3. An electrical winding comprising a plurality of coils having different capacities per pair of adjacent coils and so connected that the displacements between adjacent coils are substantially equal.

4. An electrical winding comprising a plurality of coils having different capacities per pair of adjacent coils and so connected that the voltages established between adjacent coils are inversely proportional to the capacity thereof.

5. Electrical apparatus comprising a plurality of conductors having different capacities per pair of adjacent conductors wherein the voltage between each two adjacent conductors is inversely proportional to the specific inductive capacity of the insulation therebetween and is directly proportional to their distance apart.

6. An electrical winding comprising a plurality of coils arranged in separated groups, connections extending between each two adjacent groups, the connection between each two adjacent groups extending between two coils of those groups other than those coils forming the adjacent faces of the groups, and including within its span a sufficient number of coils to establish a voltage between the two adjacent face coils of the groups substantially inversely proportional to their capacity relative to the capacity and voltage difference between each two adjacent coils of a single group.

7. An electrical winding comprising a plurality of coils arranged in separated groups, connections extending between each two adjacent groups, the connection between each two adjacent groups extending from the far coil of one of those groups to a coil of the other group and including within its span a sufficient number of coils to establish a voltage between the two adjacent face coils of the groups substantially inversely proportional to their capacity relative to the capacity and voltage difference between each two adjacent coils of a single group.

8. An electrical winding comprising a plurality of coils arranged in separated groups, connections extending between the groups, the respective connections extending between such coils of the groups as to establish a voltage between each two adjacent face coils of different groups which is substantially inversely proportional to the capacity of the respective coils relative to the voltage difference and capacity between each two adjacent coils of a single group.

9. An electrical winding comprising a plurality of coils arranged in separated groups, connections extending between the groups, the respective connections extending between such coils of the groups as to produce displacements between each two adjacent face coils of different groups substantially equal to the displacements between each two adjacent coils of a single group.

10. An electrical winding comprising a plurality of coils arranged in separated groups, connections extending between the groups, the respective connections extending between such coils of the groups as to relate the capacity of each two adjacent face coils of different groups to an inversely proportional inductance relative to the capacity and its related inductance of each two adjacent coils of a single group.

11. An electrical winding comprising a plurality of coils arranged in separated groups, connections extending between the adjacent groups, the respective connections extending between such coils of adjacent groups as to relate the capacity of each two adjacent face coils of adjacent groups to an inversely proportional inductance relative to the capacity and its related inductance of each two adjacent coils of a single group.

12. An electrical winding comprising a plurality of coils having different capacities per pair of adjacent coils and so connected that each such capacity is related to an inversely proportional inductance.

13. Electrical apparatus comprising a plurality of conductors having different capacities per pair of adjacent conductors,

wherein each such capacity is related to an inversely proportional inductance.

14. An electrical winding comprising a plurality of coils having different capacities per pair of adjacent coils and means for connecting the coils and for producing substantially equal displacements between adjacent coils.

In witness whereof I have hereunto set my hand this 29th day of December, 1914.

J STANLEY PRESTON.

Witnesses:
HELEN ORFORD,
MARGARET E. WOOLLEY.