E. E. F. CREIGHTON.

ELECTRICAL WINDING.

APPLICATION FILED NOV. 25, 1914.

1,190,120. Patented July 4, 1916.

Fig. 1.

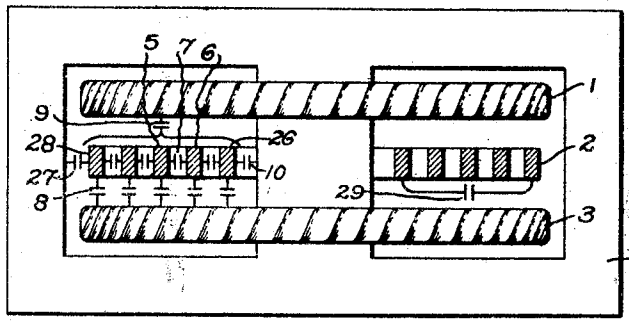
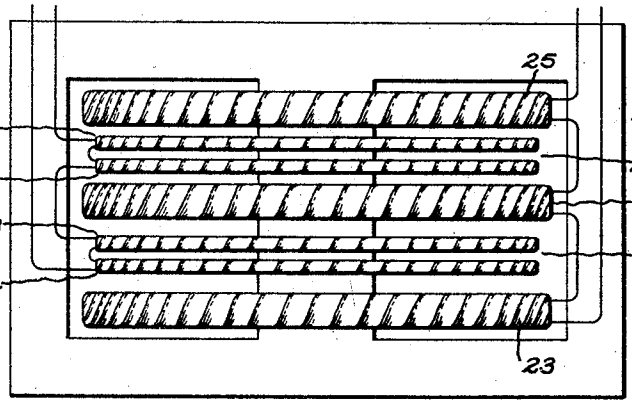


Fig. 2.



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UNITED STATES PATENT OFFICE.

ELMER E. F. CREIGHTON, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

ELECTRICAL WINDING.

1,190,120. Specification of Letters Patent. Patented July 4, 1916.

Application filed November 25, 1914. Serial No. 874,068.

To all whom it may concern:

Be it known that I, ELMER E. F. CREIGHTON, 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 Windings, of which the following is a specification.

My invention relates particularly to transformer windings comprising coils arranged in groups.

The object of my invention is to so arrange and construct such electrical apparatus that the building up of high voltages therein by abnormal frequencies is restrained and delayed.

It has been recognized that abnormally high frequencies, such as those produced by lightning, arcing grounds, etc., may give rise to disastrously high voltages within an electrical winding, if there happens to be accessible to the high frequency energy, a sufficiently large section of the winding whose natural frequency or a harmonic thereof, is equal to the abnormal frequency; in other words, if there is accessible to the high frequency a large section of the winding in resonance therewith. The energy moving with the abnormal frequency may be little and the abnormal frequency voltage at first, may be comparatively low, far from a dangerous value, but the continuous application of the high frequency to the resonating section, causes greater and greater values of the energy therein to oscillate with the applied frequency, and the voltages to rise accordingly to values dependent upon the length of time the resonating frequency is applied, the value of the energy in the section, and the damping and interference to which the oscillations are subjected.

Prior to my invention, so far as I am aware, no attention whatever has been paid in the design of any high power winding, to the natural periods of its various sections; the most common practice has been to make and arrange all similar parts of a winding, particularly the larger sections, substantially alike, that is to make all the coils substantially alike and to compose all the groups of coils of the same numbers of coils similarly placed, unless particular considerations other than those relating to the natural periods of the sections, dictated other constructions. In substantially each winding (of the type to which my invention applies) made prior to my invention, therefore, the various groups of coils thereof have approximately the same natural frequencies, and if the resonating frequency of any group appears anywhere on the system of which such a winding is a part, it is readily transmitted to the other groups, even to the innermost part of the winding, and all the groups resonate with it; occasionally a single group of coils has shown a voltage higher than the normal voltage of the entire winding.

It is possible by my invention, to prevent, or at least delay the spreading of dangerous frequencies through those electrical windings to which my invention relates and to restrain the dangerous oscillation thereof. To this end I so construct and arrange the coil groups thereof that the different groups have materially different resonance frequencies, so different that the frequency at which one group oscillates can not readily pass over the other groups and can not readily come into that group over them.

How far providing the different coil groups of the winding with different natural frequencies is carried is immaterial to my invention except as herein indicated; in other words, the number of coil groups of the windings which are provided with different natural frequencies, their arrangement and the differences between their frequencies, are subject to considerable variation according to the particular objects to be accomplished, the size of the apparatus, etc.

Preferably all the groups will have different natural fundamental frequencies and harmonics within the necessary limits as hereinafter indicated. It is possible in some cases, however, to secure substantially the same degree of safety if a plurality of groups have substantially similar frequencies, as where the high frequencies will be intermittently, as distinguished from continuously, applied, if each two of the groups of the same period are separated from each other by one or more groups of materially different periods; in other words, it is fairly satisfactory if only each two adjacent groups of the entire winding are of materially different periods or natural frequen-

cies. Preferably, however, the groups (providing there are more than two groups in a given transformer) will have not less than three different natural frequencies. In differentiating the frequencies and harmonics it will probably always be sufficient if the fundamentals and higher harmonics of the different groups are unequal below the eleventh harmonic; I am inclined to believe that no frequencies greater than 500,000 cycles per second are dangerous to electrical windings of the types now common, and hence that equalities of fundamentals and harmonics above this value are harmless except as combining groups of such high natural frequencies may result in a section of a lower and dangerous frequency. With any two adjacent groups which resonate at about the same frequencies, the greater the absolute difference between their two natural fundamentals (or between two of their harmonics, or a fundamental and a harmonic as the case may be), the greater is the restraint offered by one to the oscillation of the other; thus if one section of a winding tends to oscillate at 85000 cycles per second, another section adjacent thereto offers more restraint to such oscillation if its own natural frequency is 75000 cycles per second than it would if its own natural frequency were 80000 cycles per second. It is not necessary, however, that these differences be of extreme values, for small departures from the natural frequency of a group renders the energy oscillations therein practically harmless; to certain coils of natural frequencies comparable with those often found in transformer windings, I have applied frequencies five and one-half per cent. lower and three per cent. higher than the natural frequencies and found that they resulted in voltages of only about twenty per cent. of the extreme voltage of the natural frequency, while frequencies ten per cent. below and six per cent. above the natural frequency resulted in voltages of only about twelve per cent. of the natural frequency voltage; for greater departures from the natural frequency the voltages remained substantially the same. Comparatively small restraints to the natural oscillations, result therefore in considerable protection and will generally be sufficient to protect the windings.

I have illustrated in the accompanying drawing and hereafter described, two forms of transformers embodying my invention.

Figure 1 shows three coils about a common magnetic core, one coil being shown with separated turns, and the capacity relations of that coil and its parts being illustrated. Fig. 2 illustrates a disk coil transformer, the connections being shown diagrammatically.

The natural frequency of any group of coils of a winding depends substantially upon the relation between the inductance and capacity of that group of coils according to a law well understood; if either is increased or decreased without a variation of the other, the natural frequency or period of electrical oscillation of that group is changed accordingly. The object of my invention, therefore, may be accomplished by providing the different groups of coils of the windings with different (and proper) ratios between their respective capacities and inductances.

The capacity and inductance of each portion of a winding are affected by a number of conditions. See Fig. 1 in which I have indicated the principal features controlling the capacity of a coil; three windings 1, 2 and 3 surround the common magnetic core 4. The winding 2 has been shown with open spaces so that the capacity relation between its turns may be illustrated. Between each two of the turns, for example between the turns 5 and 6, there is a condenser action, represented here by the condenser 7. Between each of the turns and each of the adjacent coils there is a capacity action as represented by the condensers 8. Likewise, there is a capacity action, represented by the condenser 9, between the coil or the turns as a whole, and each of the adjacent coils, another represented by the condenser 10 between the turn 26 and the core 4, another between the coil as a whole and the core 4, which is also represented by the condenser 10, another represented by the condenser 27 between the turn 28 and the core 4, and still another, represented by the condenser 29, between the two sides of the coil. Each capacity action is affected by various conditions; by the spacing, the extent and shape and relative positions of the metallic surfaces, and the material between the metal surfaces. In general the inductance of any part of a winding depends upon the number of turns in that part, the space between turns, the area circumscribed and the location of that portion with respect to other circuits. Thus the inductance of a given turn depends upon the area circumscribed by that turn, its location with respect to other turns and to its spacing from them; likewise, the inductance of a coil or group of coils depends upon the number of turns in the coil or group, their sizes, and their physical relation to each other and to other circuits. These features are or will be understood by those skilled in the art.

In carrying out my invention it is possible to secure the desired differentiation between the natural frequencies of the various groups of coils by differentiating any or all of these features which control their capacities and inductances in a manner which

will be understood without further description.

In Fig. 2 I have represented an interleaved disk coil transformer, the connections of the various coils being shown diagrammatically. In carrying out my invention (considering only one winding, though my invention may be embodied in both) the groups of coils 20 and 21 are arranged to have unequal natural frequencies and higher harmonics below the eleventh harmonic. This may be done as pointed out above, by giving due regard to one or any number of the features affecting the capacity and inductance of windings. I have here represented the result as accomplished, at least partly, by the differences in the spacings of the coils. There are larger spaces between the group 21 and the coils 23 and 24 of the other winding, than between the group 20 and its adjacent coils 24 and 25. It is, of course, impossible to provide the groups of coils of the transformer illustrated with three periods, since there are but two groups, but were the number of groups greater than two, they should have preferably not less than three natural frequencies of electrical oscillation. Not only should the natural frequencies of adjacent groups be differentiated as above, but also the natural frequencies of a group and an adjacent non-similar section should be differentiated wherever such an arrangement may contain sufficient energy to prove dangerous under resonance conditions. For example, it is possible for the coil 13 to resonate with the group 20, or the coil 12 with the group 21, perhaps at the fundamental of the coil and an equal harmonic of the group; it is preferable therefore to differentiate these sections if the coils contain considerable energy.

So far in referring to adjacent sections in the description of specific embodiments of my invention, I have referred principally to those sections of any apparatus which are adjacent by reason of their direct, electrically conducting, connections; sections may also be adjacent so far as my invention is concerned, by reason of their electromagnetic connection, that is because of their mutually inductive relation, or by reason of their electrostatic relation, or by reason of any combination of electrostatic, electromagnetic and electrically conducting relations. Within this broader idea of my invention, any two sections of electrical apparatus are adjacent, which are so related to each other that energy may be transferred from one to the other.

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. In a transformer, a winding comprising a plurality of electrically connected coils assembled in groups and a second winding separating said groups, adjacent groups having unequal natural frequencies of electrical oscillation to restrain the building up of dangerous voltages through resonance.

2. In a transformer, a winding comprising a plurality of electrically connected disk coils assembled in groups and a second winding separating said groups, adjacent groups having unequal natural frequencies of electrical oscillation to restrain the building up of dangerous voltages through resonance.

3. In a transformer, a winding comprising a plurality of electrically connected coils connected in groups and a secondary winding separating said groups, adjacent groups having unequal natural fundamental frequencies of electrical oscillation and harmonics thereof to restrain the building up of dangerous voltages through resonance.

4. In an electrical apparatus, a winding comprising a plurality of electrically connected coils assembled in groups, one of said groups and an adjacent coil having unequal natural fundamental frequencies of electrical oscillation and harmonics to restrain the building up of dangerous voltages through resonance.

In witness whereof, I have hereunto set my hand this 23rd day of November, 1914.

ELMER E. F. CREIGHTON.

Witnesses:

BENJAMIN B. HULL,

MARGARET E. WOOLLEY.

Copies of this patent may be obtained for five cents each, by addressing the "Commissioner of Patents, Washington, D. C."