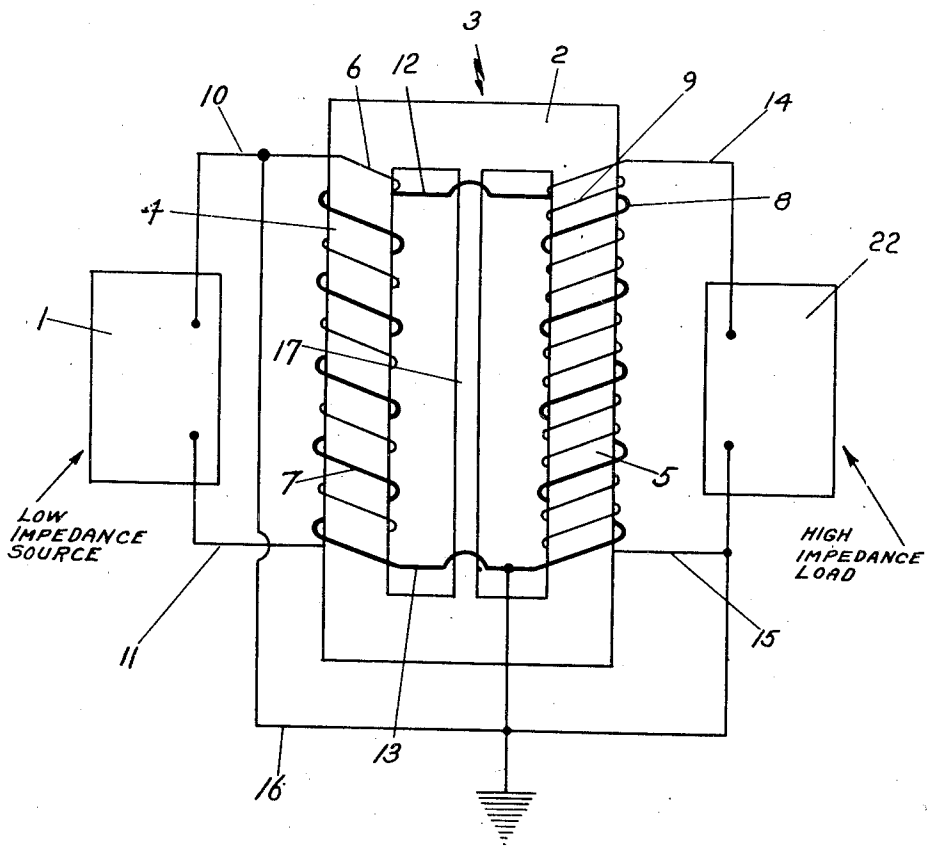
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TRANSFORMER SYSTEM

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TRANSFORMER SYSTEM

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This application is a continuation-in-part of the application of Thomas A. O. Gross entitled Electrical systems, Ser. No. 515,606, filed December 24, 1943, now abandoned.

This invention relates to electrical transformer systems of the type in which a reversal in voltage phase is produced, and more particularly to such systems as are responsive to a relatively wide band of frequencies.

In order for a transformer system to be useful over an extended band of frequencies, it is desirable that the product of the distributed capacities and the leakage inductances of the transformer system as a whole be reduced to a minimum. However, transformers which have been used to produce a phase reversal inherently have had high distributed capacities, and thus high capacity-inductance products. Thus the problem of obtaining phase reversal by transformers in systems involving a relatively wide frequency band has heretofore been so severe that transformers have not been used practically for this purpose.

An object of this invention is to devise a transformer system in which a reversal of phase is produced and in which the product of the distributed capacity and the leakage inductance thereof is reduced substantially below the minimum values heretofore obtainable.

Another object is to utilize a novel cascaded transformer arrangement to accomplish the diminishing of said capacity-inductance product.

A still further object is to utilize a phase-reversing transformer connection in a low impedance section of the transformer.

The foregoing and other objects of my invention will be best understood from the following description of an exemplification thereof, reference being had to the accompanying drawing wherein the figure is a diagram of one embodiment of my invention.

Extended band width of frequency response in a transformer, as pointed out above, can be obtained by reducing the product of the distributed capacity and the leakage inductance of the transformer windings. The leakage inductance, in any single transformation, can be reduced to a minimum by using a single layer winding each for the primary and secondary, and winding these layers with equal lengths directly one over the other. The effective distributed capacity can also be minimized by polarizing the windings so that the voltage differences between the two layers at each point along them are maintained at a minimum. For unity ratio between the number of turns of the primary and secondary windings, the distributed capacity between these windings can be made substantially zero for various types of transformers. As the turns ratio is increased, however, the distributed capacity becomes substantial. If, however, the windings are oppositely

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polarized so as to produce a maximum voltage difference between the primary and secondary windings at one end thereof, the distributed capacity of the transformer becomes large even with a unity turns ratio. A transformer for reversing the phase of the voltage inherently must have its windings polarized to produce such a maximum voltage difference between the primary and secondary windings at one end thereof. Due to the foregoing, the problem of obtaining a voltage phase reversal by a transformer, particularly where a low impedance source and a high impedance load are involved, has been so severe that transformers for producing phase reversal have not been used practically.

I have discovered, however, that if a cascaded transformer system is constructed in accordance with my invention, the difficulties heretofore encountered largely disappear, and a highly effective phase-reversing system is produced with a wide band of frequency response.

In the drawing, 1 represents a low impedance source which is to feed a high impedance load 22 with a reversal of the phase of the voltage of source 1. For this purpose a transformer 3 is utilized. The transformer comprises a core member 2 having a pair of leg sections 4 and 5. Leg section 4 carries a primary winding 6 and a secondary winding 7, preferably wound in the same direction as winding 6. Leg section 5 carries a primary winding 8 and a secondary winding 9, preferably wound in the same direction as winding 8. End conductors 10 and 11 of the primary winding 6 are connected to the source 1. Conductors 12 and 13 connect the ends of the secondary winding 7 to the ends of the primary winding 8. The end conductors 14 and 15 of the secondary winding 9 are connected to the load 22. The conductors 10, 13 and 15 are all connected to a common conductor 16 which may be a ground connection.

By the above connections, the windings 6 and 7 are polarized so as to produce the desired reversal in the phase of the voltage of source 1. I have found that even in such a phase-reversing transformation, the distributed capacity can be made relatively small by keeping the turns ratio between the windings 7 and 6 as low as possible. This ratio even may be less than than unity, that is the transformation may involve a step-down in the voltage.

In order for the low impedance source 1 to feed the high impedance load 22 efficiently, it is desirable that the impedances of the source and the load be matched to each other. This may be done if the overall voltage transformation of the transformer 3 is a step-up transformation of the proper ratio. This is due to the fact that with the usual type of load, an impedance Z connected in series with the secondary of a trans-

former is reflected as an equivalent impedance Ze in series with the primary circuit of the transformer having a value

$$Ze=\left(\frac{N_1}{N_2}\right)^2 Z$$

where

$$\frac{N_1}{N_2}$$

represents the turns ratio.

Thus the transformer section 8—9 connected in cascade with the transformer section 6—7 has the proper step-up turns ratio to give the transformer 3 the desired step-up ratio.

Since the transformer 3 represents two transformations in cascade, it is desirable that a single core structure 2 be utilized so as to eliminate any substantial increase in either size or weight as compared with a single stage transformer. By properly relating the transformer sections 6—7 and 8—9, such a single core may be used as shown. For this purpose the primary winding 8 is wound in such a direction as to set up a flux through the core 2 in the same direction as the flux established through the core 2 by the primary winding 6 during normal operation. It may be desirable to utilize a thin leg 17 of magnetic material joining the upper and lower portions of the core 2 between the two sections of the transformer to carry any unbalance flux which may exist between the two sections. Also in accordance with the general principles enunciated herein, the winding 9 is wound in the same direction as the winding 8 to minimize the distributed capacity thereof. Both transformer sections 6—7 and 8—9 preferably are of the single layer equal length type as described above.

Of course it is to be understood that the low impedance source 1 may actually be a relatively high impedance source coupled to the primary 6 through a step-down transformer which, as described above, reduces the effective impedance of the source to a relatively lower value. Thus any type of source can be converted into the requisite low impedance form for satisfactory phase reversal in accordance with my invention by such a transformer.

By utilizing the principles of my invention as described above, I have been able to construct phase-reversing transformers interconnecting low impedance sources with high impedance loads, said transformers having a substantially flat response to frequencies from about eighty cycles per second to several megacycles per second, which results had heretofore been considered practically impossible.

I believe that the beneficial effects of a transformer cascade constructed in accordance with my invention are due at least in part to the following. The capacity C effectively connected across the secondary of a transformer is reflected as an equivalent capacity Ce across the primary circuit of the transformer having a value

$$Ce=\left(\frac{N_2}{N_1}\right)^2 C$$

The relationship of the secondary impedance, including inductive impedance, to an equivalent primary impedance has already been defined above. Thus the higher the ratio of transformation, the greater will be the effect of the distributed capacity. By using the inherently high capacity phase reversal transformation only in a low ratio section of the transformer system, the

effect of the capacity of such phase reversal transformation upon the overall LC product of the system is reduced to a negligible level.

Of course it is to be understood that this invention is not limited to the details as described above as many equivalents will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. A transformer system comprising a plurality of voltage changing transformer sections connected in cascade, each of said transformer sections comprising a primary winding and a secondary winding, said windings being wound one over the other, one end of the primary winding of the section having the lowest ratio of transformation being electrically connected to the end of its associated secondary winding at the opposite end of said last-named primary and secondary windings, the windings of said section having the lowest ratio of transformation being related to produce a phase reversal of the voltage supplied thereto with respect to the common connection between said ends.

2. A transformer system comprising a plurality of voltage changing transformer sections connected in cascade, each of said transformer sections comprising a primary winding and a secondary winding, said windings being wound one over the other, one end of the primary winding of the first of said sections being electrically connected to the end of its associated secondary winding at the opposite end of said last-named primary and secondary windings, the windings of said first section being related to produce a phase reversal of the voltage supplied thereto with respect to the common connection between said ends.

3. A transformer system comprising a plurality of voltage changing transformer sections connected in cascade and adapted to produce an overall voltage step-up transformation, one of said sections comprising a step-down voltage transformer, each of said transformer sections comprising a primary winding and a secondary winding, said windings being wound one over the other, one end of the primary winding of the last-named section being electrically connected to the end of its associated secondary winding at the opposite end of said last-named primary and secondary windings, the windings of the said last-named section being related to produce a phase reversal of the voltage supplied thereto with respect to the common connection between said ends.

4. An electrical system comprising a relatively low impedance source, a relatively high impedance load, a relatively low ratio voltage transformer connected to said source, said transformer comprising a primary winding and a secondary winding, said windings being wound one over the other, one end of said primary winding being electrically connected to the end of its associated secondary winding at the opposite end of said primary and secondary windings, said windings being related to produce a phase reversal of the voltage supplied thereto with respect to the common connection between said ends.

5. A transformer system comprising a magnetic core, a pair of voltage changing transformer sections connected in cascade, each of said transformer sections comprising a primary and a secondary winding, one overlying the other, wound

on said core, one of said transformer sections having a relatively high ratio of transformation, another of said transformer sections having a relatively low ratio of transformation, the windings of said last-named section having one end of each connected together and wound in opposite directions from said connected ends, the primary winding of both of said sections being wound in a direction to send a magnetic flux through said core in the same direction, the windings of said first-named section being wound in the same direction.

6. A transformer system comprising a magnetic core, a pair of voltage changing transformer sections connected in cascade, each of said transformer sections comprising a primary and a secondary winding, one overlying the other, wound on said core, one of said transformer sections having a relatively high ratio of transformation, another of said transformer sections having a relatively low ratio of transformation, the windings of said last-named section having one end of each connected together and wound in opposite directions from said connected ends, the primary winding of both of said sections being wound in a direction to send a magnetic flux through said core in the same direction, the windings of said first-named section being wound in the same direction, and an auxiliary unbalance flux leg on said core interposed between said sections.

7. A transformer system comprising a plurality of voltage changing transformer sections connected in cascade, each transformer section comprising a core member carrying a primary and a secondary winding, each of said windings comprising a single layer of turns, the length of the primary winding of each section along its core being substantially equal to the length of its associated secondary winding along said core, one end of the primary winding of the section having the lowest ratio of transformation being electrically connected to the end of its associated secondary winding at the opposite end of said last-named primary and secondary windings, the windings of said section having the lowest ratio of transformation being related to produce a phase reversal of the voltage supplied thereto with respect to the common connection between said ends.

8. A transformer system comprising a plurality of voltage changing transformer sections connected in cascade, each transformer section comprising a core member carrying a primary and a secondary winding, each of said windings comprising a single layer of turns, the length of the primary winding of each section along its core being substantially equal to the length of its associated secondary winding along said core, one of said transformer sections having a relatively high ratio of transformation, another of said transformer sections having a relatively low ratio of transformation, one end of the primary winding of the section having the lowest ratio of transformation being electrically connected to the end of its associated secondary winding at the opposite end of said last-named primary and secondary windings, the windings of said section having the lowest ratio of transformation being related to produce a phase reversal of the voltage supplied thereto with respect to the common connection between said ends.

9. A transformer system comprising a plurality of voltage changing transformer sections connected in cascade, each of said transformer sections comprising a primary winding and a secondary winding, said windings being wound one over the other, one end of the primary winding of the section having the highest ratio of transformation being electrically connected to the adjacent end of its associated secondary winding, the windings of said section having the highest ratio of transformation being related to produce like polarity of the voltage at the unconnected ends thereof.

10. A transformer system comprising a plurality of voltage changing transformer sections connected in cascade and adapted to produce an overall voltage step-up transformation, one of said sections comprising a step-down voltage transformer and the other of said sections comprising a step-up voltage transformer, each of said transformer sections comprising a primary winding and a secondary winding, said windings being wound one over the other, one end of the primary winding of the section comprising a step-up voltage transformer being electrically connected to the adjacent end of its associated secondary winding, the windings of said last-named section being related to produce like polarity of the voltage at the unconnected ends thereof.

11. An electrical system comprising a relatively low impedance source, a relatively high impedance load, a relatively low ratio voltage transformer connected to said source, a relatively high ratio voltage transformer connected to said load, said transformers being connected in cascade, each of said transformers comprising a primary winding and a secondary winding, said windings being wound one over the other, one end of the primary winding of said high ratio voltage transformer being electrically connected to the adjacent end of its associated secondary winding, said last-named windings being related to produce like polarity of the voltage at the unconnected ends thereof.

12. A transformer system comprising a plurality of voltage changing transformer sections connected in cascade, each of said transformer sections comprising a primary winding and a secondary winding, said windings being wound one over the other, one end of the primary winding of the section having the highest ratio of transformation being electrically connected to the adjacent end of its associated secondary winding, the windings of said section having the highest ratio of transformation being related to produce like polarity of the voltage at the unconnected ends thereof, one end of the primary winding of the section having the lowest ratio of transformation being electrically connected to the end of its associated secondary winding at the opposite end of said last-named primary and secondary windings, the windings of said section having the lowest ratio of transformation being related to produce a phase reversal of the voltage supplied thereto with respect to the common connection between said ends.

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