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RESONANT DIFFERENTIAL TRANSFORMER

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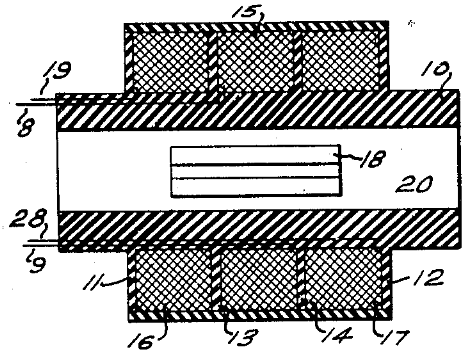

Fig.1.

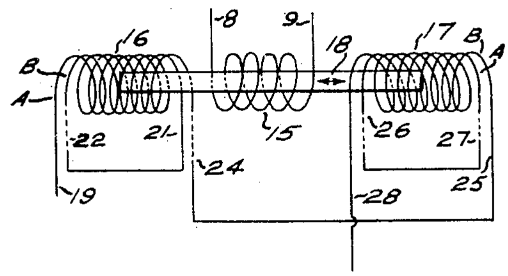

Fig.2.

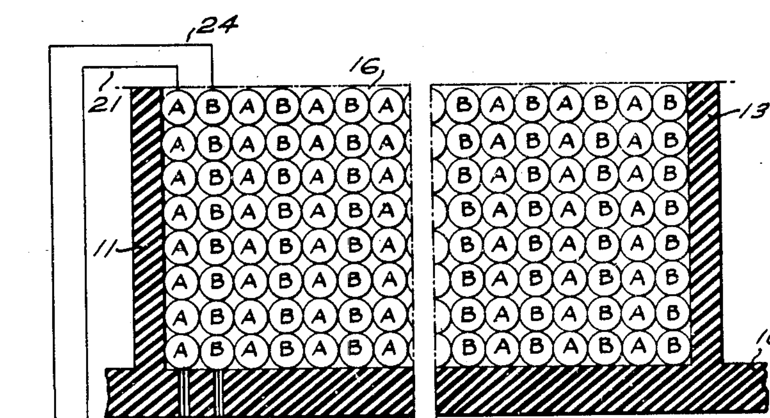

Fig.3.

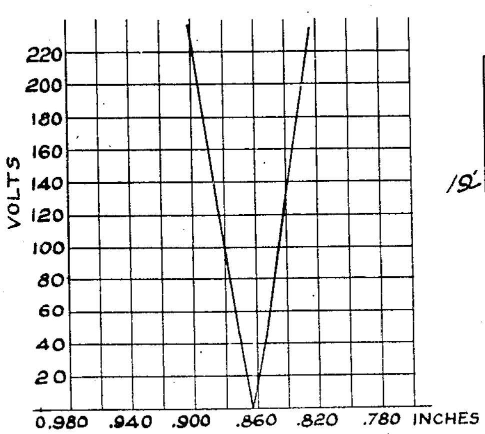

Fig.4.

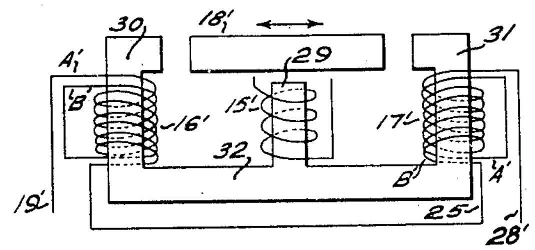

Fig.5.

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RESONANT DIFFERENTIAL TRANSFORMER

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3 Claims. (Cl. 171—119)

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This invention relates to resonant differential transformers.

As is well known, transformers of the class recited comprise hollow coils or coils wound on metal cores, with secondary coils disposed in symmetry with a primary coil and provided with a relatively movable core piece or armature. The salient characteristic of such transformers is the creation of alternating magnetic flux in the armature by the exciting or primary coil, which, in the balanced condition of the armature induces equal and mutually cancelling voltages in a pair of relatively oppositely wound series-connected secondary coils disposed in the magnetic flux. Movement of the armature to a position of asymmetry from a position of balanced symmetry relative to the primary and secondary coils creates unbalance in the voltages of opposite phase in the respective secondaries, and thus a preponderating voltage of one given phase in the output of the series-connected secondaries. Movement of the armature through the point of symmetry to asymmetrical disposition in the other direction again creates unbalance in the voltages of opposite phase in the respective secondaries, and thus a preponderating voltage of an opposite phase from that of the said one phase, in the output from the secondaries. This controlled output is obviously susceptible to many and diverse uses. As previously developed, however, such transformers, in addition to other defects, have had such a comparatively low order of magnitude of output changes as to necessitate the use of amplifying units in association therewith. They also have been relatively insensitive, and have consequently required appreciable movements of the armature in order to effect useable changes in output voltage from the secondaries. So far as known, additionally, with such transformers it has not been possible to effect a required change in output voltage while holding the armature stationary relative to the coils.

It is known that in the coils of such transformers the voltage difference existing between different parts of the coil, by producing an electrostatic field in the vicinity of the coil, has an effect which is similar to that of a more or less small capacity shunted across the terminals of the coil. This is known as the distributed capacity of the coil, and all previous efforts with which I am

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familiar have been toward reducing the distributed capacity of such coils, because of undesired resonance points which it entails, among other reasons. I have discovered that increasing the distributed capacity of such coils seemingly effects a partial resonance which modifies the apparent resistance and increases the capacitive reactance of the coil, as viewed from the terminals, and also secures resonance of a reasonable frequency, and which, from practically every viewpoint, effects such an increase in operating efficiency as to be startling.

It is among the objects of this invention: to improve the efficiency of resonant differential transformers; to obviate disadvantages of the prior art in such transformers; to provide a differential transformer with an output of such voltage as to obviate the use of amplifying units or systems; to improve the windings of coils; to provide a method of winding a coil by which the distributed capacity thereof will be increased; to provide a resonant differential transformer with such efficiency that the movement of a core piece from symmetry in such transformer will effect an output which can be indicated, measured, or used, despite the fact that the movement is of such minute size as to be previously unmeasurable; to provide a resonant differential transformer with a relatively movable core piece or armature by which, with a given oscillation input to the primary, a voltage output changing linearly from positive to negative, through a null point, can be secured with extremely minute shifts in relative positioning of the core piece; to provide a differential resonant transformer by which the magnitude and sense of voltage output can be varied by a mere change in frequency of oscillation delivered to the primary thereof; to provide a transformer assembly by which the secondary volt change in response to core movement is tremendously enhanced over any previous known assembly; to provide an improved device for converting distance motion into an electrical change; and to provide other improvements as will become apparent as the description proceeds.

In carrying out the invention in a preferred embodiment, each secondary coil of the transformer is wound with a plurality of strands in physically parallel relation until the coil is suitably built up, pursuant to which, the output end of the first strand of the plurality is brought to series connection with the input end of the next strand of the plurality, whereby the voltage difference between adjacent turns, and hence the distributed capacity of the coil, is appreciably enhanced over that existing with a single continuous turn or strand of wire.

In the accompanying drawing forming part of this description:

Fig. 1 represents a transverse longitudinal section through a transformer according to an illustrative embodiment of the invention, showing in elevation a movable armature therefor.

Fig. 2 represents a schematic diagram of the wiring of the transformer according to the illustrative embodiment thereof shown in Fig. 1.

Fig. 3 represents a fragmentary diagrammatic section in magnified scale through one of the secondaries of the transformer of Figs. 1 and 2, showing the relationship and series connections of the illustrative plurality of strands of wire of the coil.

Fig. 4 represents a diagrammatic curve of the output of the secondaries of a typical transformer constructed according to this invention, indicating the linearity of the voltage change and the magnitude thereof as functions of small core movements.

Fig. 5 represents a schematic diagram of the wiring of an illustratively modified form of transformer, utilizing a laminated core.

Referring to Fig. 1, an illustrative exemplification of the invention is disclosed in which a unitary insulating sleeve 10 is provided, having outer boundary flanges 11 and 12, for the outer edges of the secondaries 16 and 17, to be described, and the intermediate flanges or annular partitions 13 and 14, defining the inner edges of the respective secondaries and the outer boundaries of the primary coil 15. The primary or exciting coil 15 in the usual course has its terminals 8 and 9 connected to a suitable source of alternating voltage, and usually this is of relatively fixed frequency. One exception will be described later herein. A secondary coil 16 is wound from left to right between partitions 11 and 13, and is connected in series with the secondary coil 17, wound from right to left, between the partitions 12 and 14 on the transformer supporting cylinder or sleeve. A floating magnetic core or armature 18 is provided, disposed internally of the sleeve 10 in the aircore or space 20 thereof. This is suitably mounted for axial adjustment in the sleeve, and is of such mass and size as to have appreciable electromagnetic effect. The armature is preferably longitudinally slotted to reduce eddy currents. Obviously, the same electrical effects can be attained by winding both secondaries in the same direction and simply connecting the endings together to secure the bucking voltage output. The transformers as previously made before the instant invention, have had the secondary coils 16 and 17 respectively formed from a single strand of wire, and have had limited efficiency, as explained above.

In constructing a transformer according to this invention, a desired plurality of strands of wire is provided, usually increasing in number as the desirability for increased voltage differences between adjacent turns of wire becomes more evident. There may be four or more such independent strands, to be illustrative and not limitative. For simplicity and convenience of description, however, the invention will be described as utilizing two separate strands of wire, respectively A and B, for each secondary coil 16 and 17. Illustratively, enameled copper wire is preferred. For convenience, a fragment of the transformer 16, in magnified schematic disclosure, is indicated in Fig. 3. The two strands are preferably laid on together with strand A laid on adjacent to the boundary flange 11 with end 19 of strand A comprising a terminal wire, and strand B laterally juxtaposed to strand A to lie in a plane therewith tangential to the cylindrical surface of the sleeve 10 during the winding. Strands A and B are laid on in mutual parallelism in one row, until the entire area of the sleeve 10 between boundary flanges 11 and 13 has been covered, then the second row of plural strands is applied, starting, illustratively, with strand B adjacent to flange 13, etc., until the coil has been completed, with as many rows of multiple or plural strands as are desired. Obviously, this is a merely illustrative type of winding, and any random windings, interspersing layers, are permitted, if substantially identical in each secondary, and as long as the two strands are mounted, in major part at least, in co-extensive parallelism, the ends of the invention are served, regardless of the particular winding order or method or shape, thickness, or dimensions of the coil form or finished coil, or even whether the coils are separately formed and subsequently assembled together to form the transformers of this invention.

With the coil wound as just described, the finishing end of strand A, indicated at 21, is led transversely across the coil and connected in series with the beginning end of strand B, indicated at 22. The free or outer end of the latter strand, at 24, is then led transversely across the primary coil and connected to the starting end 25 of the strand B on coil 17. The free end of the latter, at 26, is led to series connection with the beginning of the strand A of coil 17, as at 27. The free end 28 of the strand B is the other terminal of the series of secondary coils.

It will be observed that any two adjacent strands, A and B, although physically in contiguity, will be electrically spaced by substantially one-half of the entire number of turns of the coil, so that the voltage difference between such adjacent turns will be appreciably greater than could possibly exist between two adjacent turns of a single continuous strand and the distributed capacity will be correspondingly enhanced.

It will also be understood that the particular method or means by which such voltage difference is obtained is not as important, perhaps, as is the actual difference itself. Thus, although it is preferred that the two strands be applied or laid on the forming frame or the like simultaneously, in parallelism during application, this is not in all cases essential, so that if one strand is first applied, with suitable spacing between turns, such spacing could be filled ultimately by the second strand, or, indeed, by an elongated or longitudinally spaced continuation of the same strand, laid between the turns of the first strand. Any other mode or manner of application of the respective strands could be resorted to for the same end. It will also be clear that the number of separate or independent strands could be almost endlessly multiplied, and each strand could have its terminal end attached to the beginning end of the next adjacent strand, and the terminal end of the latter could in turn be attached to the beginning end of the next adjacent strand, and so on, to the end that the respective turns of the coil could each be separated electrically from physically adjacent turns by multiple turns of wire.

It will be understood that the coaxial coil arrangement of the transformer shown in Figs. 1 and 2 is purely illustrative, and that exactly similar results can be obtained in a transformer utilizing laminated cores, as illustrated in Fig. 5. In this illustrative case, a central core element 29 is provided, integral with the laminated core element 30, and upon which the primary or exciting coil 15' is wound. The parallel leg extensions 30 and 31 of the core are respectively wound with the secondaries 16' and 17', each of which is formed of the respective individual strands A' and B', wound as has been described of strands A and B above. The ends of the core elements 30 and 31 are separated by an air gap within which there is floatingly supported the core element 18', movable transversely of the axis of the primary coil 15'. With the connections as previously described, symmetrical balance of the armature 18' relative to the primary coil 15' and relative to the respective secondaries 16' and 17' is secured and the output from the secondaries through leads 19' and 28' will be null. This is exactly the same in effect as is desired and secured from the first form of transformer disclosed, in which with symmetrical disposition of the core piece 18 in the primary coil 15 and relative to the secondaries 16 and 17, the output of the secondaries leads 19 and 28 is a nullity. As explained, shift of the armatures 18 or 18' in a given direction establishes unbalance and a voltage output of a selected or given phase, from the respective pairs of leads 19 and 28, or 19' and 28', as will be understood.

To explain the remarkable output of the transformer with the increased distributed capacity effected by the invention herein, reference may be made to the graph of Fig. 4, by which it will be seen that by a mere shift of the armature 18 of Figs. 1 and 2, of less than .080'', through a movement from asymmetry on one side by less than a mere .040'' from the null point or symmetry, through the null point in a movement toward asymmetry in the opposite direction of less than .040'' from the null point, or symmetry, the output of the secondaries will swing from a voltage of approximately 210 volts in one phase, through zero or nullity of voltage, to an output of approximately 210 volts in the opposite phase. This is a most remarkable sensitivity, and obviously is a voltage output and regulation which is of value of itself without requiring amplification for effective commercial or industrial use. With suitable amplification, it will be seen that with reference to the null point of no output from the secondaries, the slightest measurable core piece or armature relative movement effects such voltage change as to be measurable and useable, even to the smallest possible distance movement.

It will be understood that with such minute movement responsiveness, the device can be used alone or in tandem or in balancing-rebalancing systems, for accurate and prompt measurement of the slightest changes in torque of a given shaft, or of any distance, weight, bodily movement or shift, or pressure, or strain or the like. Any value which can be represented in part at least by a movement, can be used to establish electrical value as a function thereof.

It can be used as an accelerometer, and the like, and in any system where a null balance is sought or is to be achieved.

A further and unexpected utilization of the device lies in the fact that the resonance curve of the transformer can be predicated upon relatively low frequencies of oscillation input in the primary coil. It is an important phase of the instant invention to utilize the remarkable responsiveness of the transformer to effect control functions without any change in the relative position of the movable core piece or armature. To this end, let it be assumed that a given condition of asymmetry in core position and therefore of electrical output from the secondaries is achieved, by which, for instance, with a suitable electronic or other power amplification, a reversible electrical motor is caused to run in a given direction for whatever purpose may be indicated. It will be understood that with a given frequency of input to the primary coil, there will be a differential condition of resonance or partial resonance on one or the other or both of the secondary coils. With secondaries wound and connected as illustrated, a change in frequency may be used to increase either half of the secondary winding voltage to reverse the preponderating voltage by and reveres the phase of the output. With a two phase motor, for instance, it will be clear that with one frequency of excitation, and with the armature relatively fixed, one phase output from the secondaries will be achieved which, with said amplification, can run the motor in one direction. Change in the proper direction of the exciting frequency, without armature shift, will change the phase output and perhaps the voltage, and reverse the two phase motor.

Having thus described my invention, I claim:

1. A differential transformer comprising a coil formed of multiple turns of wire, physically adjacent turns of the coil being separated electrically by lengths of wire appreciably greater than the arcuate extent of wire in the coil between physically adjacent turns as if such adjacent turns were continuous turns of the same strand a second coil formed of multiple turns of wire, physically adjacent turns of such coil being separated electrically by lengths of wire appreciably greater than the arcuate extent of wire in the coil between physically adjacent turns as if such adjacent turns were continuous turns of the same strand, said two coils being interconnected in reverse series arrangement, a primary coil inductively coupled between said coils, and an armature movably disposed within said three coils.

2. A resonant differential transformer comprising a first secondary coil formed of a plurality of turns of a wire strand, means separating the respective plurality comprising turns of another strand of wire, means joining the said strands in series, a second secondary coil comprising a second plurality of turns of a wire strand, means separating the second respective plurality comprising turns of another strand of wire, means joining the said strands of the second secondary coil in series, each secondary having a higher distributed capacity than if formed with unseparated turns of a wire strand, means coupling the first and second secondaries in bucking series, a primary coil for exciting the said secondaries, and an armature relatively movable with respect to said primary and secondary coils.

3. A differential resonant transformer comprising a pair of axially aligned spaced hollow secondary coils joined in bucking series relation, each secondary coil comprising a plurality of turns

of a wire strand respectively mutually separated axially of the coil by the respective turns of another wire strand, with said strands of each coil being joined in series, a primary hollow coil disposed between and in axial alignment with the respective secondaries, and an armature relatively movably disposed in the primary coil and extending partially at least into one of said secondaries.

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