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(54) **A ferro-resonant-type transformer.**

(57) A transformer wound for ferro-resonant transformer response on a core of conventional transformer material and dimension. The principal secondary winding flux path saturates in both the external core legs of the transformer as well as the center core leg, and therefore has more losses than a traditionally constructed ferroresonant transformer where only the center core leg saturates, but the difference in such losses is more than compensated for by the savings in construction, since conventional transformer materials and techniques are employed for manufacturing the transformer disclosed herein.

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BACKGROUND OF THE INVENTION

Field of the Invention

This invention pertains to a device known as a ferro-resonant transformer and specifically to an improved structure therefor.

Description of the Prior Art

A ferro-resonant transformer, sometimes referred to as a "Sola" regulator, is a special type of transformer that accepts an applied square wave voltage, and, because of inherent properties of the transformer, furnishes a more sinusoidal alternating current output. A capactior is connected across the secondary of the transformer tuned near the resonant frequency of the ac to achieve this operating mode.

In a conventional ferro-resonant transformer, the cores or legs of the transformer are comprised of laminations of a steel known for its magnetic efficieny and referred to in the industry as "ferro-resonant steel". Steel grade M6 or better have heretofore been thought to be necessary for obtaining ferro-resonant transformer operation. Such steel can be made in very thinly laminated parts and result in very small losses due to eddy currents.

Now referring to the magnetic operation of a prior art ferro-resonant transformer, such a transformer traditionally includes winding for both the primary and secondary wound about a center core or leg of ferro-resonant steel. The external legs of the transformer are likwise comprised of laminated ferro-resonant steel and the dimensions are such that the sum of the cross-sectional dimension of the external legs exceeds the cross-sectional dimension of the center leg to reduce losses.

There are also more turns on the secondary winding than on the primary winding. In operation, the primary winding does not cause sufficient flux density in the principal path through related core to cause saturation and, therefore, operates in the linear mode. However, the secondary winding does cause sufficient flux density in the center leg of the core related to its operation and therefore does not operate in a linear mode. In fact, on the B-H curve (flux denisty-coercive force curve), operation is such that a large coercive force is required for a small change of flux density and, hence, provides good regulation properties. The external legs, because of their dimensional relationship to the center leg, do not saturate. It has heretofore been believed that it was necessary to avoid saturating the external legs because to do so would create too many losses and therefore such a structure would be unsatisfactorily inefficient.

However, it should be noted that ferro-resonant transformer of the traditional design described above is an expensive structure to manufacture compared with a conventional transformer. First, the steel is much more expensive. Grade M19 is perfectly acceptable for a conventional transformer compared with Grade M6 for a ferro-resonant transformer of traditional design. Next, a conventional transformer is generally evenly dimensioned with respect to the flux paths of both the primary and secondary windings. That is, the center core leg is usually dimensioned so that it is exactly twice in cross-section to the sum of the cross-section dimensions of the external legs. Both these factors prevent the use of conventional transformer laminations for the construction of a ferro-resonant transformer.

Further, it has not been known how to standardize ferro-resonant transformer construction so that the same component parts can be assembled in nearly the same fashion for operation with respect to various input voltages for providing the same rated volt-ampere rating for the transformer.

Therefore, it is a feature of the present invention to provide an improved ferro-resonant-type transformer that does not employ ferro-resonant steel, but the less expensive steel employed in conventional transformers.

It is another feature of the present invention to provide an improved ferro-resonant-type transformer that employs core dimensions common for conventional transformers.

It is still another feature of the present invention to provide an improved ferro-resonant-type transformer that is constructed in such a way that it is connectable to various input driver circuits, all parts being common to a conventional transformer.

Summary of the Invention

The invention embodiment disclosed shows a transformer core of a "T" configuration made of laminated steel commonly employed in conventional transformers. The external legs are each in an "L" configuration and are likewise made of laminated steel commonly employed in conventional transformers. The primary winding has fewer turns than the secondary winding and the secondary winding has a sufficient number of turns to saturate the entire principal flux path related to the secondary windings, including the center leg, the external legs and the shunts.

The windings are provided in layers for the primary so as to have connections for operating in connection with an inverter connected to a battery or other dc source over a common range of voltages. The secondary is also provided with convenient taps.

Brief Description of the Drawings

So that the manner in which the above-recited features, advantages and objects of the invention, as well as others which will become apparent, are attained and can be understood in detail, more particular description of the invention briefly summarized above may be had by reference to the embodiment thereof which is illustrated in the appended drawings, which drawings form a part of this specification. It is to be noted, however, that the appended drawings illustrate only a preferred embodiment of the invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

In the Drawings:

Fig. 1 is a plan view of a ferro-resonant-type transformer in accordance with the present invention, also showing flux paths for both the primary winding and the secondary winding.

Fig. 2 is a top view of a transformer bobbin as it is positioned with respect to the legs of a transformer in accordance with the present invention.

Fig. 3 is a partial side view of a vertical cross-section of a ferro-resonant-type transformer in accordance with the present invention.

Fig. 4 is a schematic diagram of the primary winding for a ferro-resonant-type transformer in accordance with the present invention when connected for operation with respect to a square wave input derived from a 30-volt dc source.

Fig. 5 is a schematic diagram of the primary winding for a ferro-resonant-type transformer in accordance with the present invention when connected for operation with respect to a square wave input derived from a 60-volt dc source.

Fig. 6 is a schematic diagram of the primary winding for a ferro-resonant-type transformer in accordance with the present invention when connected for operation with respect to a square wave input derived from a 120-volt dc source.

Fig. 7 is a schematic diagram of the secondary winding for a ferro-resonant-type transformer connected to a capacitor for resonant operation near the desired frequency of operation.

Fig. 8 is an overall schematic diagram of a ferro-resonant transformer in a typical connection configuration.

Description of the Preferred Embodiment

Now referring to the drawings, and first to Figs. 1, 2 and 3, it is typical that a transformer employ a stack of laminated parts. The number of laminates is not so material as the dimension of the stack. In a 1000 VA ferro-resonant-type transformer in accordance with the present invention it has been found convenient to provide stacks of grade M19 steel laminates that is 3-3/4 inches high in depth dimension 10 for each the center leg and the two external legs. Width 12 of the center core leg 11 is 1-1/2 inches and width 14 of each of the external legs 15 and 17 is 3/4 inches. Hence, the dimension in cross-section of the sum of the external legs is equal to that of the center leg.

It is typical to have the primary winding and the secondary winding of a conventional transformer wound on bobbins made of glastic, a non-magnetic combination of fiberglas and plastic. For conventional transformers having center core laminates 1-1/2 inches wide, the stack is normally 3 inches. Therefore, two bobbins are used to make one bobbin 16. Split 18 shows where these two bobbin parts are joined.

Turns 20 for the primary winding are shown in Fig. 3 wound on bobbin 16. In a similar fashion turns are wound on a separate bobbin for the secondary winding. The windings are separated from each other by an air gap. For the transformer being described, the air gap between the center leg and external leg is 3/4 of an inch wide, as identified by numeral 22. A shunt 24 fills most of the air gap, width dimension 26 being 0.660 of an inch. The depth dimension is 3 inches and the height is 0.98 of an inch. The shunt is also made of laminated sections, the laminations being shown endwise in Fig. 3 for the shunt. A similar shunt 28 is provided in the opposite air gap. Pieces of Nomex fill up the remainder of the air gaps not occupied by the shunts.

The principal flux path for the primary winding is shown in Fig. 1 as $\varnothing_p$ and the prinicipal path for the flux path related to the secondary winding is shown in Fig. 1 as $\varnothing_s$. It should be understood that complementary paths for both windings also pass through the other external leg in addition to the leg illustrated. There is some flux for both windings that travel the entire core length, and thus also pass through the other winding from the winding creating the flux.

The segments or the windings which overall make up the primary winding just described are shown in Figs. 4, 5 and 6. In Fig. 4, winding 30A and 30B comprise the first two layers; windings 32A and 32B comprise the second two layers; windings 34A and 34B comprise the third two layers, and windings 36A and 36B comprise the fourth two layers. Each layer set is separated by an insulating layer of Nomex and the parallel connections are made as shown. Small driver windings 38 and 40 share the final layer. Each of the four windings comprise 46 turns of number 14 wire. The driver windings each have 5 turns of number 16 wire.

Fig. 5 shows a configuration wherein the same four windings 30, 32, 34 and 36 are used without the center tap connections employed in Fig. 4. Fig. 6 shows a configuration wherein windings 30 and 32 are connected in series and windings 34 and 36 are connected in series and the connection between the two series connections provides a center tap for the entire primary. Again, the driver windings are the same as for the Fig. 4 and Fig. 5 structures.

The secondary winding comprises 238 turns of number 12 wires and is wound to provide seven layers of 34 turns per layer. Taps are provided at the 72nd, 93rd and 162nd turns to provide 120-volt, 240-volt and 277-volt for a 400-volt overall secondary. Capacitor 40 across the secondary at 39 micofarads tunes the secondary to a resonant frequency just off 60 Hz for successful ferro-resonant operation.

A typical overall schematic diagram for the ferro-resonant-type transformer just described is shown in Fig. 8.

Such a structure provides operation of the primary winding in the linear range and the secondary winding in a satisfactory saturated mode for variations 85 to 100 percent of the voltage inputs shown in Figs. 4, 5 and 6. Regulation can be improved with a larger capacitor 40, but losses do increase. However, with the values shown, although greather than with prior art ferro-resonant transformers, the losses are not great.

A regulation rating of 2-1/2 is a common design goal (volts in secondary times circulating current equals 2-1/2 times the VA rating for the primary). In this case, the circulating current is a little over 6 amperes for an overall regulation rating of 2.8, which is quite good.

The output waveform includes some high distortions which can be filtered out by appropriate components (not shown), if desired. Also, the output waveform can be further shaped to be more sinusoidal, if desired.

While a particular embodiment of the invention has been shown and described, it will be understood that the invention is not limited thereto, since many modifications may be made and will become apparent to those skilled in the art.

WHAT IS CLAIMED IS:

1. A ferro-resonant type transformer, comprising
a laminated center leg made of conventional transformer steel,
a pair of laminated external legs made of conventional transformer steel, the cross-sectional dimension of the center leg equalling the sum of the cross-sectional dimension of said center leg,
a primary winding wound about said center leg having sufficient turns and resistance so as to operate within the linear range with respect to applied rated square wave voltage,
a secondary winding wound about said center leg and spaced apart from said primary winding, and
a shunt between said primary winding and said secondary winding,
said secondary winding having sufficient turns and resistance so that the steel in the center leg underneath said secondary winding and the return flux path through said external legs and said shunt, flux saturates for rated volt amperes, therefore resulting in a non-square wave output with good regulation and without excessive losses in ferro-resonant-type transformer action.

2. A ferro-resonant-type transformer in accordance with claim 1, wherein said primary winding is wound in insulated layers readily tapped for connection to multiple applied voltage connections to obtain rated volt ampere performance.

3. A ferro-resonant-type transformer in accordance with claim 1, wherein each of said primary winding and said secondary winding are wound on non-magnetic bobbins.

FIG.1

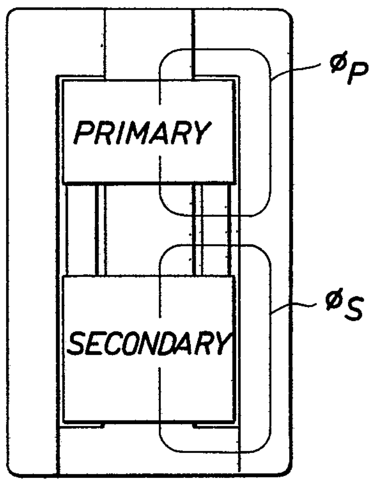


FIG. 2

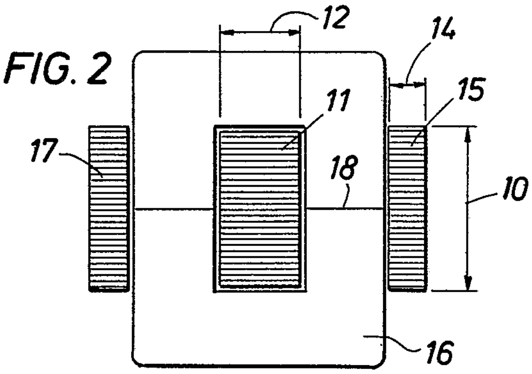


FIG. 3

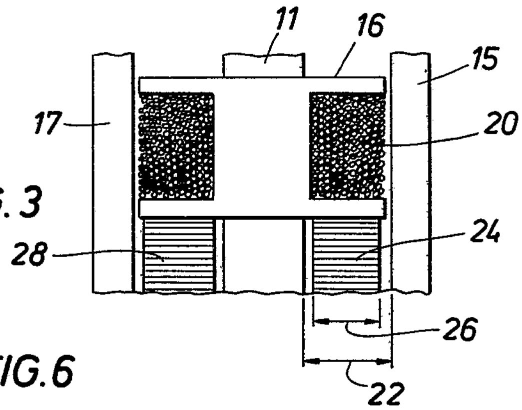


FIG.4

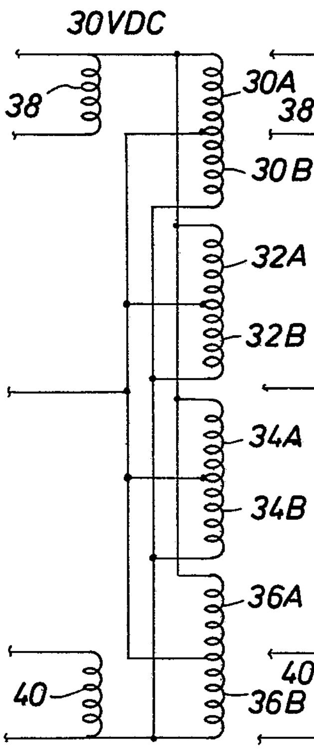


FIG.5

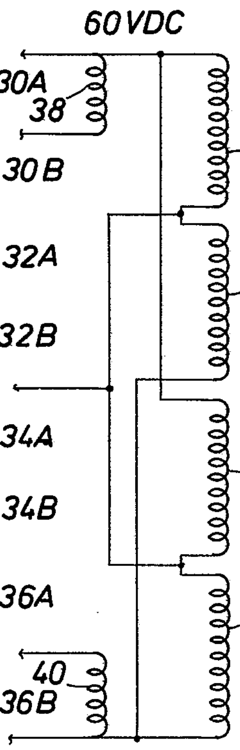
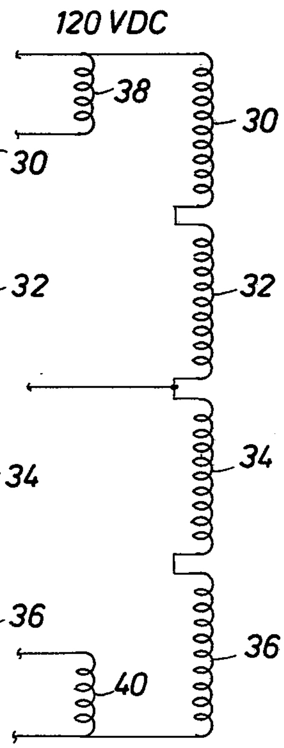


FIG.6



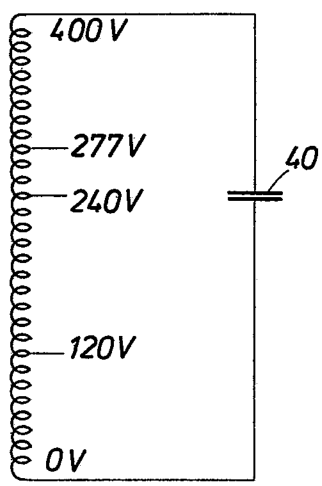


FIG.7

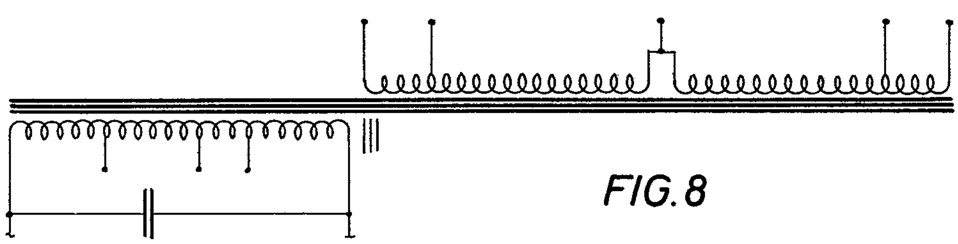


FIG.8