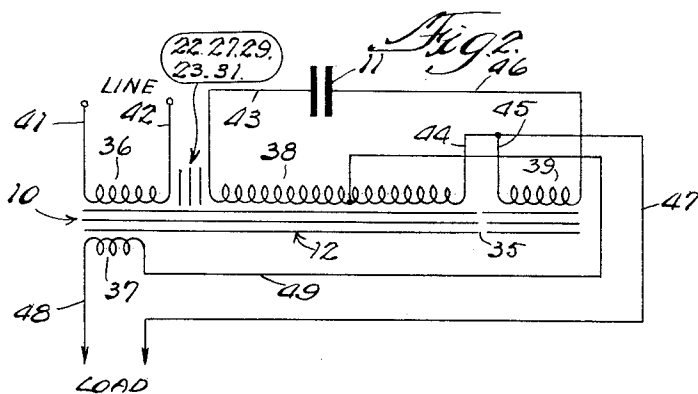
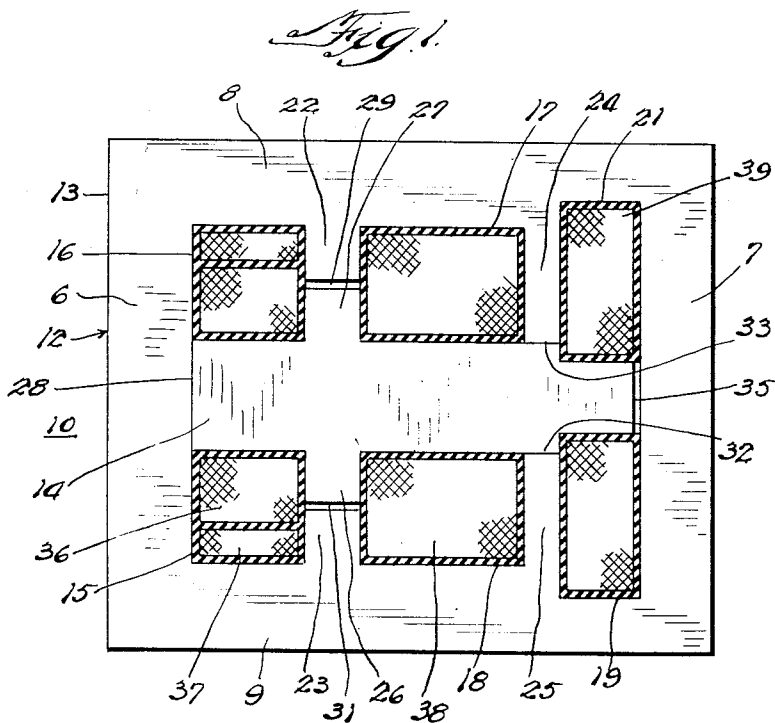


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TRANSFORMER HAVING CONSTANT AND
HARMONIC FREE OUTPUT VOLTAGE
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TRANSFORMER HAVING CONSTANT AND HARMONIC FREE OUTPUT VOLTAGE

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This invention relates to voltage transforming and regulating apparatus, and to core and coil constructions therefor, more particularly to such apparatus having a substantially harmonic free output voltage, and it is an object of the invention to provide improved apparatus and constructions of the character indicated.

It is a further object of the invention to provide improved apparatus of the character indicated having an output voltage which is substantially constant irrespective of variations of input voltage over a certain range, and which is substantially free of harmonics.

It is a further object of the invention to provide an improved transformer.

To provide a source of alternating current voltage of a desired frequency which is free of harmonics, that is, a sine wave, has long been a problem because of the undesired effects produced thereby. For example, instruments which receive a voltage having harmonics therein may give erroneous and sometimes erratic indications. Apparatus supplied with a voltage having harmonics therein may overheat, and its useful life may be lessened. If the transformer which is supplying a voltage is responsible for the generation of harmonics, the supply transformer as well as the apparatus connected to it may overheat.

Commercial power systems supplying alternating current voltage approach the desired condition of a harmonic free voltage, and a large amount of technical effort is devoted thereto. However, even with the extensive attention directed to this problem, it frequently occurs, in industrial areas particularly, that the supply voltage has an undesired percentage of harmonics.

In the Patent No. 2,143,745, Joseph G. Sola, entitled "Constant Voltage Transformer," there is disclosed and claimed apparatus including a transformer and a condenser wherein a substantially constant output voltage is obtained throughout a certain range of variation in input voltage. While the output voltage of apparatus constructed according to the said patent has good wave form, that is, one largely free of harmonics, under certain conditions the voltage output has included as much as five (5) per cent of third harmonic.

Filter circuits which are connected between the output of a source and a load and which serve to substantially reduce or eliminate harmonics are known. Such filters generally require the use of additional condensers and inductors and will correct the output voltage only when load current is flowing. Moreover, the correction may depend upon the amount of the load, there being the greatest correction at full load and substantially none at no load.

Accordingly, it is a further object of the invention to provide an improved transformer which will provide a constant output voltage substantially free of harmonics, which does not require additional condensers or inductors, and which will substantially eliminate the harmonics from no load to full load.

It is a further object of the invention to provide an improved transformer of the character indicated which will have improved efficiency in operation and which is economical to manufacture.

In carrying out the invention in one form, a transformer is provided having substantially constant output voltage and a substantially harmonic free output voltage and comprising in combination, a core, a primary winding and a secondary winding on the core, a high reluctance shunt magnetically disposed between the primary

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and secondary windings, a third winding disposed on the core in a position to link with a portion of the leakage flux of the secondary winding and to be substantially free of any linkage with the leakage flux of the primary winding, a condenser which is connected in circuit with the secondary winding and the third winding, the condenser having a value of capacity such that when the transformer is excited with a voltage of predetermined magnitude and frequency a condition of a series resonant nature exists at that frequency, and means for connecting a load circuit to a certain portion of the secondary winding.

For a more complete understanding of the invention, reference should be had to the accompanying drawings in which:

Figure 1 is a sectional view of a transformer core and coils according to one form of the invention, and

Figure 2 is a diagrammatic representation of a system according to the invention and employing the core and coils of Fig. 1.

Referring to Figs. 1 and 2 of the drawing, the invention is shown embodied in regulating apparatus including a core and coil arrangement 10 having input, output, regulating and compensating windings and a condenser 11 connected to certain of these windings, all to be more particularly described.

The core and coil arrangement 10 comprises a core 12 which may be made of laminations stamped in the form shown and made of suitable material such, for example, as 26 gauge transformer "C" steel. The core, as shown, is composed of laminations or layers, each of which consists of two pieces, and when assembled into a stack of desired thickness form an outer piece or shell 13 and a center leg 14. The outer shell includes a pair of end legs 6 and 7 and a pair of side legs 8 and 9. The laminations of center leg 14 may be stamped from the pieces forming the outer shell 13 as part of the same process during which the openings or coil windows 15, 16, 17, 18, 19 and 21 are also formed. A core of the proper thickness is formed by assembling together the required number of outer shell laminations and pressing into the appropriate space the same number of center leg laminations assembled together, as is well understood in this art.

Each lamination of the outer shell 13, as shown, comprises a complete or continuous piece of metal with no joints therein. It will be understood, however, that the same configuration can be made up of individual pieces if so desired. Projecting inwardly from leg 8 between the coil windows 16 and 17 is a member 22 formed of the corresponding parts of the laminations of shell 13, and projecting inwardly from leg 9 between coil windows 15 and 18 is a member 23 also formed of the corresponding parts of the laminations of shell 13. Projecting inwardly between coil windows 17 and 21 is a member 24 formed of parts of the laminations of shell 13, and projecting inwardly between coil windows 18 and 19 is a member 25 also formed of the corresponding parts of the laminations of shell 13. Projecting outwardly from the center leg 14 are members 26 and 27 formed of corresponding parts of the center leg laminations and so disposed as to lie between the coil windows 15 and 18 and 16 and 17 and to be disposed opposite the members 23 and 22, respectively, when the center leg 14 is disposed in shell 13 with the right end thereof forming the joint 28.

The members 22 and 27 are spaced from each other by a nonmagnetic gap 29, and the members 23 and 26 are spaced from each other by a nonmagnetic gap 31. The members 24 and 25 are formed of such a length as to tightly abut the center leg 14 at the joints 32 and 33 and have a cross-sectional area substantially less than that of the end leg 7 of the outer shell 13. The center leg 14 is formed of a length so as to tightly abut the outer shell at joint 28 at one end and to leave a nonmagnetic gap 35 between the other end of the center leg and the inside surface of end leg 7.

Coil windows 15 and 16 comprise a space within which a primary winding 36 and a compensating winding 37 are disposed; coil windows 17 and 18 form a space within which a secondary winding 38 is disposed;

and coil windows 19 and 21 comprise a space within which a neutralizing winding 39 is disposed. Each of the coils or windings 36, 37, 38 and 39 comprise an appropriate number of turns and are provided with sufficient insulation, as is shown schematically in Fig. 1. Each of the coils may be preformed and placed upon the center leg and the unit pressed into the outer shell so as to form the nonmagnetic gap 35 and the abutting joints 28, 32 and 33.

The members 22 and 27 and gap 29, and members 23 and 26 and gap 31, form a high magnetic leakage path between the primary winding 36 and the secondary winding 38. The width of the members 22, 27, 23 and 26, and the length of the nonmagnetic gaps 23 and 31 are chosen so as to provide the desired amount of magnetic leakage reactance, as will become clear subsequently in this specification. While the members 22 and 27 and gap 29, and members 23 and 26 and gap 31, as shown, form a high magnetic leakage pathway, it will be understood that the high magnetic leakage pathway may be formed in other well understood manners.

The members 24 and 25, the end of leg 14 together with the end leg 7 and the nonmagnetic gap 35 complete the end path for magnetic flux generated by the primary winding. Since the joints 32 and 33 are press-fits, there is little magnetic reluctance thereat, and consequently the members 24 and 25 form a return path which carries the major portion of the primary flux. These members, however, are formed narrower than the end leg 7 whereby a small percentage of the primary flux flows through the end leg 7. The nonmagnetic gap 35 produces high reluctance in the path of the primary flux, thereby reducing the amount of flux which would flow through leg 7 if the gap were not there, and increasing the percentage of primary flux which flows through members 24 and 25.

The structure as thus far described in Fig. 1 is illustrated diagrammatically in Fig. 2, the same reference characters being used in the two figures to designate corresponding parts. Thus the windings 36 and 38 are disposed on a common core with a high leakage reactance shunt 22, 27, 29, 23, 26, and 31 disposed therebetween, winding 39 is disposed on the same magnetic core with the nonmagnetic gap 35 separating the core parts, and winding 37 is disposed in a closely coupled relationship to winding 36.

The effect of the high leakage path between primary winding 36 and secondary winding 38 is to relatively loosely couple these windings so that each of the windings has a high leakage reactance, and nonmagnetic gap 35 tends to isolate the winding 39 from the flux of the primary winding.

The primary winding 36 is adapted to be connected to a line or source by conductors 41 and 42. The secondary winding 38 has one of its ends connected by means of a conductor 43 to one terminal of condenser 11, and has its other end connected by means of a conductor 44 to one end of neutralizing winding 39 by a conductor 45. The other end of neutralizing winding 39 is connected by means of a conductor 46 to the other terminal of condenser 11. The conductors 44 and 45 connected together may be connected to one side of a load circuit through a conductor 47, and the other side of the load may be connected through a conductor 48 to one end of a compensating winding 37, the other end of which is connected by means of a conductor 49 to a tap on the secondary winding 38. The load circuit may then be traced as follows: From one side of the load through conductor 47, conductor 44, the right-hand portion of winding 38, conductor 49, winding 37, and conductor 48 to the other side of the load.

The operation of the apparatus may perhaps best be understood by considering its operation in two phases; that is, as a constant voltage apparatus alone, and as the combination of the constant voltage and the harmonic elimination or neutralizing apparatus. Considering first the constant potential aspects of the apparatus, it may be made such in one form by removing, in effect, the neutralizing winding 39. Referring to Fig. 2, this may be accomplished by connecting conductor 46 to conductors 44 and 47 and disconnecting conductor 45 from conductors 44 and 47. When so connected, the apparatus of Figs. 1 and 2 is essentially similar to the form of the apparatus illustrated in the Patent No. 2,143,745, already hereinbefore referred to. When connected in this form as only a constant potential device,

the members 24 and 25, together with leg 7, form a portion of the return circuit for the primary winding flux and provide a return leg having substantially the same effective cross section as the other flux return legs 8 and 9.

For a complete understanding of the operation of the device in this form as a constant voltage transformer, reference may be had to the aforesaid Patent No. 2,143,745. Briefly, however, when voltage above a certain magnitude is applied to the primary winding 36 through conductors 41 and 42, a condition approximating series resonance is set up in the apparatus, and particularly in the circuit including condenser 11 and winding 38. When this condition exists, a substantially constant voltage is obtained across conductors 47 and 49 over a wide range of variations in voltage applied to the primary winding. Such small changes as occur in this voltage may be compensated for by the winding 37 which is closely coupled to winding 36 and which is in such a relation as to buck the voltage existing across conductors 47 and 49. Thus, if the primary voltage rises and the output voltage would tend to rise on account thereof, the compensating winding prevents it. Likewise, if the primary voltage falls and the output voltage tends to fall, the bucking voltage is also reduced and the output voltage remains the same. By proper choice of turns of winding 37, the load voltage, that is, the voltage appearing across conductors 47 and 48, is made substantially constant.

While explanation of the operation of this form of the device as a constant potential apparatus does not lend itself to simple terms, it is thought that the currents flowing in the condenser 11 and winding 38, due to the existing resonance condition, set up a flux condition in the portion of the core underneath and directly associated with the winding 38, due to the presence of the shunts between the primary and secondary windings 36 and 38, such that changes in flux caused by changes in voltage across the primary winding are largely absorbed in the shunts and thus do not change the flux conditions of the secondary winding. The output voltage of the device as a constant voltage transformer has good wave shape, but it does have appreciable percentages of harmonics in it which are eliminated by the presence of the neutralizing winding 39. When the device is operating as a constant voltage apparatus and the winding 39 is present in the core but is not connected to the circuit, the winding 39 will, of course, have a voltage induced into it since a certain percentage of flux will course through the center leg 14 and through the end leg 7. With the core constructed as shown and described, it has been found that the voltage of coil 39 has a high percentage of odd harmonics in it, that is, third, fifth, seventh and ninth, etc. There is also present a certain value of fundamental since the winding 39 is linked by a small percentage of the flux set up by the primary winding. The presence of the odd harmonic voltages in winding 39 is due to the linkage of winding 39 by the leakage flux created by winding 38 when current flows through the condenser 11 and winding 38. This leakage flux, of course, has two pathways to follow, one of these including a portion of the central leg 14, the members 24 and 25, a portion of the legs 8 and 9 of the core, and the shunts 22, 27, 29 and 23, 26, 31. The other pathway includes the portion just described except the members 24 and 25, and further includes the leg 7 and the gap 35. The relative reluctances of these two paths determine the percentage of flux created by winding 38 which links with winding 39, that is, that portion of the secondary leakage flux which flows across gap 35 and through leg 7. The leakage flux of the primary winding 36 flows largely through the shunts 22, 27, 29 and 23, 26, 31 and thus does not link with winding 39.

Consider now the second phase of the device. The winding 39 is connected in circuit with and in additive polarity to winding 38 and with condenser 11 as shown, to form a constant voltage and harmonic free device. When so connected the combined voltage of windings 38 and 39 is increased over the sum of the voltages of these windings prior to such connection. With the connections so made, the percentage of odd harmonics existing in the winding 38 and across the conductors 47 and 49 is very much reduced and a constant voltage output also is had. They are, in fact, reduced to a virtually negligible amplitude. After the connection has been made, as shown in Fig. 2, the harmonic voltage still

exists across winding 39 and also across the condenser 11, but these harmonic voltages are of such phase that they neutralize the harmonics which formerly existed in the winding 38. For example the third harmonic, which exists in winding 39, is induced therein by the leakage flux from winding 38, and this harmonic voltage is approximately 180° out of phase with the third harmonic voltage existing in winding 38.

With winding 39 connected into circuit in additive polarity, there has been, in effect, a number of turns added to the secondary winding, but these turns and the core configuration produce harmonic elimination and do not destroy the constant voltage. The flux in the core remains such that the condition of a series resonant nature still exists and hence substantially constant voltage exists across winding 38. In order to have the proper value of output voltage with the higher voltage available when winding 39 is connected in circuit with winding 38 in additive polarity, the number of turns of winding 38 may be less than in a construction having only constant voltage output of the same value.

The number of turns in winding 39, the cross-sectional area of members 24 and 25, the length of gap 35, and the cross-sectional area of leg 7 enter into the magnitude of the third harmonic voltage produced as compared with the fundamental voltage in winding 39. The fundamental component is not essential since winding 38 may have a sufficient number of turns to produce the necessary value thereof, and it is thought that by coupling the winding 39 to the winding 38, as shown, the necessary third harmonic neutralizing voltage is obtained while at the same time the fundamental voltage is not changed much.

Reduction of the harmonic voltages, and consequently currents in winding 38, reduces the heating of the windings and of the iron thereby making the transformer itself more efficient and economical, this being an advantage in addition to the desirable effects due to the lack of harmonics in loads.

By way of additional and more complete disclosure, one form of apparatus which was constructed and operated may be particularly described. This apparatus had a continuous rating of 500 volt amperes, a rated primary (across conductors 41 and 42) voltage range of 90 to 125 volts, a rated load voltage (across conductors 47 and 48) of 115 volts, and a rated load current of 4.35 amperes. In this apparatus the primary winding 36 had 106 turns of No. 13 copper wire arranged in 10 layers of 11 turns per layer, the winding 37 had 12 turns of No. 14 copper wire arranged in one layer of 12 turns, the secondary winding 38 had 405 turns of No. 15 copper wire arranged in 14 layers of 29 turns each, and the winding 39 had 207 turns of No. 15 copper wire arranged in 23 layers of 9 turns each. That portion of winding 38 lying between conductors 44 and 47, that is, the load portion of the winding, had 290 turns arranged in 10 layers.

The core of the apparatus described was designed to operate at a flux density of 100,000 lines per square inch and consisted of a stack of laminations $3\frac{1}{8}$ inches thick of No. 26 gauge transformer "C" steel. The length of side legs 8 and 9 was $6\frac{5}{16}$ inches and the length of end legs 6 and 7 was 5 inches; the width of end leg 6 and side legs 8 and 9 adjacent windings 36 and 38 was $\frac{7}{8}$ of an inch; the width of side legs 8 and 9 adjacent winding 39 and the width of end leg 7 was $\frac{5}{8}$ of an inch; the width of members 24 and 25 was $\frac{5}{16}$ of an inch; the width of center leg 14 inside of coils 36 and 38 and members 24 and 25 was $1\frac{1}{4}$ inches, and the width of leg 14 inside of coil 39 was $1\frac{3}{16}$ of an inch; the width of shunt members 22, 27, 23 and 26 was $\frac{1}{2}$ of an inch; the length of gaps 29 and 31 was 0.050 of an inch; and the length of gap 35 was 0.150 of an inch. The width of center leg 14 inside of coil 39 may be the same as inside of coil 38 and the number of turns in coil 39 changed to fit the different space of windows 19 and 21.

The condenser 11 had a capacity of 16 microfarads and was rated at 660 volts.

By way of further disclosure, the results of a harmonic analysis on the foregoing apparatus, as described and particularized, may be summarized. The first analysis was made at no load; that is, there was no load connected across conductors 47 and 48. The winding 36 was connected to a sine wave generator supplying 115 volts R. M. S. A harmonic analysis of the sine wave generator voltage indicated that the voltage supplied

to winding 36 had a fundamental component (60 cycles) of arbitrarily assigned amplitude equal to 100 per cent, and a third harmonic of 1.1 per cent of the fundamental, the remaining harmonics being less than one per cent of the fundamental and consequently negligible. With this same connection, the R. M. S. voltage across condenser 11, that is, across combined windings 38 and 39, was 610 volts. The harmonic analysis of this voltage showed on the basis of a fundamental of arbitrarily assigned amplitude equal to 100 per cent, a third harmonic having an amplitude of 7 per cent, and a fifth harmonic having an amplitude of 2 per cent all in terms of the fundamental. The voltage across the winding 39 had an R. M. S. amplitude of 122 volts. The harmonic analysis showed on the basis of a fundamental of arbitrarily assigned amplitude equal to 100 per cent, a third harmonic having an amplitude of 100 per cent, a fifth harmonic having an amplitude of 20 per cent, a seventh harmonic having an amplitude of 4 per cent, and a ninth harmonic having an amplitude of 17 per cent, all in terms of the fundamental. The voltage across winding 38 had an R. M. S. amplitude of 522 volts, the harmonic analysis showing on the basis of a fundamental of arbitrarily assigned amplitude equal to 100 per cent, a third harmonic having an amplitude of 1.1 per cent, a seventh harmonic having an amplitude of 1 per cent, and a ninth harmonic having an amplitude of 1.8 per cent, all in terms of the fundamental. Correspondingly, the voltage across that portion of winding 38 between conductors 44 and 49 (load winding) had an R. M. S. amplitude of 127 volts, the harmonic analysis showing on the basis of a fundamental of arbitrarily assigned amplitude equal to 100 per cent, a third harmonic having an amplitude of .4 per cent, a fifth harmonic having an amplitude of .6 per cent, a seventh harmonic having an amplitude of 1.2 per cent, and a ninth harmonic having an amplitude of 1.6 per cent, all in terms of the fundamental. The output voltage, that is, the voltage across conductors 47 and 48, had an R. M. S. value of 114 volts with the harmonic analysis showing on the basis of an arbitrarily assigned fundamental component having an amplitude equal to 100 per cent, a third harmonic having an amplitude of .4 per cent, a fifth harmonic having an amplitude of .7 per cent, a seventh harmonic having an amplitude of 1.3 per cent, and a ninth harmonic having an amplitude of 1.7 per cent, all in terms of the fundamental.

The percentage of harmonics at the load conductors 47 and 48 is of the same general order as that of the applied voltage, the third harmonic being an improvement and some of the higher harmonics being very slightly increased.

In the apparatus as described and for the harmonic values given, when the conductor 46 was connected to the conductor 44, that is, the winding 39 was removed from the circuit as previously described, and the same sine wave generator was connected to the winding 36, the voltage across winding 36 had an R. M. S. amplitude of 115 volts. A harmonic analysis thereof showed on the basis of a 60 cycle or fundamental component arbitrarily assigned an amplitude of 100 per cent, a third harmonic having an amplitude of .8 per cent, a fifth harmonic having an amplitude of .4 per cent, and a seventh harmonic having an amplitude of .3 per cent, all in terms of the fundamental. The voltage across condenser 11 or across winding 38 had an R. M. S. amplitude of 467 volts, the harmonic analysis showing on the basis of a fundamental component of 100 per cent, a third harmonic having an amplitude of 23 per cent, and a fifth harmonic having an amplitude of 6 per cent, all in terms of the fundamental. The portion of winding 38 forming the load winding, that is, the winding connected across conductors 47 and 49, had an R. M. S. amplitude of 113 volts, the harmonic analysis showing on the basis of a fundamental component arbitrarily assigned an amplitude of 100 per cent, a third harmonic having an amplitude of 23 per cent, and a fifth harmonic having an amplitude of 6 per cent, all in terms of the fundamental. Under these conditions, the output voltage, that is, across conductors 47 and 48, had an R. M. S. amplitude of 100 volts, the harmonic analysis showing on the basis of a fundamental component arbitrarily assigned an amplitude of 100 per cent, a third harmonic having an amplitude of 27 per cent, a fifth harmonic having an amplitude of 7 per cent, and a seventh harmonic having an amplitude of one per cent, all in terms of the fundamental. The voltage across winding 39 had an R. M. S. amplitude of 73 volts, a harmonic

analysis showing on the basis of a fundamental component arbitrarily assigned an amplitude of 100 per cent, a third harmonic having an amplitude of 100 per cent, a fifth harmonic having an amplitude of 78 per cent, a seventh harmonic having an amplitude of 13 per cent, and a ninth harmonic having an amplitude of 6 per cent, all in terms of the fundamental.

A comparison of the relative harmonic values across conductors 47 and 48 with the condenser connected to include the winding 39 and to exclude it, reveals the reduction in the harmonic content of the output voltage.

A similar harmonic analysis was made with the apparatus operating at full load with the sine wave source as already described providing 115 volts across the primary winding 36. With the condenser 11 connected as shown in Fig. 2, the output voltage across conductors 47 and 48 had an R. M. S. amplitude of 112 volts, the harmonic analysis showing on the basis of a 60 cycle or fundamental component arbitrarily assigned an amplitude of 100 per cent, a third harmonic having an amplitude of 1.1 per cent, a fifth harmonic having an amplitude of .4 per cent, a seventh harmonic having an amplitude of 1.6 per cent, and a ninth harmonic having an amplitude of 1.2 per cent. These harmonic values are not substantially different from those taken at no load. Under the full load condition described, the voltage across winding 39 had an R. M. S. amplitude of 111 volts, the harmonic analysis showing on the basis of a fundamental component arbitrarily assigned an amplitude of 100 per cent, a third harmonic having an amplitude of 98 per cent, a fifth harmonic having an amplitude of 16 per cent, a seventh harmonic having an amplitude of 11 per cent, and a ninth harmonic having an amplitude of 11 per cent, all in terms of the fundamental. The voltage across condenser 11 had an R. M. S. value of 593 volts with the harmonic analysis showing on the basis of a fundamental component arbitrarily assigned an amplitude of 100 per cent, a third harmonic having an amplitude of 13 per cent, a fifth harmonic having an amplitude of 1.5 per cent, a seventh harmonic having an amplitude of .2 per cent, and a ninth harmonic having an amplitude of .1 per cent, all in terms of the fundamental. The voltage across winding 38 had an R. M. S. amplitude of 512 volts, the harmonic analysis showing a fundamental component arbitrarily assigned an amplitude of 100 per cent, a third harmonic having an amplitude of 1.7 per cent, a fifth harmonic having an amplitude of zero per cent, a seventh harmonic having an amplitude of 1.4 per cent, and a ninth harmonic having an amplitude of 1.2 per cent.

With full load being supplied by the transformer, and with the condenser 11 connected so as to remove winding 39 from the circuit, that is, conductor 46 connected to conductor 44, the output voltage across conductors 47 and 48 had an R. M. S. amplitude of 97 volts, the harmonic analysis showing on the basis of a fundamental component arbitrarily assigned an amplitude of 100 per cent, a third harmonic having an amplitude of 23 per cent, a fifth harmonic having an amplitude of 6 per cent, and a seventh harmonic having an amplitude of .7 per cent. The voltage of winding 38 or condenser 11 had an R. M. S. amplitude of 452 volts, the harmonic analysis showing a fundamental component arbitrarily assigned an amplitude of 100 per cent, a third harmonic having an amplitude of 20 per cent, a fifth harmonic having an amplitude of 5 per cent, and a seventh harmonic having an amplitude of .4 per cent. Comparing the relative harmonic value between the full load condition wherein the neutralizing winding 39 is connected into and out of the circuit, reveals that the harmonic content is very much reduced by the presence of winding 39 in the core structure defined.

The loads fed by the transformer in the preceding tests were resistance loads.

The structure as shown in Fig. 2 and having the harmonic analysis as given, was connected to a regular power source of 60 cycles but with R. M. S. amplitudes of 100, 115 and 130 volts. Under this condition of voltage of winding 36, the voltage across conductors 47 and 48 had an R. M. S. value of 109.5.

While particular embodiments of the invention have been shown, it will be understood, of course, that the invention is not limited thereto since many modifications may be made, and it is, therefore, contemplated by the appended claims to cover any such modifications as fall within the true spirit and scope of the invention.

The invention having thus been described, what is claimed and desired to be secured by Letters Patent is:

1. A transformer having substantially constant output voltage and a substantially harmonic free output voltage comprising, a core, a primary winding and a secondary winding on said core, a high reluctance shunt magnetically disposed between said windings, a condenser having a value of capacity such that when connected across said secondary winding and the transformer is excited with a voltage of predetermined magnitude and frequency a condition of a series resonant nature exists at the said frequency, a third winding disposed on said core in a position to link with a portion of the leakage flux of said secondary winding and to be substantially free of any linkage with the leakage flux of said primary winding, said secondary winding, said third winding and said condenser being connected in circuit, and means for connecting a load circuit to at least a certain portion of said secondary winding.

2. A transformer having substantially constant output voltage and a substantially harmonic free output voltage comprising, a core, a primary winding and a secondary winding on said core, a high reluctance shunt magnetically disposed between said windings, a condenser having a value of capacity such that when connected across said secondary winding and the transformer is excited with a voltage of predetermined magnitude and frequency a condition of a series resonant nature exists at the said frequency, a third winding disposed on said core in a position to link with a portion of the leakage flux of said secondary winding and to be substantially free of any linkage with the leakage flux of said primary winding, said secondary winding, said third winding and said condenser being connected in circuit with said third winding in additive polarity to said secondary winding, a compensating winding disposed on said core in close coupled relationship with said primary winding and connected in bucking relationship to said secondary winding, and means for connecting a load circuit to at least a certain portion of said secondary winding and to said compensating winding.

3. A transformer having substantially constant output voltage and a substantially harmonic free output voltage comprising, a core, a primary winding and a secondary winding on said core, a high reluctance shunt magnetically disposed between said windings, a condenser having a value of capacity such that when connected across said secondary winding and the transformer is excited with a voltage of predetermined magnitude and frequency a condition of a series resonant nature exists at the said frequency, a harmonic eliminating winding disposed on said core in a position to link with a portion of the leakage flux of said secondary winding and to be substantially free of any linkage with the leakage flux of said primary winding, said secondary winding, said harmonic eliminating winding and said condenser being connected in circuit, and means for connecting a load circuit to at least a certain portion of said secondary winding.

4. A transformer having substantially constant output voltage and a substantially harmonic free output voltage comprising, a core, a primary winding and a secondary winding on said core, a high reluctance shunt magnetically disposed between said windings, a condenser having a value of capacity such that when connected across said secondary winding and the transformer is excited with a voltage of predetermined magnitude and frequency a condition of a series resonant nature exists at the said frequency, a third winding disposed on said core in a position to link with a portion of the leakage flux of said secondary winding and to be substantially free of any linkage with the leakage flux of said primary winding, said secondary winding, said third winding and said condenser being connected in a series circuit with said third winding in additive polarity relative to said secondary winding, and means for connecting a load circuit to at least a certain portion of said secondary winding.

5. A transformer having substantially constant output voltage and a substantially harmonic free output voltage comprising, a core, a primary winding and a secondary winding on said core, a high reluctance shunt magnetically disposed between said windings, a condenser having a value of capacity such that when connected across said secondary winding and the transformer is

6. A transformer having substantially constant output voltage and a substantially harmonic free output voltage comprising, a core, a primary winding and a secondary winding on said core, a high reluctance shunt magnetically disposed between said windings, a condenser having a value of capacity such that when connected across said secondary winding and the transformer is excited with a voltage of predetermined magnitude and frequency a condition of a series resonant nature exists at the said frequency, a third winding on said core, a low reluctance shunt magnetically disposed between said third winding and said primary and secondary windings, and high reluctance means disposed in the flux path of said third winding, said secondary winding, said third winding and said condenser being connected in circuit, and means for connecting a load circuit to at least a certain portion of said secondary winding.

8. A transformer having substantially constant output voltage and a substantially harmonic free output voltage comprising, a core, a primary winding disposed on one leg of said core, a secondary winding disposed on said one leg, said primary and secondary windings being relatively loosely coupled thereby to provide said windings with high leakage reactance, a condenser having a value of capacity such that when connected across said secondary winding and the transformer is excited with a voltage of predetermined magnitude and frequency a condition of a series resonant nature exists at the said frequency, a third winding on said one leg, a low reluctance shunt disposed between said third winding and said secondary winding, high reluctance means in said one leg beyond said shunt, and means for connecting a load circuit to at least a certain portion of said secondary winding.

10. A transformer having substantially constant output voltage and a substantially harmonic free output voltage comprising, a core, a primary winding and a secondary winding on said core, a high reluctance shunt

15 11. A transformer having substantially constant output voltage and a substantially harmonic free output voltage comprising, a core, a primary winding and a secondary winding on said core, a high reluctance shunt magnetically disposed between said windings, a third winding disposed on said core in a position to link with a portion
20 of the leakage flux of said secondary winding and to be substantially free of any linkage with the leakage flux of said primary winding, a condenser, said third winding in additive polarity to said secondary winding and said condenser being connected in circuit with said secondary
25 winding, said condenser having a value of capacity such that when the transformer is excited with a voltage of predetermined magnitude and frequency a condition of a series resonant nature exists at the said frequency, and means for connecting a load circuit to at least a certain
30 portion of said secondary winding.

13. A transformer having substantially constant output voltage and a substantially harmonic free output voltage comprising, a core, a primary winding and a secondary winding on said core, said primary and secondary windings being relatively loosely coupled thereby to provide said windings with high leakage reactance, a condenser having a value of capacity such that when connected across said secondary winding and the transformer is excited with a voltage of predetermined magnitude and frequency a condition of a series resonant nature exists at the said frequency, a third winding disposed on said core in a position to link with a portion of the leakage flux of said secondary winding and to be substantially free of any linkage with the leakage flux of said primary winding, said secondary winding, said third winding and said condenser being connected in circuit with said third winding in additive polarity to said secondary winding, and means for connecting a load circuit to at least a certain portion of said secondary winding.

14. A transformer having substantially constant output voltage and a substantially harmonic free output voltage comprising, a core, a primary winding and a secondary winding on said core, said primary and secondary windings being relatively loosely coupled thereby to provide said windings with high leakage reactance, a condenser having a value of capacity such that when connected across said secondary winding and the transformer is excited with a voltage of predetermined magnitude and frequency a condition of a series resonant nature exists at the said frequency, a third winding disposed on said core in a position to link with a portion of the leakage flux of said secondary winding and to be substantially free of any linkage with the leakage flux of said primary winding, said secondary winding, said third winding and said condenser being connected in circuit with said third winding in additive polarity to

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said secondary winding, a compensating winding disposed on said core in close coupled relationship with said primary winding and connected in bucking relationship to said secondary winding, and means for connecting a load circuit to at least a certain portion of said secondary winding and to said compensating winding.

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