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[54] MODULATED OUTPUT TRANSFORMERS

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[52] **U.S. Cl.** **307/17,** 323/48, 323/50, 323/51, 336/130, 336/184
[51] **Int. Cl.** **G05f 3/04**
[58] **Field of Search** .....307/17, 30; 323/44 R, 48, 50, 323/51; 336/130, 170, 184

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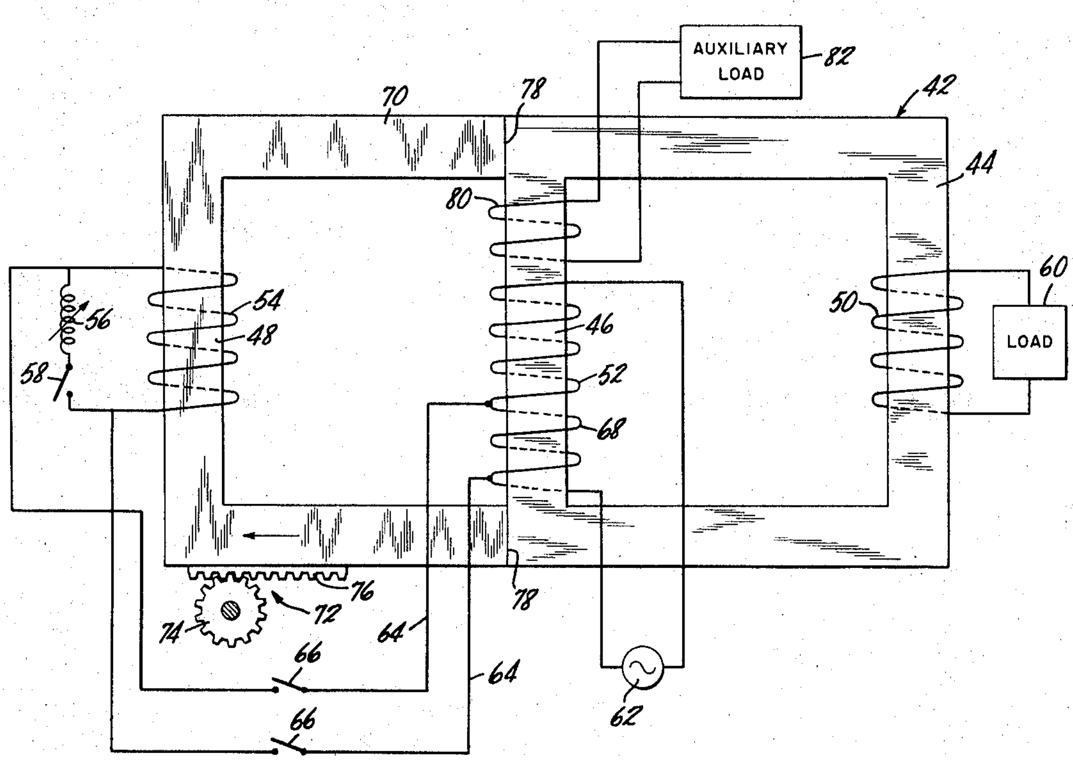
[57] **ABSTRACT**

A transformer core has three legs. A variable output secondary winding encircles one leg, and a primary winding encircles another. The voltage across the variable output secondary winding is controlled by varying the amount of leakage flux passing through the third leg. This can be accomplished by providing a separately formed core piece that is movable to vary its area of contact with the third leg. Alternatively, a control winding can be provided which encircles the third leg. The current induced in the control winding, which is modulated by a variable control impedance connected across it, produces a flux that, in proportion to its strength, opposes the primary winding flux, thereby increasing the amount of flux that passes through the secondary winding. A fixed output voltage can be obtained from an additional secondary winding that encircles the same leg as the primary winding.

8 Claims, 2 Drawing Figures



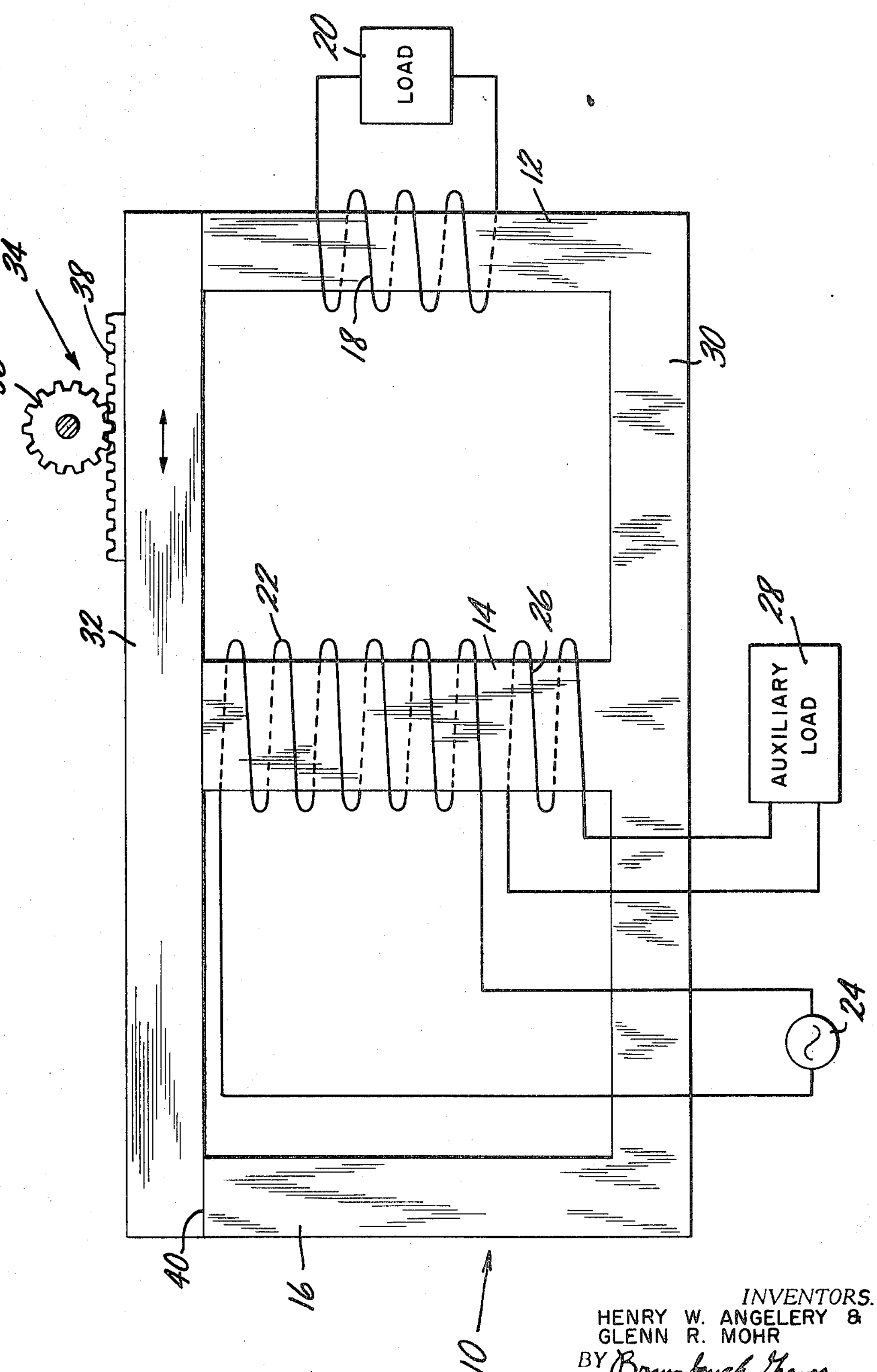


FIG. 1

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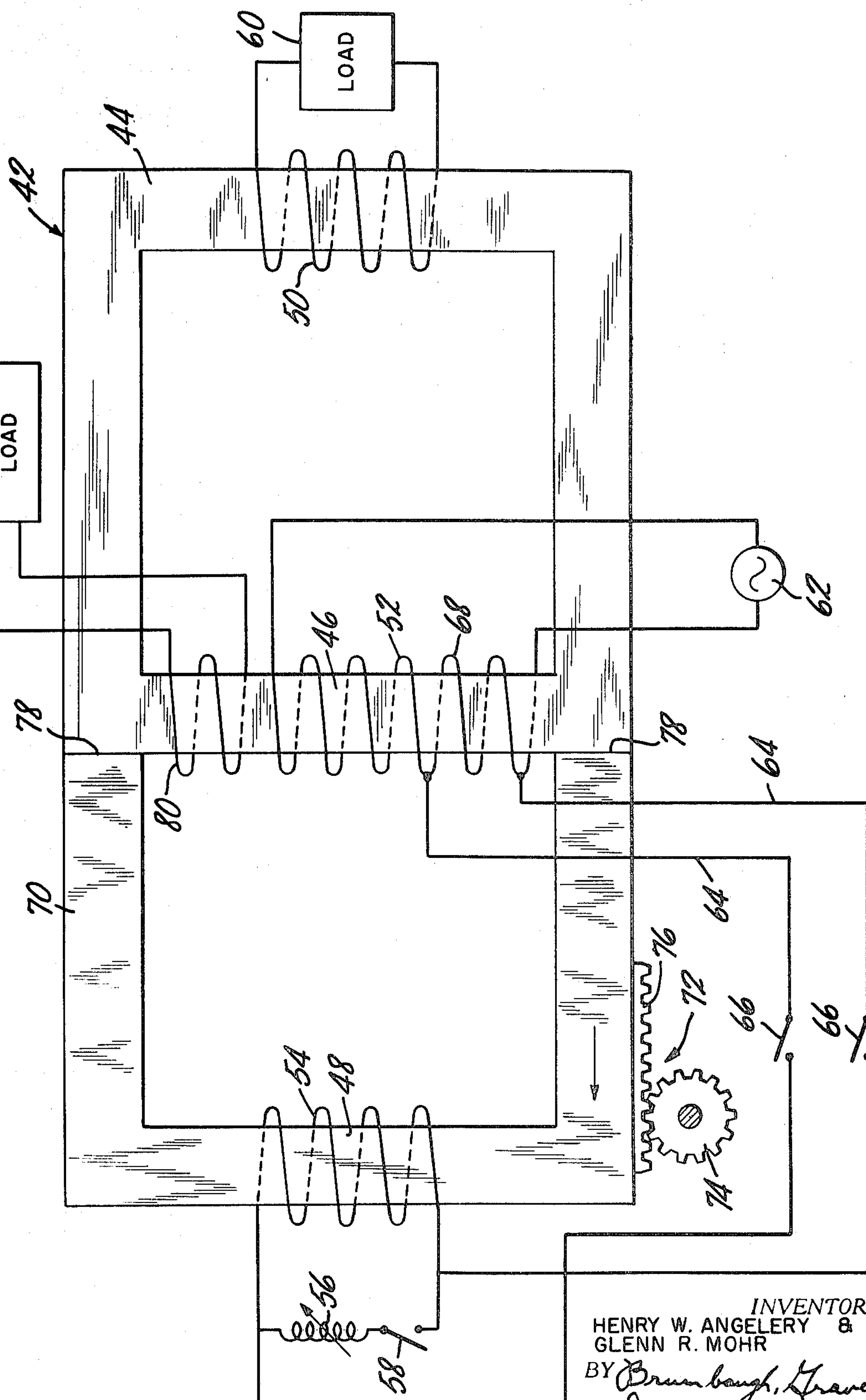

FIG. 2

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MODULATED OUTPUT TRANSFORMERS

BACKGROUND OF THE INVENTION

This invention relates to transformers, and, more particularly, to transformers having a variable output voltage.

Conventional transformers employ a primary winding to which power is supplied and a secondary winding from which power is withdrawn. The core, which is made of a high permeability material such as iron or steel, provides a path for the flux produced when an alternating current flows through the primary winding. A portion of this primary winding flux passes through the leg on which the secondary coil is wound. This causes an output voltage to appear across the secondary winding. Flux produced by the primary winding that does not link the turns of the secondary winding, whether because of the intentional provision of a path for this flux or because of the unavoidable flow of some flux through unintended paths, is called leakage flux. It is a fundamental precept of conventional transformer design that the output voltage of the secondary winding is equal to the number of turns of the secondary winding, divided by the number of turns of the primary winding, multiplied by the fraction of primary winding flux that links the secondary winding, minus other losses that occur within the transformer. If a constant power supply voltage applied to the primary winding is assumed, the output voltage at the secondary winding is then fixed as an invariable function of the construction of a particular transformer.

Conventional step-down transformers are usually employed to reduce the voltage entering an industrial facility from the high level of the long distance power transmission lines to a lower level that is consistent with safety requirements and the design parameters of individual pieces of equipment. Shell-type transformers having a core including three legs arranged in a row and joined together at both ends are frequently used for this purpose.

It is most desirable and economical to vary the voltage supplied to some common equipment, e.g., water heaters, in inverse proportion to the coincident power demands of other equipment, thereby tending to stabilize the total power demand of the facility and increase its load factor. Separate units are, therefore, employed in combination with step-down transformers to vary the voltage over a desired range. These units are often expensive and inefficient. They sometimes produce highly undesirable transient conditions while changing their output voltage. A transformer capable of supplying a variable output voltage at its secondary winding would eliminate the need for additional equipment to provide a variable output. It would be further desirable if this transformer were capable of varying its output without producing substantial transients. Such transformers would also be useful as, for example, switching devices because transients are a major problem in that environment.

SUMMARY OF THE INVENTION

This invention is a transformer that has a variable output and does not produce substantial transients as the output is varied. It comprises a core including first, second, and third legs arranged parallel to each other in a row. A variable output secondary winding encircles the first leg, and a primary winding encircles the second leg. A modulating means is provided for varying the amount of leakage flux passing through the third leg, whereby the amount of flux linking the turns of the secondary winding can be varied. This provides a variable output. A fixed output is supplied by an additional secondary winding that encircles the second leg.

In one embodiment of the invention, the amount of leakage flux passing through the third leg is controlled by the position of a separately formed core piece. A means for moving this core piece is provided to vary the area of contact between the movable piece and the third leg.

In another embodiment, a control winding encircles the third leg. A variable control impedance is connected across the control winding. The current induced in the control winding excites the leg which it encircles to produce a flux which opposes the primary winding flux in that leg. As the control impedance decreases, this current increases causing more opposition to the primary winding flux. As the opposition to the flux increases, a larger portion of the primary winding flux flows through the first leg, thereby increasing the output at the secondary winding.

The opposition to the passage of leakage flux through the third leg can be further increased by connecting the control winding in parallel with a portion of the primary winding or by making part of the core movable to interpose at least one non-magnetic gap in its path.

The first, second, and third legs can be arranged in any order, but in the preferred embodiments the second leg, which is encircled by the primary winding, is centrally disposed.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the invention, reference may be had to the following detailed description of the preferred embodiments taken in conjunction with the accompanying drawings wherein:

FIG. 1 shows a variable output transformer constructed in accordance with the invention; and

FIG. 2 shows another variable output transformer also constructed in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows a transformer including a core **10** having a first leg **12** disposed along one side, a centrally disposed second leg **14**, and a third leg **16** disposed along the other side. A variable output secondary winding **18** encircles the first leg **12** and is connected to a load **20**. A primary winding **22** encircles the second leg **14** and is connected to an alternating current power supply **24**. A fixed output secondary winding **26** encircles the second leg **14**, along with the primary winding **22**, and is connected to an auxiliary load **28**. The word winding is used here instead of the word coil because the primary winding **22** and the fixed output secondary winding **26** could be part of the same coil as in an autotransformer. This arrangement would, nevertheless, be considered to include two windings as that term is used here.

The core **10** also includes a stationary cross piece **30** that is integrally formed with the legs **12**, **14**, and **16** and connects them together at one end. It further includes a separately formed cross piece **32** disposed along the opposite ends of the legs **12**, **14**, and **16**.

A means **34** for moving the separate cross piece **32** consists of a rotatable gear **36** and a rack **38** attached to the cross piece **32**. By moving the separate cross piece **32**, it is possible to vary the area of contact **40** between the cross piece **32** and the third leg **16**. In this way the amount of leakage flux that passes through the third leg **16** can be varied.

The total flux produced when the second leg **14** is excited by the primary winding **22** must be divided between the two available flux paths: the first leg **12** and the third leg **16**. As the size of the contact area **40** is decreased, the reluctance of the path through the third leg **16** is increased and a larger amount of flux will, therefore, flow through the variable output secondary winding **18**, thus increasing the variable output voltage. All of the flux produced by the primary winding **22** links the turns of the fixed output secondary winding **26** regardless of the position of the movable cross piece **32**.

The transformer of FIG. **1**, when connected to a constant voltage power supply **24**, provides a variable output at the secondary winding **18** and a fixed output at the secondary winding **26**. The load **20** which receives the variable output may be, for example, an electric water heater which can conveniently consume power when it is most economically available. The auxiliary load **28** may be, for example, electric lights which must receive a substantially constant voltage to operate effectively.

Another transformer constructed in accordance with the invention is shown in FIG. **2**. It has a core **42** which includes a first leg **44**, a centrally disposed second leg **46**, and a third leg **48** arranged parallel to each other in a row. A variable output secondary winding **50** encircles the first leg **44**, a primary winding **52** encircles the second leg **46**, and a control winding **54** encircles the third leg **48**. A variable control impedance **56** is connected across the control winding **54**. A switch **58** is provided by which the control winding **54** can be open circuited. The variable output secondary winding **50** is connected to a load **60** which is adapted to consume power when it is most economically available. The primary winding **52** is connected to a constant voltage alternating-current power supply **62**.

The direction of the windings **52** and **54** is such that the flux produced by the primary winding **52** induces a current in the control winding **54** which in turn induces flux in the third leg **48** that opposes the primary winding flux. Opposition to the primary winding flux in the third leg **48** causes a larger portion of this flux to pass through the first leg **44**, and, as the amount of flux in the first leg **44** increases, the voltage across the variable output secondary coil **50** increases. Thus, the output of the secondary winding **50** can be controlled by adjusting the control impedance **56**, thereby varying the strength of the current flowing in the control winding **54**. The variable control impedance **56** may be a resistor, an inductor, or a combination of a resistor and an inductor. Preferably, it consists of a coil and a high permeability core which is arranged to be movable into and out of the coil to vary the impedance.

As long as the value of the control impedance **56** is above zero, some flux will pass through the third leg **48**. This can be avoided by connecting the control winding **54** across a voltage that will produce a flux in opposition to the primary winding flux. Therefore, two leads **64** and a pair of switches **66** are arranged to selectively, upon closing the switches **66**, apply an appropriate voltage to the control winding **54**. This voltage is taken from a winding that encircles the second leg **46** which may be portion **68** of the primary winding **52** to which the leads **64** are connected.

To further provide for the attenuation of the flow of primary winding flux in the third leg **48**, the core **42** incorporates a movable core piece **70** which includes the third leg **48**. A means **72** for moving the core piece **70** includes a rotatable gear **74** and a rack **76** attached to the core piece **70**. By rotating the gear **74**, the core piece **70** can be moved away from the remainder of the core **42**, thereby interposing non-magnetic gaps in the path of primary winding flux passing through the third leg **48**. When the core piece **70** is moved away, these gaps occur at a pair of locations **78** where the U-shaped core piece **70** abuts against the remainder of the core **42**. By moving the core piece **70** a sufficient distance from the remainder of the core **42**, the primary winding flux in the third leg **48** can be reduced almost to zero. Transients can be substantially eliminated when the core piece **70** is moved away, by first closing the switches **66** to minimize the primary winding flux in the third leg **48**. This feature is particularly important when the transformer is used as a switching device.

The transformer of FIG. **2**, like the transformer of FIG. **1**, is capable of providing a fixed output in addition to the variable output of the secondary winding **50**. A fixed output secondary winding **80** encircles the second leg **46** along with the primary winding **52** and is connected to an auxiliary load **82** that requires a fixed voltage power supply. The fixed output secondary winding **80** and the primary winding **52** could be part of the same coil as in an autotransformer.

An advantage of the transformers of FIGS. **1** and **2** is that they do not rely on saturation to control the flow of flux or to modulate the output voltage. The cores **10** and **42** can be dimensioned so that the voltage applied to the primary winding does not produce saturation at any point. Therefore, the waveform at the variable output secondary winding corresponds to the waveform applied to the primary winding. This is advantageous in many transformer applications.

The embodiments described above are intended to be illustrative of the invention, and many variations and modifications will occur to those skilled in the art. The scope of the invention is intended to be defined not by the preferred embodiments described above but only by the appended claims.

We claim:

1. A transformer having fixed and variable outputs comprising a core including three interconnected legs, a variable output secondary winding encircling the first leg, a primary winding encircling the second leg, a fixed output secondary winding encircling the second leg, a control winding encircling the third leg, a variable control impedance connected across the control coil, the direction of each winding being such that the flux produced in the third leg by the control winding op-

poses the primary winding flux, whereby the voltage induced in the variable output secondary winding varies in accordance with the control impedance value selected and a set of leads and at least one switch arranged to selectively connect the control winding in parallel with a winding that encircles the second leg to produce additional flux in the third leg which opposes the flux produced by the primary winding.

2. The transformer of claim **1** wherein the control impedance is a variable inductor.

3. The transformer of claim **1** wherein a portion of the core is movable to interpose at least one non-magnetic gap in the path of the leakage flux passing through the third leg and increasing the flux passing through the first leg.

4. The transformer of claim **1** wherein the core is dimensioned so that it does not become saturated at any point by the voltage applied to the primary coil.

5. A variable output transformer comprising a core including three legs, a secondary winding encircling the first leg, a primary winding encircling the second leg, a control winding encircling the third leg, a variable control impedance connected across the control winding, and a set of leads and at least one switch arranged to connect the control winding to a winding that encircles the second leg, the direction of the windings and the arrangement of the leads being such that the primary winding flux and the voltage applied by the leads both contribute to a current flow in the control winding that produces a flux in opposition to the primary winding flux in the third leg.

6. The transformer of claim **5** wherein the winding that the leads are connected to is a portion of the primary winding.

7. A variable output transformer comprising a core including three legs, a secondary winding encircling the first leg, a primary winding encircling the second leg, a control winding encircling the third leg, the direction of the windings being such that the current induced in the control winding produces a flux which opposes the flow of primary winding flux in the third leg, a variable control impedance connected across the control winding whereby the current flowing therethrough can be varied, a movable core piece, a means for moving the movable core piece whereby at least one non-magnetic gap can be interposed in the path of primary winding flux passing through the third leg to further attenuate its flow and a set of leads and at least one switch arranged to selectively connect the control winding in parallel with a winding that encircles the second leg to produce additional flux in the third leg which opposes the flux produced by the primary winding.

8. The transformer of claim **7** wherein the movable core piece includes the third leg.

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