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MEANS FOR SEPARATELY CONTROLLING THE FILAMENT CURRENT AND VOLTAGE ON AN X-RAY TUBE

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Fig. 1.

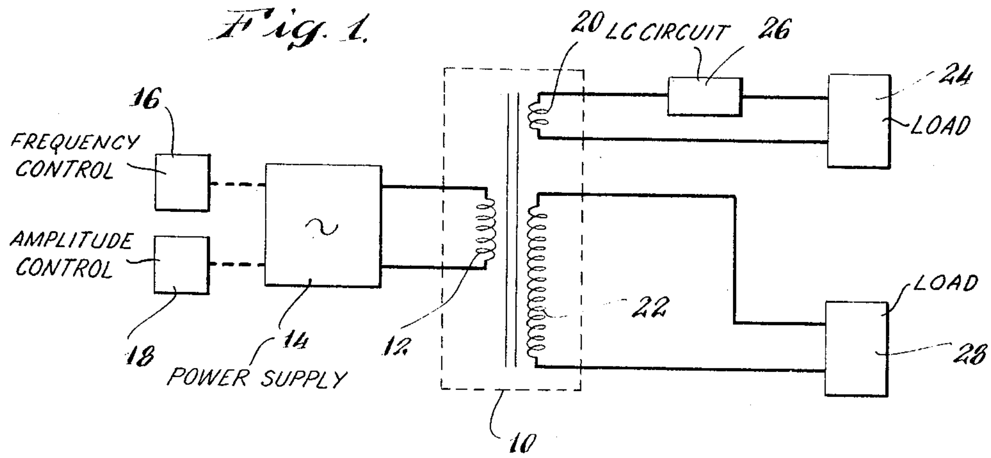
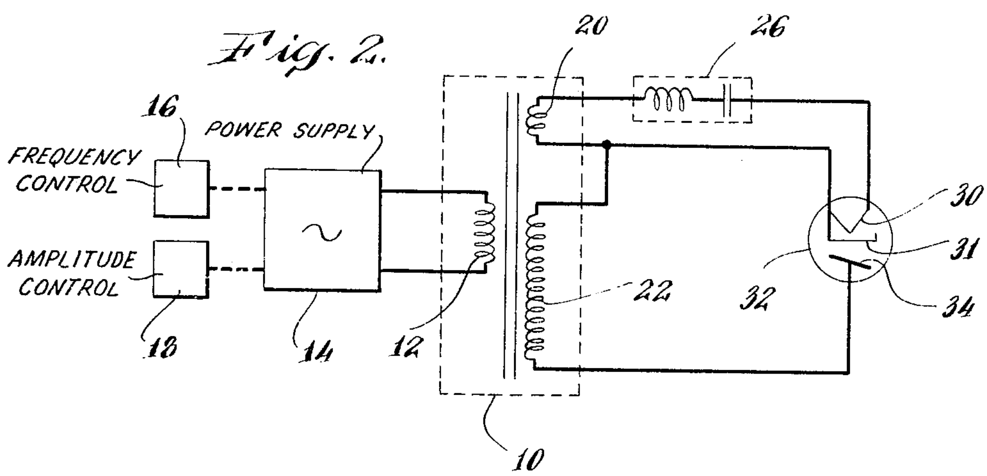


Fig. 2.



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MEANS FOR SEPARATELY CONTROLLING THE FILAMENT CURRENT AND VOLTAGE ON AN X-RAY TUBE

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Continuation of application Ser. No. 263,043, Mar. 5, 1963. This application Feb. 23, 1965, Ser. No. 434,529
17 Claims. (Cl. 250—103)

The present invention relates to apparatus for separately controlling the output voltage amplitudes of plural secondary windings from a common primary winding of a single transformer, and more particularly to means for energizing the cathode and the anode of an X-ray tube from a single transformer while permitting separate control over the current in the cathode and the voltage on the anode.

This application is a continuation of co-pending application Serial Number 263,043, Circuit for Controlling Voltages to a Plurality of Loads, filed March 5, 1963 in the name of James F. McNulty, now abandoned, and assigned of record to Automation Industries, Inc.

It is often necessary or desirable to separately control a plurality of voltages supplying a single apparatus. One example of such an apparatus is the standard X-ray tube. The relatively low filament voltage is controlled so as to control the temperature of the filament and therefore the magnitude of the current reaching the anode. The magnitude of the high voltage between the anode and the cathode determines the amount of acceleration of the free electrons toward the anode whereby the energy or wave length of the X-rays is determined. It is highly desirable that these two voltages be controlled separately and independently of each other.

Extremely high voltages are employed in X-ray tubes, particularly on the anode. Accordingly, heretofore it has been customary to employ a first or separate filament heating transformer which is specially insulated to withstand high voltages together with a second separate high voltage transformer for the anode. The voltages in these two transformers are then separately controlled. This arrangement necessitates two separate transformers and results in a large, bulky and heavy X-ray assembly.

Furthermore, because of the dangers to human life, heretofore high voltage insulation has been provided for most of the controls serving the X-ray tube. These requirements further increased the size and weight of the X-ray apparatus. In addition, the amount of electrical capacitance in the system has been increased. Similar problems occur with respect to magnetrons, amplitrons, klystrons, traveling wave tubes, and other anode grounded tubes.

One of the primary objects of this invention is to provide new and improved apparatus for simultaneously and independently controlling a plurality of voltage outputs.

Another important object is to provide such apparatus wherein a reduction in the number of circuit elements is obtained; wherein the control elements are electrically isolated from high voltage regions; wherein reductions in system cost and weight are achieved; and wherein system capacitance is reduced.

It is also an object of this invention to provide a control system for an X-ray apparatus wherein the cathode or filament and the anode are both energized from a single set-up transformer whereby the size and weight of the X-ray apparatus is greatly reduced.

In the limited number of embodiments disclosed herein the foregoing objects are accomplished by means of a transformer having a primary winding energized from a common power source which is variable in both frequency and voltage amplitude. The transformer includes a plurality of secondary windings that are separately coupled to their respective loads. At least one frequency responsive impedance is coupled to at least one of the secondary windings and its respective load. As the frequency of the power supply varies, the impedance varies and the division of power between the two loads varies.

These and other features and advantages of the present invention will become readily apparent from the following description of a limited number of embodiments thereof, particularly when taken in connection with the accompanying drawings wherein like reference numerals refer to like parts and wherein:

FIG. 1 is a schematic diagram illustrating a circuit embodying one form of this invention; and

FIG. 2 is a schematic diagram of an X-ray apparatus and control system therefore embodying another form of the present invention.

Referring to the drawings in more detail and particularly to FIG. 1, there is illustrated a transformer **10** having a primary winding **12** supplied from a power source **14** of variable frequency and amplitude. The frequency and amplitude of the output of power supply **14** are separately controlled by any of the means known to the prior art through a frequency control **16** and an amplitude control **18**.

The transformer **10** includes a plurality of secondary windings. The secondary windings are coupled to the primary winding by a single common iron core **15**. Although the secondaries may be of the same voltages the first secondary winding **20** provides a relatively low voltage while the other secondary winding **22** provides a high voltage.

The first secondary winding **20** is coupled to a first load **24** so as to supply the power thereto. The secondary winding **22** is coupled to a second load **28** so as to supply the power thereto independently of the first load.

At least one of the couplings between the load and its secondary includes a frequency responsive impedance **26**. The magnitude of this impedance **26** is effective to vary as the frequency of the power flowing therethrough varies. The impedance **26** may be coupled to either or both of the loads **24** and **28**. However, in the present instance, it is connected in series with the load **24**.

The impedance **26** may be of any desired variety; however, in the present instance it is a so-called LC tuned circuit. Such a circuit includes an inductance and a capacitance tuned to resonate at a particular frequency. As the frequency approaches the tuned resonant frequency the impedance rapidly decreases toward zero.

A further embodiment of this invention is illustrated in FIG. 2, wherein elements corresponding to those shown in FIG. 1 are given similar reference numerals. In the embodiment of FIG. 2, the invention is particularly adapted to control of an X-ray tube. The frequency responsive impedance **26** is connected in series with transformer secondary **20** to supply the voltage across filament **20** of X-ray tube **32**. In this embodiment the impedance is shown as including an inductance **25** and a capacitance **27**. The load supplied by the secondary winding **22** of transformer **10** is the high voltage load between the cathode **31** and the anode **34**.

To illustrate the operation of this invention, the tuned circuit **26** is shown as a series resonant circuit. It is, of course, readily apparent that any frequency responsive circuit such as a filter network may be employed.

It is desirable for the impedance **26** to have as high a Q as practical in the given application. The circuit is tuned for resonance at or near one end of the frequency range of the power source **14**. This will produce large changes in impedance with very small changes in frequency whereby a relatively narrow bandwidth may be employed.

At the resonance frequency, the tuned circuit 26 presents essentially no voltage drop in the filament voltage circuit. Accordingly, the full voltage developed across transformer secondary 20 is applied to the filament 30 of the X-ray tube 32 or to the load 24 illustrated in FIG. 1.

If the frequency of power source 14 is maintained at a constant frequency such as near resonance, the amplitude of its output voltage may be varied to control both secondary voltages in accordance with the turns ratio of the transformer 10. On the other hand, if the output voltage amplitude of the power source remains constant, a slight frequency shift will result in more and more of the output voltage of secondary 20 being developed across the tuned circuit 26 and a correspondingly smaller amount be applied across the filament 30 or the load 24. The frequency variation, however, has essentially no effect upon the output voltage of secondary winding 22.

The frequency control 16 and the amplitude control 18 of the power source 14 may be either separately adjustable or mechanically interconnected to track in a predetermined manner.

For example, proper frequency control can result in maintenance of a fixed secondary load voltage at load 24 even though the voltage amplitude is varying and thereby changing the voltage applied to load 28. This may be particularly desirable in the embodiment of FIG. 2 as it allows variation of the tube control voltage while maintaining a fixed filament supply. This control may also be accomplished automatically by varying the frequency of power source 14 by a feedback signal proportional to the output voltage amplitude of the power source or either of the secondary windings.

It will be noted that many advantages are achieved by the apparatus of this invention. For example, the filament voltage and the high voltage of X-ray or other apparatus may be separately controlled without the need for a separate high voltage insulated filament transformer even though the anode 34 is at ground potential.

Separate control of two high potential outputs may be achieved without the need for high voltage insulated controls. The method is easily applicable to control from a remote location. Also, a wide range of control is available and very little interaction occurs between the two controls.

In one example, as applied to a 70,000 volt X-ray transformer, the circuit of the invention has proved capable of either maintaining a constant filament voltage while varying the high voltage output over a 4:1 range or of varying filament voltage over a 4:1 range while maintaining a fixed high potential.

It will also be apparent to those skilled in the art that many variations and modifications may be made in this invention without departing from the spirit and scope thereof. For example, the circuit of this invention is not limited to the particular fields set forth herein, but is equally suitable to any type of apparatus. Furthermore, although the use of a series LC circuit has been specifically described, the invention is not so limited. Any type of frequency responsive circuit or impedance may be employed to accomplish the results set forth. For example, other forms of resonant circuits or non-resonant circuits such as filter networks may be employed. Other variations and modifications will also be apparent.

Accordingly, the foregoing disclosure and description thereof are for illustrative purposes only, and do not in any way limit the scope of the invention which is defined only by the claims which follow.

I claim:

1. Apparatus for separately controlling the voltages to a plurality of loads which comprises:

transformer means having a primary winding and at least first and second secondary windings;

power supply means connected to said primary winding, said power supply means being controllable to selectively vary both the frequency and amplitude of the voltage applied to said primary winding;

frequency-responsive resonant circuit means connected to said first secondary winding;

first load means electrically connected to said first secondary winding and said resonant circuit means; and

second load means electrically connected to said second secondary winding, whereby variation of the output voltage frequency of said power supply varies the voltage amplitude to said first load means.

2. The apparatus of claim 1 wherein said resonant circuit is a series circuit.

3. The apparatus of claim 2 wherein said resonant circuit is in series with said first secondary winding.

4. The apparatus of claim 2 wherein said resonant circuit is an L–C circuit.

5. The apparatus of claim 1 wherein one of said load means includes the heater of a thermionic tube and the other of said load means includes the anode-cathode circuit of said tube.

6. The apparatus of claim 5 wherein said tube is an X-ray tube.

7. Apparatus of the class described for separately controlling two loads, including the combination of

a variable frequency, variable amplitude power supply for supplying alternating power,

a transformer having a primary winding coupled to said power supply and a pair of secondary windings,

first means for coupling one of said primary windings to a first load,

second means for coupling the other of said primary windings to a second load,

an impedance in at least one of said coupling means, said impedance being responsive to the frequency to produce a voltage differential that is a function of the frequency,

a load control coupled to said power supply for varying the frequency of said alternating power, and

a second load control coupled to said power supply for varying the amplitude of the alternating power.

8. Apparatus of the class described for separately controlling two loads, including the combination of

a variable frequency, variable amplitude power supply for supplying alternating power,

coupling means connected to said power supply for coupling said supply to a first load and a second load,

a frequency responsive impedance in said coupling means,

a load control coupled to said power supply for varying the frequency of said alternating power, and

a second load control coupled to said power supply for varying the amplitude of the alternating power.

9. Apparatus of the class described for separately controlling two loads, including the combination of

a variable frequency power supply for supplying alternating power,

coupling means connected to said power supply for separately coupling said supply to first and second loads,

a frequency responsive impedance in said coupling means, and

a load control coupled to said power supply for varying the frequency of said alternating power.

10. Apparatus of the class described for separately controlling two loads, including the combination of

a variable frequency power supply for supplying alternating power,

first coupling means connected to said power supply for coupling said supply to a first load,

second coupling means connected to said power supply for coupling said supply to a second load,

a frequency responsive impedance in at least one of said coupling means, and a load control coupled to said power supply for varying the frequency of said alternating power.

11. X-ray apparatus of the class described including the combination of

a variable frequency, variable amplitude power supply for supplying alternating power,
a step-up transformer having a primary winding coupled to the power supply,
an X-ray tube having an anode and a cathode,
a first secondary winding coupled to the cathode to supply a cathode current thereto,
a second secondary winding coupled to the anode and cathode for maintaining a high voltage between the anode and cathode,
a frequency responsive impedance in series with the first secondary winding and the cathode to produce a voltage differential thereacross that is a function of the frequency whereby the voltage on the cathode and the cathode current vary, and
a cathode current control coupled to the power supply for varying the frequency of the power from the supply and the voltage differential across the impedance, and
an anode voltage control coupled to the power supply to vary the amplitude of the power from the supply and the voltage on the anode.

12. X-ray apparatus of the class described including the combination of

a variable frequency power supply for supplying alternating power,
a step-up transformer having a primary winding coupled to the power supply,
an X-ray tube having an anode and a cathode,
a first secondary winding coupled to the cathode to supply current thereto,
a second secondary winding coupled to the anode and cathode for maintaining a high voltage between the anode and cathode,
a frequency responsive impedance in series with the first secondary winding and the cathode to produce a voltage differential thereacross that is a function of the frequency, and
a frequency control coupled to the power supply for varying the frequency of the power from the supply.

13. X-ray apparatus of the class described including the combination of

a power supply for supplying alternating power at a predetermined frequency,
a step-up transformer having a primary winding coupled to the power supply and a pair of secondary windings,
an X-ray tube having an anode and a cathode,
first means coupling the first of the secondary windings to the cathode to energize the cathode,
second means coupling the second of the secondary windings to the cathode and anode,
a frequency responsive impedance in at least one of said couplings,
first control means coupled to the power supply for varying the voltage on the anode,
a second control means coupled to the power supply for varying the current in the cathode,
one of said control means being effective to vary the frequency of the alternating power from the power supply and the other of said control means being effective to vary the amplitude of said alternating power.

14. X-ray apparatus of the class described including the combination of

a power supply for supplying alternating power at a predetermined frequency.
a step-up transformer having a primary winding coupled to the power supply and a pair of secondary windings,
an X-ray tube having an anode and a cathode,
first means coupling the first of the secondary windings to the cathode to energize the cathode,
second means coupling the second of the secondary windings to the cathode and anode,
a frequency responsive impedance in at least one of said couplings, and
a frequency control coupled to the power supply for varying the frequency of the power from the supply.

15. X-ray apparatus of the class described including the combination of

a power supply for supplying alternating power at a predetermined frequency,
an X-ray tube having an anode and a cathode,
first means coupling the power supply to the cathode to supply a cathode current thereto,
second means coupling the power supply to the anode to maintain the anode at a high voltage,
a frequency responsive impedance in at least one of said coupling means,
first control means coupled to the power supply for varying the voltage on the anode,
second control means coupled to the power supply for varying the current in the cathode,
one of said control means being effective to vary the frequency of said alternating power and the other of said control means being effective to vary the amplitude of said alternating power.

16. X-ray apparatus of the class described including the combination of

a power supply for supplying alternating power at a predetermined frequency,
an X-ray tube having an anode and a cathode,
first means coupling the power supply to the cathode to supply a cathode current thereto,
second means coupling the power supply to the anode to maintain the anode at a high voltage,
a frequency responsive impedance in at least one of said coupling means, and
a frequency control coupled to the power supply for varying the frequency of the power from the supply.

17. X-ray apparatus of the class described including the combination of

an alternating power supply,
an X-ray tube having an anode and a cathode,
means coupling the power supply to the cathode and to the anode,
a frequency responsive impedance in said coupling means, and
a frequency control coupled to the power supply for varying the frequency of the power from the supply.

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