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MAGNETRON CURRENT CONTROL SYSTEMS

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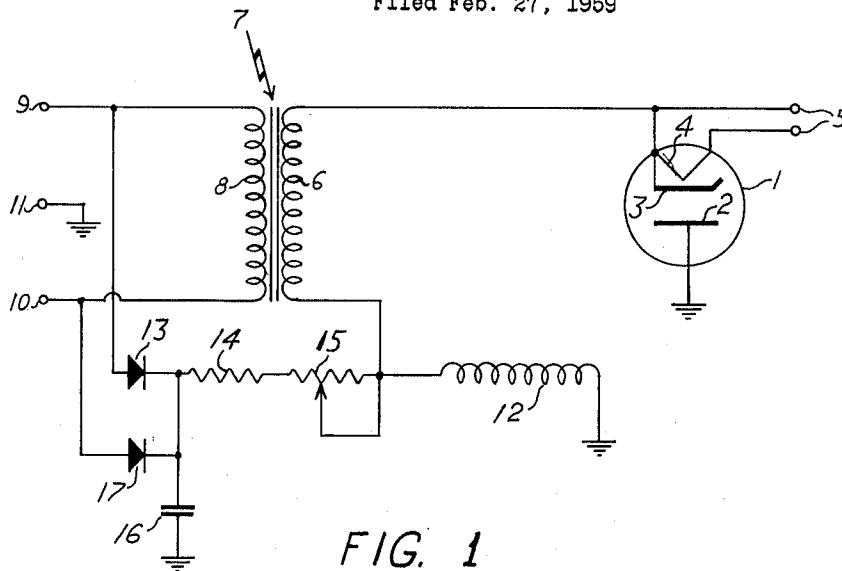


FIG. 1

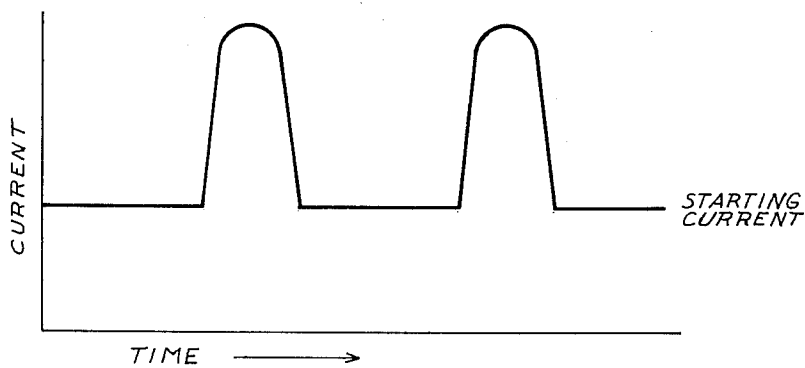


FIG. 2

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This invention relates in general to electronic oscillator tubes of the magnetron type and more particularly pertains to a system for controlling the anode current of a magnetron oscillator.

A magnetron is an electron tube whose operation is characterized by the interaction of electrons with the electric field of a circuit element, the interaction occurring in a steady magnetic field and resulting in the generation of radio frequency power. Magnetrons may utilize either a permanent magnet or an electromagnet to establish the steady magnetic field. This invention pertains to that class of magnetrons having an electromagnet for establishing the steady magnetic field. It is well known that variations in line voltage or variations in the impedance of the load into which the magnetron operates cause the anode current in the magnetron to vary. Where the variation in load impedance is excessive, the magnetron oscillator may shift frequency because of a phenomenon known as frequency pulling. It is an objective of this invention to provide a control system for maintaining the anode current of a magnetron within acceptable limits despite variations in line voltage, load impedance, or both line voltage and load impedance.

The present invention is a system in which the magnetron oscillator tube is employed as a half wave self rectifier and the current flowing to the anode of the magnetron is controlled by varying the intensity of the magnetic field in the tube established by an electromagnet through whose coil flows the rectified anode current. A starting current, obtained from a full wave rectifier and smoothing filter, is also caused to flow in the coil of the electromagnet so that a magnetic field, due to the starting current, is present in the magnetron to which there is added periodically the magnetic field due to the anode current pulse of the magnetron. Control of the magnetron's anode current is effected thus, through an electromagnet in a system which efficiently utilizes a minimum number of magnetic components to accomplish current stabilization during line and load variations. Utilization of the minimum number of magnetic components increases the reliability of the system's operation while permitting a reduction in cost.

The arrangement of the magnetron current control system and the distinctive features of the invention can be apprehended by a perusal of the following detailed description when considered in conjunction with the accompanying drawing in which:

Fig. 1 is a schematic representation of the preferred embodiment of the invention; and

Fig. 2 is a graph showing the variation with time of the current flowing in the field coil of the electromagnet.

Referring now to Fig. 1 of the drawing, there is shown in schematic form a preferred embodiment of the invention which includes a magnetron oscillator tube 1 of the type in which a steady magnetic field is established by an electromagnet. As is customary in magnetron operation, the anode 2 of the tube is grounded. The cathode 3 of the magnetron is heated by an element 4 in the

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tube which causes electrons to be emitted from the activated cathode surface. An electrical current is caused to flow in the heating element 4 by a voltage impressed at terminals 5. The cathode 3 is connected to the secondary winding 6 of a transformer 7, the primary winding 8 of that transformer being connected to terminals 9 and 10. A line voltage which is balanced to ground is impressed on terminals 9, 10, and 11. For example, a line voltage of two hundred and thirty volts may be impressed between terminals 9 and 10 so that one hundred and fifteen volts appear between terminals 9 and 11, and one hundred and fifteen volts appear between terminals 10 and 11. The field coil 12 of the magnetron electromagnet is connected at one end to secondary winding 6 and is grounded at its other end. A full-wave rectifier and filter network are connected between the line voltage input terminals 9, 10, 11 and the field coil 12. The diode rectifier 13 is connected to terminal 9 and through fixed resistor 14 and adjustable resistor 15 to field coil 12. A filter capacitor 16 is connected between ground and diode 13. Another diode rectifier 17 interconnects terminal 10 and capacitor 16. The rectified current passing through diodes 13 and 17 is filtered by the action of capacitor 16 and resistors 14 and 15 to reduce the ripple content to tolerable limits. The rectified filtered current, which is termed the starting current (see Fig. 2), flows through field coil 12 and causes a magnetic field to be established in the magnetron tube 1. The line voltage impressed across primary winding 8 is stepped up by transformer 7 so that a high voltage, which may be in order of six to ten kilovolts depending upon the specific magnetron type employed, appears across secondary winding 6, and this alternating high voltage is applied between anode 2 and cathode 3, those two elements causing the magnetron tube to function as a self rectifier. Since the current through the magnetron also flows through field coil 12, the field coil is energized by the starting current and the current flowing to the anode 2, as indicated in Fig. 2. The magnetic field in the magnetron will increase with the flow of current to the anode, and the magnetic field will be at a maximum during the anode current pulse because the magnetron current flows through the field coil of the electromagnet. Increasing the magnetic field in this manner tends to cause the tube to operate in a region of higher efficiency and also tends to reduce the peak anode current. Variations in anode current due to an increase in line voltage at terminals 9, 10 and 11 are regulated, because where the line voltage increases, the starting current supplied to the field coil tends to increase as well as the anode current. The increase of current in field coil 12 causes an increase in intensity of the magnetic field in tube 1 and thus reduces the normal characteristic gain in anode current. Conversely, where the line voltage decreases, the starting current tends to decrease, as does the anode current. The decrease of current through field coil 12 reduces the intensity of the magnetic field in tube 1, resulting in an increase in the normal characteristic gain in anode current. By this action, the excursions of anode current due to fluctuations in line voltage are maintained within acceptable limits.

Anode current excursions due to variations in the load connected to the output of the magnetron are also regulated by the system illustrated in Fig. 1. Where the load condition is such that the anode current tends to decrease, the intensity of the magnetic field in the magnetron will decrease, and with the anode voltage unaffected, the change in anode current which normally would occur if the intensity of the magnetic field were unchanged is reduced. Ideally, the magnetron would operate into a matched load so that the maximum amount

of power would be absorbed by the load. With the disclosed system, however, the magnetron can operate into loads which are severely mismatched without encountering excessive excursions in anode current.

There has been described a system for electromagnetically controlling the anode current of a magnetron oscillator which employs a minimum number of magnetic components to accomplish stabilization during line and load variations. The system illustrated is at present considered to be the preferred embodiment of the invention, but modifications will readily occur to those knowledgeable in the electronics art. It is not, therefore, desired that the invention be limited to the specific arrangement shown and described, but rather it is intended to include in the scope of the appended claims all such modifications as are within the spirit of the invention.

What is claimed is:

1. A magnetron anode current control system comprising a magnetron tube having an electromagnet for establishing a magnetic field in said tube, a transformer, means connecting the field coil of said electromagnet and the secondary winding of said transformer in series with cathode and anode of said tube, a rectifier having its output coupled into said field coil, and means for impressing a voltage on said rectifier and the primary winding of said transformer.

2. A magnetron anode current control system comprising a magnetron tube having an electromagnet for establishing a magnetic field in said tube, a transformer, means serially connecting the field coil of said electromagnet and the secondary winding of said transformer between the cathode and anode of said tube, a rectifier, a filter network connected between said rectifier and said field coil, and means for simultaneously impressing a voltage on said rectifier and the primary winding of said transformer.

3. A magnetron anode current control system comprising a magnetron tube, an electromagnet having a

field coil for establishing a magnetic field in said tube, a transformer having its secondary winding connected between the cathode of said tube and one end of said field coil, means establishing a circuit between the anode of said tube and the other end of said field coil, a filter network connected to said field coil, a full wave rectifier connected to said filter, and means for impressing a voltage on said rectifier and the primary winding of said transformer.

4. A magnetron anode current control system comprising a magnetron tube, an electromagnet having a field coil for establishing a magnetic field in said tube, a transformer having its secondary winding connected between the cathode of said tube and one end of said field coil, means returning the other end of said field coil and the anode of said tube to a reference potential, a filter network connected to said field coil, and a current rectifier connected between the primary winding of said transformer and said filter network.

5. A magnetron anode current control system comprising a magnetron tube, an electromagnet having a field coil for establishing a magnetic field in said tube, a transformer having its secondary winding connected between the cathode of said tube and one end of said field coil, means electrically interconnecting the other end of said field coil and the anode of said tube, a source of alternating voltage connected to the primary winding of said transformer, a full wave rectifier connected to said alternating voltage source, and a resistance-capacitance filter network connected between said rectifier and said field coil.

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