

[54] **REGULATED POWER SUPPLY CIRCUIT FOR A HEATING MAGNETRON**

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[*] Notice: The portion of the term of this patent subsequent to Feb. 21, 1991, has been disclaimed.

[22] Filed: **Oct. 1, 1973**

[21] Appl. No.: **402,110**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 739,778, June 25, 1968, abandoned, said Ser. No. 739,778, is a continuation-in-part of Ser. No. 432,241, Feb. 12, 1965, abandoned, which is a continuation-in-part of Ser. No. 288,714, Sept. 13, 1972, Pat. No. 3,792,369.

[52] U.S. Cl. **331/71; 219/10.55; 328/253; 331/86; 331/185**

[51] Int. Cl. **H03b 9/10; H05b 9/00**

[58] Field of Search **331/71, 86-91, 331/185, 186; 219/10.55; 315/283; 328/253; 258; 262; 268**

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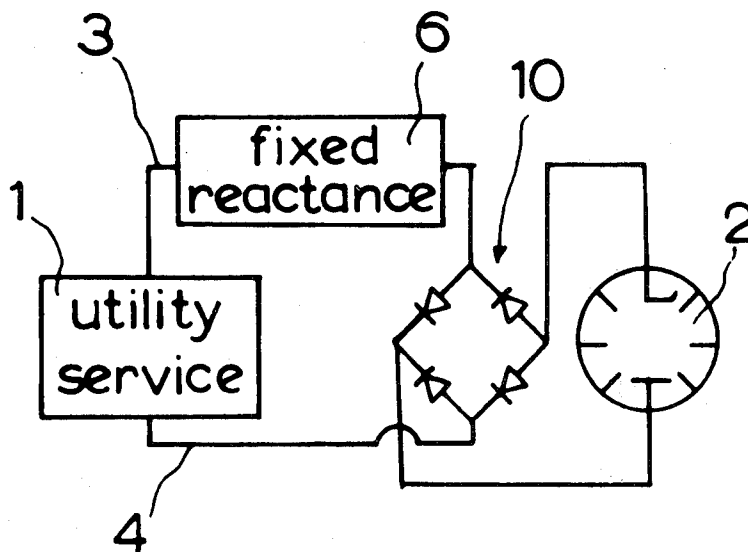
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Primary Examiner—Siegfried H. Grimm

[57] **ABSTRACT**

A fixed-reactance is combined in series with a magnetron to regulate, to resonate and to provide higher effective voltage, where, when said fixed-reactance is a capacitive reactance, means are provided for DC operation of said magnetron and AC operation of said capacitive reactance, and where, by selecting the size of said fixed-reactance to be larger than the operating resistance of said magnetron, said fixed-reactance provides the regulation required by said magnetron during normal voltage variations of the supply voltage of an electric utility service by limiting the non-linear current change of said magnetron, when said magnetron is subject to said normal voltage variations, to a substantially linear current change. A saturable reactor regulating circuit is described in combination with said reactance-magnetron regulating circuit.

9 Claims, 11 Drawing Figures



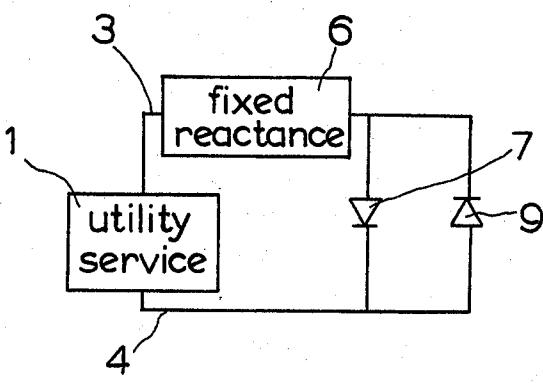


FIG. 1

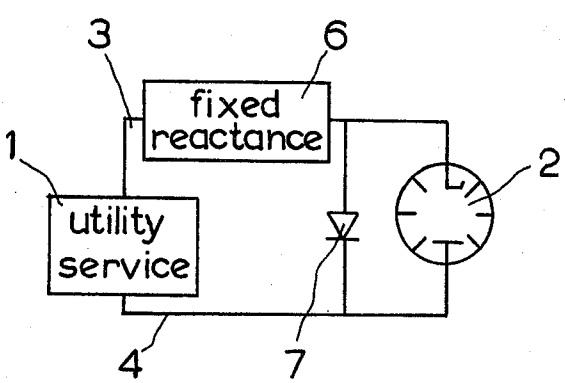


FIG. 2

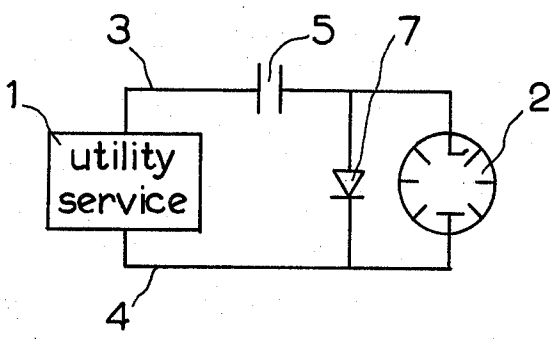


FIG. 3

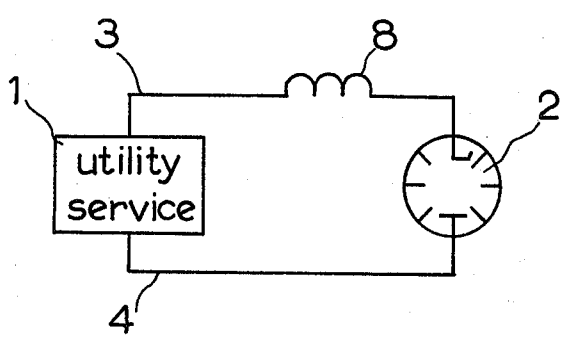


FIG. 4

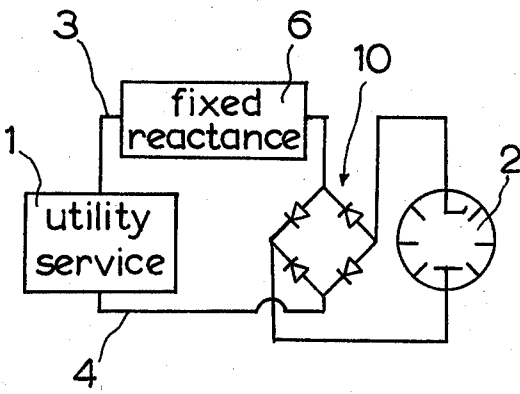


FIG. 5

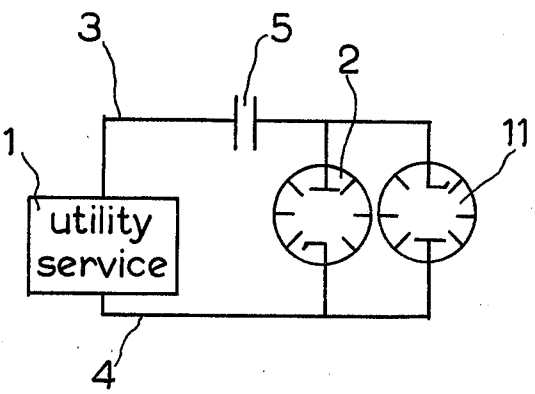


FIG. 6

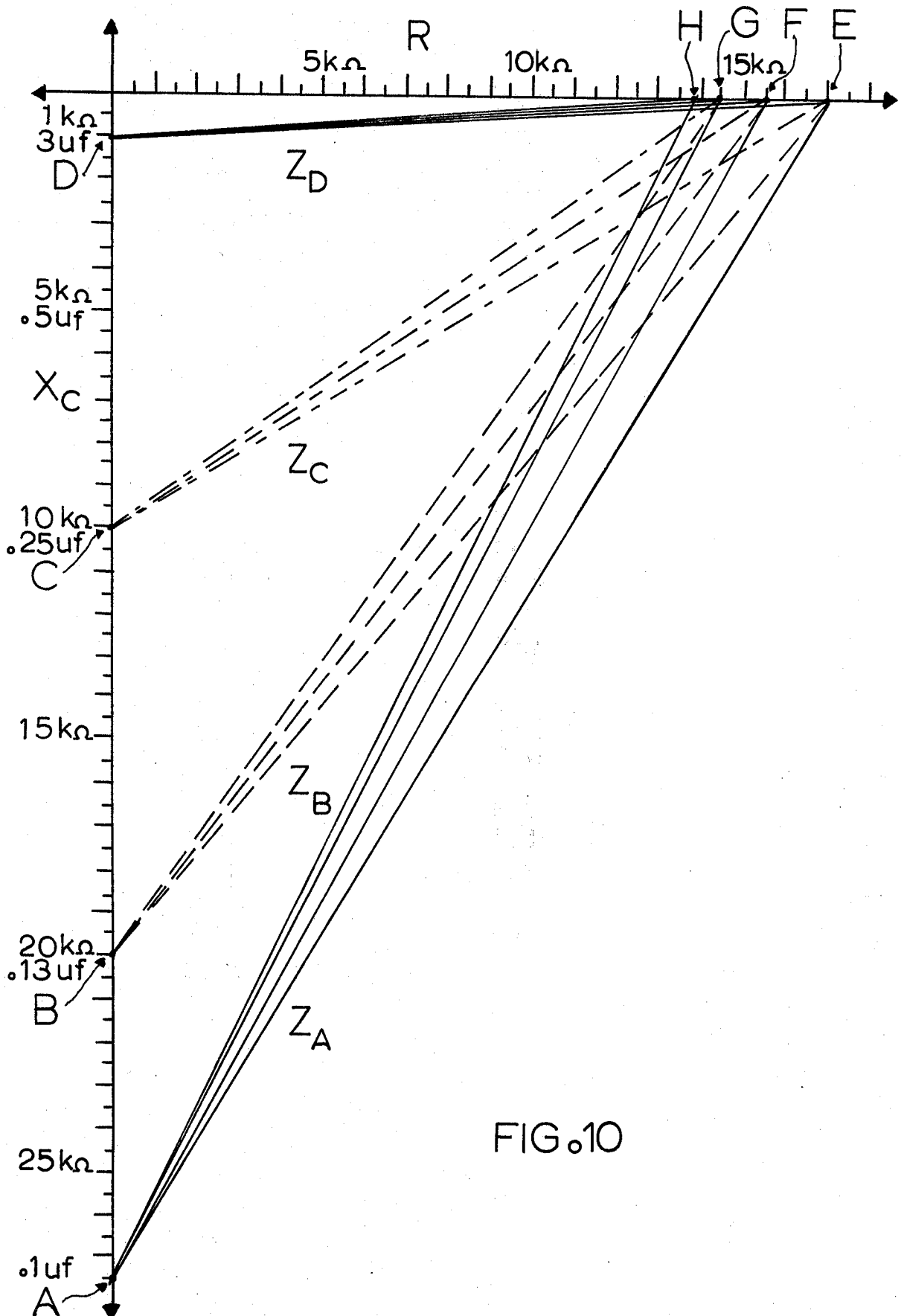


FIG. 10

REGULATED POWER SUPPLY CIRCUIT FOR A HEATING MAGNETRON

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of Ser. No. 739,778, filed June 25, 1968, now abandoned, and said Ser. No. 739,778 was a continuation-in-part of Ser. No. 432,241, filed Feb. 12, 1965 and now abandoned; and, this application is a continuation-in-part of Ser. No. 288,714, filed Sept. 13, 1972 now U.S. Pat. No. 3,792,369.

BACKGROUND OF THE INVENTION

Various systems have been employed to regulate magnetron power supplies in microwave ovens. For instance, in prior art, to provide the needed regulation, temperature sensitive resistors have been placed in series with the magnetron; the magnetron's current has been directed through the magnetron's electromagnetic field coil; and saturable reactors have been utilized in the primary of the magnetron's high voltage transformer. But, said resistors are power wasting, said electromagnets are space wasting — useless in permanent magnet magnetrons — and said saturable reactors are both cumbersome, expensive and require supplementary circuitry to energize their control windings.

I have discovered that a specially selected size, fixed-reactance connected in series with the discharge circuit of a heating magnetron can provide the principal regulation required by said magnetron when said magnetron is subject to normal voltage variations of an electric utility supply service. Said fixed-reactance can be either an inductance or a capacitance. Employing a capacitance to regulate a magnetron affords additional advantages in that, the capacitance can be chosen to resonate with the inductance of a transformer to provide a variable resonant gain, and an input voltage lower than the voltage required to cause the magnetron to oscillate can be used.

In most cases, the fixed-reactance regulation of this invention is sufficient, but for those who require even better regulation to provide an exact amount of microwave power for a precise period of time, I have discovered that said fixed-reactance combines with and simplifies other known regulating circuitry. For instance, I will describe an improved saturable reactor regulating circuit in combination with said fixed-reactance regulating circuit. In said improved saturable reactor circuit, the control winding can be placed in series with the primary of a magnetron's high voltage transformer which obviates the need for another source of power to power the control winding. And, since said control winding now carries a large portion of the transformer's primary current, the main winding can be physically smaller than that of saturable reactors employed in prior art.

SUMMARY OF THE INVENTION

Accordingly, it is an object of this invention to connect a selected fixed-reactance in series with the discharge circuit of a magnetron to regulate said magnetron during normal voltage variations of an electric utility service.

It is an object of this invention to create circuitry to resonate a continuous-wave, heating-magnetron power supply.

It is an object of this invention to create a novel combination of said fixed reactance-magnetron series regulation with prior art regulating circuits.

And, it is an object of this invention to describe an improved circuit to vary the power output of said series fixed reactance-magnetron regulating circuit.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 illustrates a fixed reactance in series with a short circuit across a utility service.

FIG. 2 is the circuit of FIG. 1 where a magnetron has been substituted for one of the diodes of the short circuit.

FIG. 3 is fixed capacitance in series with the discharge circuit of a magnetron connected across a utility service.

FIG. 4 is an embodiment of the invention where a fixed inductance is in series with a magnetron and both connected across a utility service.

FIG. 5 is a variation of FIG. 2 where a full wave bridge rectifier is employed.

FIG. 6 is the circuit of FIG. 3 where a second magnetron is substituted for the diode.

FIG. 7 is a chart of the voltage across the magnetron of FIG. 3 or one of the magnetrons of FIG. 6.

FIG. 8 is another embodiment of the invention where a transformer is combined with the circuit of FIG. 3.

FIG. 9 is another embodiment of the invention where an improved saturable reactor circuit is combined with the circuit of FIG. 8.

FIG. 10 is a chart of the reactance of the fixed reactance, the resistance of a magnetron and their combined impedance presented to an electric utility service supply.

FIG. 11 is another embodiment of the invention where the circuit of FIG. 3 is combined with the variable resistance of U.S. Pat. No. 3,760,291.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates the operation of a fixed-reactance 6 in series with a short circuit, diode 7 and diode 9, connected across a standard 60 cycle alternating voltage electric utility service 1. In FIG. 1, current from line 3 of an electric utility service 1, during one alternation, flows through fixed-reactance 6 and diode 9 to reach line 4 of service 1. On the alternate half cycle current flows in the opposite direction through diode 7. The size of fixed-reactance 6 and the voltage of service 1 determines the amount of current that will flow. The full voltage drop of service 1 appears across fixed-reactance 6.

FIG. 2 illustrates FIG. 1 where magnetron 2, a diode, is substituted for diode 9. A magnetron is similar to a zener or reference diode in that they break down and discharge at fixed voltages, their current handling and power handling capabilities can be large while their operating voltage range is small and substantially constant. Also, a zener diode and a magnetron have a fixed wattage which, if exceeded, will result in their destruction. Hence, both a zener or reference diode and a magnetron require circuitry which prevents their maximum design current and wattage from being exceeded. Additionally, a magnetron requires a positive means to maintain its power output substantially constant over normal voltage variations in its supply voltage. This invention provides said positive means to maintain a

magnetron power output substantially constant over normal service 1 voltage variations. FIG. 2 operates essentially as the circuit of FIG. 1 with the exception that during an alternation when said magnetron discharges the voltage drop of utility service 1 divides and appears across magnetron 2 (as magnetron 2's discharge voltage, regardless of the voltage of said service 1), and a related voltage drop appears across fixed-reactance 6. As will be described in more detail, the values of fixed-reactance 6 and magnetron 2's discharge voltage are chosen to complement one another to regulate said magnetron.

In FIG. 3, a series-parallel circuit of magnetron 2 and diode 7 is connected across power lines 3 and 4 of a conventional, alternating utility service 1, as a 4,160 volt power line. Magnetron 2 is operated half wave and capacitance 5 is operated full wave. Diode 7 is required to conduct in a direction opposite and in parallel to that of magnetron 2 to make said half wave and full wave operation compatible. Rather than diode 7, other conducting means disposed to conduct in a direction opposite that of magnetron 2, can be employed, for example, in FIG. 5, a four-diode-bridge, full wave rectifier 10 or, in FIG. 6, a second magnetron 11.

In operation, in FIG. 3, when the half cycle of alternating electric utility service 1, applied across magnetron 2, is plate negative, cathode positive, no current flows through magnetron 2, but, current flows through diode 7 to charge capacitance 5. On the alternate half cycle, plate positive, cathode negative, magnetron 2 discharges across service 1 via capacitance 5 as well as discharging from the electric charge accumulated on capacitance 5 from said previous half cycle.

FIG. 7 is a chart of the voltage impressed on capacitance 5 available to discharge magnetron 2, and helps explain how the circuit diagrammed in FIG. 3 operates. Capacitance 5 charges to point A, through diode 7, during one half of one half cycle. After point A is reached, capacitance 5 attempts to discharge in response to changing alternate voltage until A₁ is reached and a full cycle is completed. In each recycle, capacitance 5 attempts to discharge again and again. From point B to point D the voltage impressed by the alternating service 1 adds to the charge A stored on capacitance 5, with point C representing the maximum potential difference. Voltage A-C is twice the source voltage. All voltages after point A attempt to discharge magnetron 2. P represents a point on the curve A-C, where the potential difference A-P equals the voltage necessary to discharge magnetron 2. Hence, a capacitance 5 can be employed to discharge magnetron 2 when magnetron 2's discharge voltage is below twice the supply voltage of service 1 and can also be employed when magnetron 2's discharge voltage is less than the supply voltage of service 1.

FIG. 6 illustrates how two magnetrons, 2 and 11, are connected in parallel so as to conduct on alternating half cycles and are combined with and controlled by capacitance 5. In FIG. 6, at least one magnetron must discharge at less than the voltage of service 1 while the second magnetron can discharge at a voltage equal to said lesser voltage or up to twice the voltage of service 1.

FIG. 4 is a series circuit, comprising a simple, two-terminal inductance 8 in one mesh with magnetron 2, connected across power lines 3 and 4 of a conventional, high-voltage, alternating, service 1, as 4,160

volts. In operation, in FIG. 4, when the half cycle of the voltage of service 1, applied across magnetron 2, is plate negative, cathode positive, magnetron 2 blocks series current flow and inductance 8 lies dormant. On the alternating half cycle of voltage, plate positive, cathode negative, magnetron 2 discharges, across electric service 1, through inductance 8.

Inductance 8 is a current sensitive device which responds in proportion both to the rate of change in current and the amount of current discharging through magnetron 2. Inductance 8, by its nature first resists the discharge of current through magnetron 2 and then resists the cessation of said discharge.

The action of inductance 8 combined with the discharge device, as magnetron 2, is different than the same inductance in series combination with a conventional load. With a conventional load, an inductance starts to build up a charge, a voltage drop, from the beginning of each cycle in competition with said conventional load with which it is in series. In contrast to a conventional load, sufficient voltage must appear across magnetron 2 to enable it to discharge and, only as a result of magnetron 2's discharging, can inductance 8 become effective.

FIG. 5 illustrates the combination of a reactance 6, a magnetron 2 and a full wave rectifier bridge 10.

FIG. 8 is FIG. 3 with the addition of a transformer 28. The effective input voltage to capacitor 5, rectifier diode 7 and magnetron 2 now is the secondary voltage of transformer 28. Magnetron 2 can be a magnetron designed to discharge at a voltage less than twice the output voltage of transformer 28. Further, I have discovered that the inductance of transformer 28 can be chosen to resonate with capacitance 5. The benefits of a resonant circuit are well known.

A magnetron is a device capable of converting electrical power into electronic power (e.g., radio waves) at projected 98% efficiency. Individual magnetron — representative of the family of cross field microwave generating tubes which include amplitrons — have been designed to handle one Megawatt of continuous wave power output (many Megawatts of pulse power output). More than one magnetron can be ganged together to provide many Megawatts of power output. A magnetron is an enclosed device which incorporates a high intensity magnetic field, which is provided by magnets. High frequency oscillation is produced in a magnetron by an electron (vs. ionized gas in a conventional arc discharge) beam emitted by a heated cathode, moved in curved or spiral paths within lobes or cavities because of said high intensity magnetic fields. The frequency produced is dependant on the geometry of the magnetron and the strength of the magnetic field. The high frequency energy of the magnetron is picked up by a probe extending into the interior of the magnetron in the path of the spiralling electrons and is transmitted to the load by means of wave guides, coaxial cables and the like. Energy is emitted to the load by means of a suitable horn or antenna in a manner well known in the art.

Magnetrons are energized by means of pulsed direct current at high voltages, for example 5,500 volts. When said voltage is applied between the anode and the cathode of a magnetron, it requires a considerable potential to start the magnetron oscillating, and thereafter current flows with a non-linear characteristic. Although a non-linear device, the magnetron reacts as a positive

resistance device in that an increase in voltage results in an increase in current, but the problem of operating and controlling a magnetron is complicated by the fact that small increments of voltage change will result in rather high variations in current.

A magnetron is a discharge device, but it is different from common discharge devices. The discharge of the carbon arc furnace, the fluorescent light and the mercury vapor rectifier tube is initiated by a voltage level that exceeds, for example, 130%, the sustaining voltage. The discharge of a magnetron starts gently (e.g., 60%) and builds up exponentially to crest at full power (e.g., 100%) of the applied voltage. Magnetrons also differ from conventional discharge devices for, to prevent their operating in an improper mode, they are purposely turned off each cycle. This unique, purposeful turning off of magnetron 2 permits inductance 8, when combined in the same circuit in the same series mesh with magnetron 2, to unsaturate and prepare to respond to the next maximum change in circulating current when magnetron 2 again turns from off to on in addition to responding to the amount of circulating current, per se.

The capacitive reactance 5 and the inductive reactance 8, of FIGS. 3 and 4, both are 90° out of phase with the circuit resistance offered by magnetron 2. The discussion that follows for capacitive reactance 5 is valid for inductive reactance 8 with an appropriate change in phase relationship.

It is desirable that the regulation of a microwave oven compares favorably with the regulation of an electric oven. Assuming a fixed resistance heating element, an electric oven at 115 volts, 1,000 watts would require 13.25 ohms of resistance at 8.7 amps which at 105 volts ($R = 13.2$ ohms and $I = 7.92$ amps) would deliver 834 watts and which at 125 volts ($R = 13.2$ ohms and $I = 9.45$ amps) would deliver 1,180 watts. It follows that in said electric oven $\pm 8.7\%$ voltage change results in $+18\%/-16.6\%$ wattage change.

In FIG. 10 and Tables 1 and 2, there appear values taken from the manufacturer's data of an Amperex Model DX 206 magnetron representative of other magnetrons. Table 1 lists some unregulated characteristics of the DX 206 magnetron.

Table 1's unregulated characteristics can be compared with the semi-regulated and regulated characteristics of Table 2. Table 2 provides values for FIG. 10. It can be seen from Table 1 that a -1.82% voltage change from the nominal operating voltage across said DX 206 magnetron will result in a -11% reduction in power. A $+1.82\%$ change from nominal will result in a $+9\%$ increase

Table 1

% I	I	E	% E	R	W	% W
-10%	.315	5400v	-1.82%	17.15k	980w	-11%
0	.350	5500v	0	15.70k	1100w	0
+10%	.380	5600v	+1.82%	14.50k	1200w	+9%

Table 2

X _c	R	R ohms	Z ohms	E _z	% E _z	cos ϕ =R/Z
A	E	17.15k	32.4 k	5120v	-6.8 %	.529
A	F	15.70k	31.4 k	5500v	0	.5

Table 2-Continued

	X _r	R	R ohms	Z ohms	E _z	% E _z	cos φ =R/Z
5	A	G	14.50k	30.9 k	5960v	+8.37%	.475
	A	H	13.90k	31.2 k	6400v	+16.36%	.446
	B	E	17.15k	26.2 k	4140v	-6.55%	.655
	B	F	15.70k	25.35k	4430v	0 %	.619
	B	G	14.50k	24.7 k	4770v	+7.8 %	.588
	C	E	17.15k	19.8 k	3140v	-3.22%	.867
	C	F	15.70k	18.55k	3245v	0 %	.846
	C	G	14.50k	17.6 k	3390v	+4.47%	.824
10	D	E	17.15k	17.2 k	2720v	-1.45%	.998
	D	F	15.70k	15.75k	2760v	0 %	.998
	D	G	14.50k	14.55k	2850v	+3.26%	.998

in output power. Since United States electric service voltages rarely vary over as wide a range as 105 to 125 volts set forth for electric ovens, and to make magnetron calculations which will compare to said electric oven calculations, said $\pm 1.82\%$ voltage calculations were selected for magnetron power variations similar to electric oven power variations.

FIG. 10 is a chart of the capacitive reactance X_c of a capacitor on the y axis and the resistance R, of said DX 206 magnetron, plotted on the X axis. The resultant impedance, Z_A to Z_D, which appears across utility service 1, determines the series current that will flow through capacitance 5 and magnetron 2 for a given service 1 voltage.

While FIG. 10 is a reactive-resistive plot, in the discussion that follows, voltage, current and power values that are associated with said reactive-resistive points on said reactive-resistive plot are inferred. Referring to Table 2, FIG. 3 and 7, a brief discussion of design considerations and operation follows:

1. A magnetron 2 is selected which can deliver a desired mean power output, point F. Point H is magnetron 2's absolute-maximum, allowable, power operating point. The upper and lower limits, maximum-point G and minimum-point E, of a desirable regulated condition around mean power point F, are selected.

2. There are normal operating voltage variations present in an electric utility service voltage. An alternating electric utility service is chosen whose low voltage variation is higher than one half the voltage whose application across magnetron 2 will result in the selected maximum power output point G (an inductive reactance, FIG. 4, differs — the lowest voltage of the utility service must be higher than maximum voltage, point G). Now, turning to the maximum voltage of said electric utility service 1 (a maximum fixed by both government laws and an electric utility company's equipment and policy), a capacitance 5 is selected whose capacitive reactance both fixes the maximum current that can flow at said maximum voltage and results, additionally, in a predetermined, design regulation requirement. For example: the power output of magnetron 2 is a function of its plate current. The current, that circulates through resistive magnetron 2 and capacitive reactance 5, is a result of the combined impedance they present to the electric utility service 1. The resistance R of magnetron 2, at a preselected maximum (i.e., at a less than absolute-maximum high-power point H), high-power output point G is calculated from known design characteristics. A capacitive reactance value is calculated whose reactance X_c added vectorially to resistance R, at point G, results in (again using the highest normal voltage variation of said electric utility service 1) the proper impedance Z to permit said desired

design current to circulate which results in point G. It can be seen, in Table 2, that each higher-voltage, electric utility service voltage requires a smaller capacitive reactance and provides better regulation for said given magnetron. The standard utility (A to D and higher) service 1 voltages (as 4,160, 13,200 and 26,400 volts) selected should be one that complements said given magnetron and value of capacitance to most nearly result in, at mean and minimum line voltages, magnetron 2's corresponding mean high-power point F and minimum high-power point E. The higher the utility service voltage the better the regulation at the expense of the power factor. It should be noted that the mean high-power point F voltage, 5,500 volts, of Table 1 and 2 is not a standard electric utility service voltage, but said voltage can be obtained with the transformer of FIG. 8.

In Table 2, (FIG. 3) A-F to D-F could designate different arbitrary electric utility services. The higher the electric utility service's voltage, the better the regulation is over normal power line voltage variations — service 1 would have to vary an unreasonable +16.36% above normal in plot A-F, to reach absolute maximum operating utility voltage A-H. Utilizing even higher utility voltages than those illustrated will result in a smaller power factor and better regulation. If said arbitrary utility voltage, D-F, is slightly more than one half (in this example, 2,760 volts) of said magnetron's design discharge voltage F (in this example, 5,500 volts) regulation is poor.

Some push button microwave vending ovens can require a more exact amount of regulation for a definite number of seconds. To achieve this precise control, saturable reactor circuits have been employed in the primary circuit of a magnetron high voltage transformer. These saturable reactor circuits are space consuming, expensive, and require an additional power supply to power their control winding. Heretofore, has been described how a selected capacitance in series with the discharge circuit of a magnetron can regulate said magnetron. Next there will be described an improved saturable reactor circuit to combine with and additionally regulate said series reactance-magnetron regulating circuit.

In FIG. 9, alternating current passes from side 3 to side 4 of an AC power service via a saturable reactor 29 and associated control circuit 30, to and through primary winding 31 of transformer 28. Saturable reactor 29 and control circuit 30 includes the main winding 12 of saturable reactor 29 in series with section 31a-31b of the primary winding 31 and this series is in parallel with the AC input of full wave bridge rectifier 13.

Bridge rectifier 13's output passes through the control winding 15 of saturable reactor 29 in series with transistor control circuit 14. Control circuit 14 consists of a transistor 17 whose DC output is varied by a variable bias resistor 18 employed conventionally in conjunction with other bias resistors 19-19. Transistor 17's output can also be varied by an external signal transferred into transistor circuit 14 by transformer 20. This external signal transferred into transistor circuit 14 can be developed by conventional sensors in magnetron 6's wave guide or, as illustrated, a sensor circuit 21 placed to respond to the current passing through magnetron 2. In sensor circuit 21 a voltage drop, corresponding to a pulsating DC current passing through magnetron 2, appears across resistor 22. Any voltage

drop across resistor 22 higher than the breakdown voltage of zener diode 23 will cause zener diode 23 to conduct and in turn voltage pulses will appear across resistor 24 which, relayed via transformer 20, bucks the bias on transistor 17 to limit the current flowing through control winding 15 and ultimately the current flowing through magnetron 2.

The circuit in FIG. 9 operates as follows: In operation a voltage drop occurs across main winding 12 and across the AC input of full wave bridge rectifier 13. The output of bridge rectifier 13 causes current to flow through control winding 15 in series with transistor circuit 14. If variable bias resistor 18 is adjusted to no resistance, no bias will be present, negligible current will flow through transistor circuit 14 and control winding 15 and the main winding 12, unsaturated will reduce the amount of voltage reaching magnetron 2 to, as designed, either stop it oscillating or limit its power output. More bias on transistor 17 means more current through the control winding 15, and more saturating of the main winding 12, and so, more voltage to magnetron 2. Too much current flowing through magnetron 2 means larger peak current passing through zener diode 23 and reflecting through transistor circuit 14 to limit magnetron 2's current. As an option, one leg of bridge rectifier 13 can be returned to a point 31b which is lower on primary 31 than point 31a. The voltage drop from 31a to 31b is now available, when the main winding 12 is saturated, to supply a larger voltage drop across control circuit 30.

Since capacitor 5 provides regulation, saturable reactor 29 does not have to supply as much regulation or be as large as would be necessary if capacitance 5 was not present. Since the current operating control winding 15 passes through primary 31 of transformer 28, the main winding 12 of saturable reactor 29 requires less current handling ability and can be physically smaller. No external power source is needed to independently power control winding 15 as was necessary in prior art.

The duty cycle of a heating magnetron at 60 cycles is relatively long and the magnetron's resistance, R, is high. The capacitance time constant, RC, and the inductance time constant, L/R, can have an effect on the operation and regulation and should taken into consideration in all calculations. FIG. 11 illustrates the regulating circuit of FIG. 5 combined with the variable resistance 35 of my U.S. Pat. No. 3,760,291 to make a variable regulated circuit. Inductance 8 can be more useful than would be capacitance 5 in FIG. 11, because as R rises the L/R time constant falls and makes inductance 8 effectively larger in relation to the resistance of variable resistance 35 to provide an increasingly greater wattless component of variable control.

It should be noted that fixed-reactance 6 not only provides a heating magnetron power supply circuit with essential regulation, but said fixed reactance 6 can act as a "fuse" means, if magnetron 2 shorts out, to limit runaway destructive short circuit current from damaging said circuit.

Multiphase alternating electric utility service lines can be employed and regulated. These multiphase lines represent a multiplication of FIG. 3 where additional capacitors regulate each phase separately. The fixed-reactance regulating means of this invention can be part of full wave capacitor doubler circuit.

Although this invention has been described with a certain degree of particularity it should be understood

that the present disclosure has been made only by way of example and that numerous changes in the detail of construction and the combination and arrangement of parts may be restored to without departing from the spirit and scope of the invention.

I claim:

1. An operating circuit for energizing a heating magnetron from an alternating voltage electric utility service which comprises:

a non-saturating, fixed-reactance in series with the discharge circuit of said magnetron said reactance having a magnitude such that for normal variations in the voltage of said electric utility service said reactance both limits the plate current of said magnetron to a value below said magnetron's maximum allowable plate current and maintains said plate current substantially constant.

2. In an operating circuit according to claim 1, wherein said fixed-reactance is an inductance whose inductive reactance has a magnitude equal to at least one half of said magnetron's mean operating resistance.

3. An operating circuit according to claim 1, wherein said fixed-reactance is the capacitive reactance of a fixed capacitor.

4. An operating circuit according to claim 3, wherein said capacitive reactance has a magnitude equal to at least one half of said magnetron's mean operating resistance.

5. An operating circuit for energizing a heating magnetron from an alternating voltage electric utility service which comprises:

a non-saturating, fixed-reactance in series with the discharge circuit of said magnetron to regulate said magnetron's power output over normal variations in the voltage of said electric utility service, and where the value of the resultant impedance of said magnetron-fixed reactance series circuit is such that a $\pm 10\%$ change in said utility service's mean output voltage, appearing across said series circuit, results in less than $\pm 20\%$ wattage change in the mean power output of said magnetron.

6. An operating circuit, according to claim 5, which

includes:

a transformer whose primary is connected across said alternating electric utility service and whose secondary is connected across said fixed reactance-magnetron series discharge circuit.

7. In an improved operating and regulating first circuit for energizing a heating magnetron which includes a magnetron plate transformer with a primary and a secondary winding, means to connect said transformer primary winding to an alternating voltage electric utility service, a magnetron, means to connect said transformer's secondary winding to said magnetron, means connected to said first circuit for limiting the plate current of said magnetron to a value below said magnetron's maximum allowable plate current for maintaining said plate current at a substantially constant current over normal variations in the voltage of said electric utility service, and an improved second regulating circuit, said improved second regulating circuit comprises in combination:

non-saturating fixed reactance in series with the secondary winding of said transformer and the discharge circuit of said magnetron where the value of the resultant impedance of said magnetron-fixed reactance series circuit is such that a $\pm 10\%$ voltage change in said utility service's mean output voltage will result in less than a $\pm 10\%$ wattage change in the mean power output of said magnetron.

8. An operating circuit according to claim 7, wherein said fixed-reactance is the capacitive reactance of a fixed capacitor,

rectifier means across said magnetron which permits said capacitor to charge and discharge during alternating voltage variations of said utility service, and where said capacitive reactance is chosen to resonate with the inductive reactance of said transformer.

9. In an operating circuit according to claim 7, wherein said first circuit means for maintaining the plate current substantially constant is a saturable reactance.

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