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Performance Improvement of Power Control System for Driving MGT

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Abstract : This paper describes the performance improvement of power control system of magnetron(MGT) for microwave oven. The MGT is used extensively in household microwave oven and industrial microwave heating devices, and is operated by 3.0[kV]~5.0[kV] dc high voltage. The proposed power supply is consisted of a bridge rectifier, step-up converter(SUC) and its controller, half bridge inverter(HBI) and its controller, and full wave double voltage rectifier(DVR). In the proposed system, a good power factor can be obtained by the SUC' switching method that the inductor current waveforms follows that of the rectified voltage, and a line input power can be controlled to a range of 17.5[%] by duty ratio(DR) adjustment of the HBI.

Key words : Magnetron, Microwave oven, Step-up converter, Power factor

1. Introduction

The microwave oven heats food by means of 2.45[GHz] microwave radiation that is produced by MGT.

MGT is used extensively in household microwave oven and industrial microwave heating devices. It is operated by 3-5[kV] dc high voltage that is supplied by HBI and DVR, this dc power is converted to the microwave that cooks the food[1]-[3].

The dc power should be controlled in order to make the best use of cooking characteristics according to the kinds of food, but usually, it is controlled by the on-off time adjustment of input power because of price competitive power and simple structure.

In the meantime, most switching power supplies use a bridge rectifier and a bulk storage capacitor to derive dc voltage from the utility ac line.

In this rectifying circuit, ac line current flows when the instantaneous ac voltage exceeds the capacitor voltage, the resulting spikes of line current are nonsinusoidal with a high content of harmonics[4]-[6].

A size of the capacitor is bigger, the width of line current is narrower and the peak value is higher[5].

By phenomenons that refered in above

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sentense, RFI problem is caused, power factor is grown worse[4].

Also, because load current is inversely proportional to power factor under the condition of equal power and voltage, the power loss is inversely proportional to the square of power factor.

This paper describes the characteristics improvement of switching power supply for driving microwave oven, this switching power supply has higher power factor and can linearly control dc power to various food.

2. System configuration

Fig. 1 shows MGT control block diagram for microwave oven. Main circuit is comprised of a bridge rectifier, step-up converter(SUC) and its controller, half bridge inverter(HBI) and its controller, double voltage rectifier(DVR), and MGT.

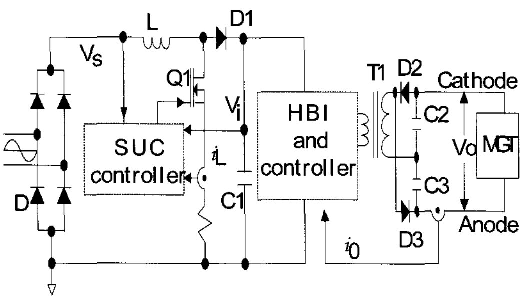


Fig. 1 MGT control block diagram

The SUC circuit is made up of different kind of elements, such as inductor L, MOSFET Q1, diode D1, capacitor C1, and can be used, with additional control and sensing circuit, as converter that supply stepped-up dc voltage(V_i) to HBI and as power factor corrector

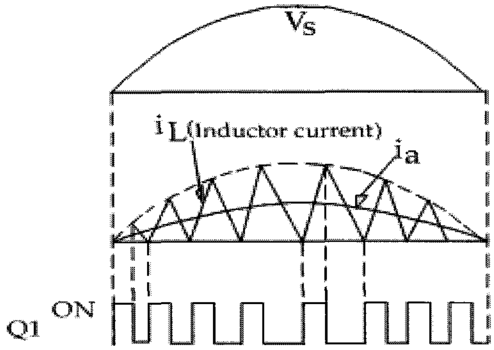


Fig. 2 Operation waveforms of SUC

Fig. 2 shows SUC operating waveforms, and switching element Q1 is operated so that most complex load appear resistance load to the ac line(so that ac line power factor approaches to 1). SUC controller is a power factor correction controller which operates in the critical conduction mode.

Q1 is turned on when the current flowing in an inductor L, inductor current(i_L) reaches zero and turned off when the inductor current meets the rectified voltage(reference voltage, V_S). In this way, inductor average current(i_a) is controlled so that the period and amplitude follows those of V_S, respectively, therefore, a good power factor is obtained[5], [6].

In the SUC circuit, the inductance of inductor L is 430[uH], and turn-number is 30. HBI is composed of two capacitors, two switching elements and step-up transformer T1.

The primary inductance of T1 is 650[uH] when substitute V_i=400[V], D_m =0.42, Δi=1.29[A], f_s=50[kHz] to Eq. (1), and turn-ratio of the primary and secondary side is 1:10, and switching elements is used IRF450A.

$$L \fallingdotseq \frac{V_i/2 * D_m}{2\triangle i * f_s} \qquad (1)$$

where D_m is maximum duty ratio, $\triangle i$ is the primary maximum current, and f_s is switching frequency.

HBI controller is fully implemented with a PIC16F874 so that the various function, such as initial power selection by push button switch, over current shutdown using 8 bit A/D conversion can be implemented, and IR2113 is used for gate driver of two switching elements.

The MGT is a diode-type electron tube which is used to produce the required 2.45[GHz] of microwave energy.

The MGT includes the anode, the cathode, the antenna, and the permanent magnets, as shown in Fig. 3(a), where cathode is located in the center of the MGT and has highly negative potential.

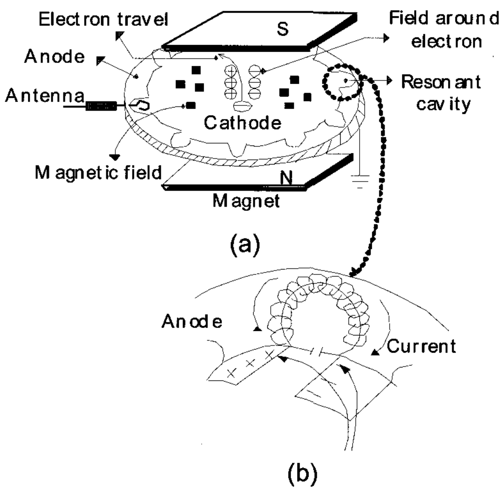


Fig. 3 MGT internal structure

Magnetic field is uniform and is applied in perpendicular direction with a circular ring so that it is parallel with the axis of the cathode.

Electrons tend to move from a point of negative potential toward a positive potential where no magnetic field is applied. The magnetic field around the moving electron adds to the permanent magnetic field on the right side of the electron's path and subtracts from the permanent magnetic field on the left side. This action weakens the field on the left side, therefore, the electron path bends to the left side.

An alternating current is induced because the physical structure of the anode forms the equivalent circuit of a series of resonant inductive-capacitive circuits, as shown in Fig. 3(b). The currents around the resonant cavities cause them to radiate electromagnetic energy at that resonant frequency.

3. Experiment and discussion

Table 1 shows specifications for the MGT. Fig. 4 is the experimental device that is composed of control system part, microwave oven part that is including MGT, and measurement part.

The MGT that is used for experiment is 2M213 produced by LG, and experimental devices include high voltage probe (N2771A), current amplifier(TM502A) and probe (A6302), oscilloscope and etc.

Table 1 Magnetron specifications (2M213)

Item		Specification
Frequency		2.46[GHz]
Output Power		560[W]
Anode Current	Mean	150[mA]
	Peak	900[mA]
Filament Current		10.3[A]
Anode Voltage		3.9[kV]
Efficiency		70[%]

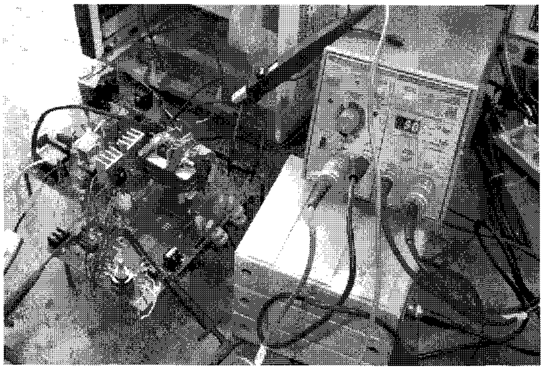


Fig. 4 Experimental devices

Fig. 5 shows waveforms of Q1 gate signal (Ch1), rectified voltage(V_S, Ch2), inductor current(i_L, Ch3).

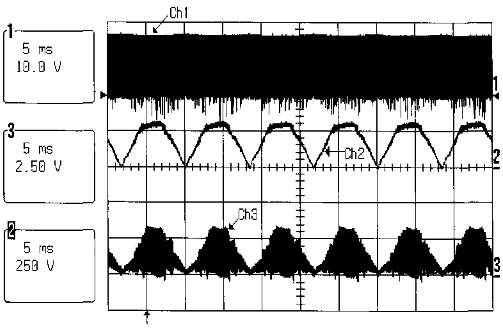


Fig. 5 Waveforms of SUC

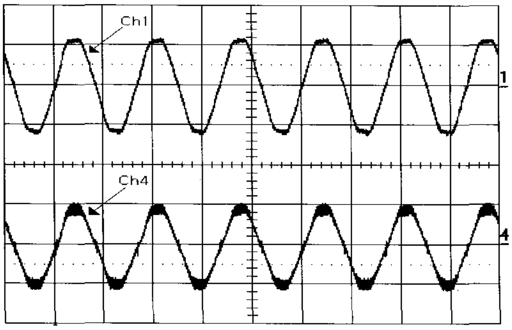


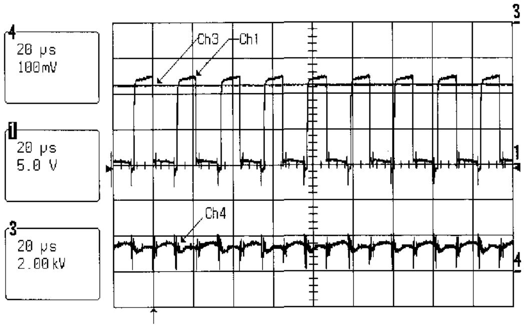
Fig. 6 Waveforms of line input source (ch1: input voltage(300V/div), ch4: input current (2.5A/div))

Fig. 6 shows waveforms of ac line voltage(Ch1) and current(Ch4), and the power factor keeps more than 98[%].

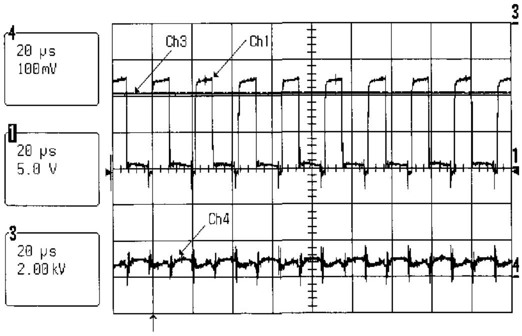
Fig. 7 shows waveforms of MGT input voltage(V_O, Ch3) and current(Ch4) to evaluate DC power control by DR regulation of switching elements for HBI under 46[kHz] frequency.

Fig. 7(a) shows the resulting waveforms of MGT input voltage and current, and they are 3.573[kV] and 65.2[mA] respectively, when DR is 41.5[%].

Fig. 7(b) shows the resulting waveforms of MGT input voltage and current, and they are 3.875[kV] and 48[mA] respectively, when DR is 38[%].



(a) f=46[kHz], DR=41.5[%]



(b) f=46[kHz], DR=38[%]

Fig.7 MGT output characteristics with duty ratio variation of HB inverter switching pulse.(ch1: gate pulse (5V/div), ch3: MGT anode voltage (2kV/div), ch4: MGT anode current(100mA/div))

In this paper, line input power is controlled linearly from maximum 285[W] to minimum 235[W], and the control range of line input power is 17.5[%].

Fig. 8 shows characteristics curves of power control by DR regulation under constant 46[kHz] frequency.

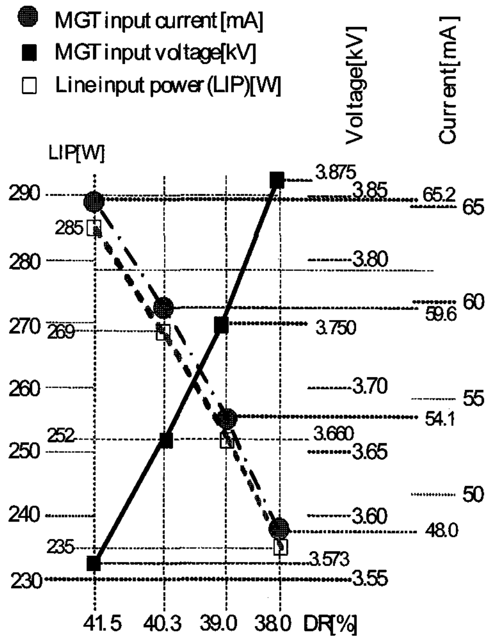


Fig. 8 Characteristics curves of power control by DR regulation of HBI

As shown in Fig. 8, line input power(LIP) includes MGT heater power 24[W], and LIP can be controlled extensively to 17.5[%] because MGT input current can be controlled to 26.38[%] when MGT input voltage changes in the range of 7.8[%].

At this time, the efficiencies in maximum and minimum power reach 90[%] and 89[%] respectively, and average efficiency is 89.8[%].

4. Conclusions

Experiments are carried out using the proposed circuit. Some characteristic results are shown below

(1) According to result that switching of Q1 element is acted so that form of inductor average current is same with that of the rectified voltage in SUC circuit, the line power factor could be kept more than 98 [%].

(2) Differing from conventional MGT control system which controls MGT input power by on-off time adjustment of line input power, proposed system can have excellent cooking characteristic to different kinds of the food because it can control line input power to a range of 17.5[%].

(3) Because semiconductor elements that is used to HBI inverter is operated by half of input voltage, voltage stress of switching element could be reduced by half, and the circuit elements could be minimized.

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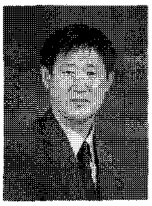
Author Profile



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