A Study on Constant Power Control of Half Bridge Inverter for Microwave Oven

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ABSTRACT

For the global microwave market, high RF power or deluxe model is applying for Inverter gradually. In this study, 120V/1200W high power Inverter was proposed and verified by an optimized design of PFM-type. Especially the steady power output control was fulfilling at +/- 10% input voltage variation.

1. Introduction

As a power supply system, Inverter is applying for the microwave oven increasingly due to following merit. Firstly, Inverter type power supply system can be designed high power easier than LC resonance type power supply system.[1][2] Firstly, linear power output can be obtained and controlled precisely. Accordingly, Cooking and defrost performance for microwave oven function is improved.

In this paper, PFM(Pulse Frequency Modulation) control suitable for the microwave oven Inverter is described. A compensation circuit accompanied by input voltage variation and IGBT operating circuit is proposed and major characteristics were tested for the half-wave bridge Inverter of designed series resonance type.

2. Inverter system design for microwave oven

2.1 Proposed Inverter system

Table 1 shows specification of Inverter for microwave oven. Fig. 1 shows the proposed block diagram that consists of Inverter power supply part and micom controller.

The power output compensation circuit in power supply part of Inverter is to detect input voltage variation. The output voltage of DA converter is in inverse proportion as input voltage variation by this output and compensated. Accordingly, this compensation circuit is to function as input voltage variation and compensated DA converter output is connected to the non-inverting terminals of OP AMP.

CT(Current Transformer) is inserted in a terminal of power supply and its output is connected to the inverting(-) terminal of OP AMP to be same voltage level as OP AMP output. And, this OP AMP output is flow out the integrator and a basis signal for frequency control of PWM.

Table 1 Specification of Inverter

ITEM	Value
Rated Input	120V/60Hz
RF power output	1200 W
Efficiency	More than 60%
ibm	Less than 1.5A
ebm	Less Than 4.8kV

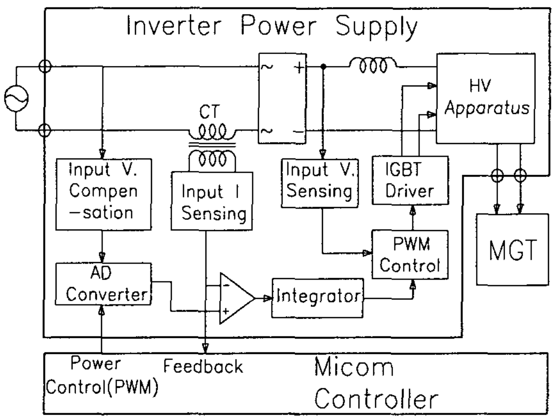

Fig.1 Proposed Inverter block diagram

PWM signal of micom is an input of Photo Coupler in Fig. 2 and this signal is to be a voltage source using A, flows out DA converter and obtains output B. Table 2 shows voltage of point A for input voltage.

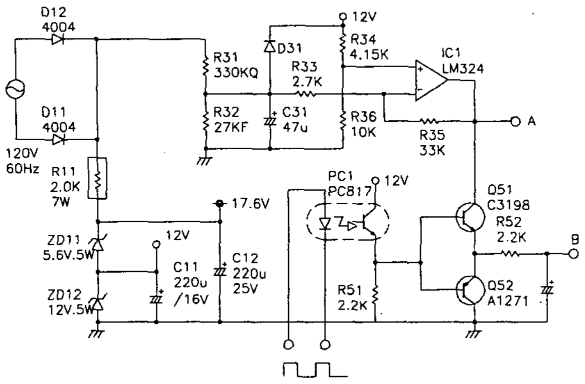

Fig. 2 Circuit diagram of DA converter & power supply

Table 2 Output voltage of negative AMP.

Input V	108V	120V	132V
Point A[V]	10.8	9.7	8.6

3. SRHBI(Serial Resonant Half Bridge Inverter) design

3.1 SRHBI analysis

Fig. 3 shows SRHBI circuit and functional wave form for magnetron operating. It consists of half-bridge type using two switches and operates serial resonance between the primary coil of transformer and C_{r1}, C_{r2}.

The current wave form for each shows in Fig. 3. Current i_{in} that is supplied from input section C_f is correctly a half of transformer primary rectified current i_L. However, a maximum value of switch current is same as transformer primary current i_L.

Fig. 4 shows turn-on current direction when each mode is splitted a switching period of each switch.

(1) mode 1 ($t_0 \sim t_1$) :

This mode is switch S_1 ON period and serial resonance current between transformer primary coil and C_{r1}, C_{r2} is flowed through this switch. So, the current form has similar to sign. Before half period of resonance is completed, switch S_1 will be OFF and transform to ZVS(Zero Voltage Switching) mode.

(2) mode 2 ($t_1 \sim t_2$) :

This mode is all switches OFF period and initial voltage of C_{a1} and C_{a2} at t1 is 0V and V_{in} of input terminal voltage. These initial voltages will exchange each other though a serial resonance between transformer primary coil inductance and C_{a1}, C_{a2}. So, the voltage of C_{a1} and C_{a2} at t_2 is V_{in} of input terminal voltage and 0V for each. At this time, inverse parallel diode of S_2 will be in forward bias and turn-on, and then this mode will be transformed to next mode

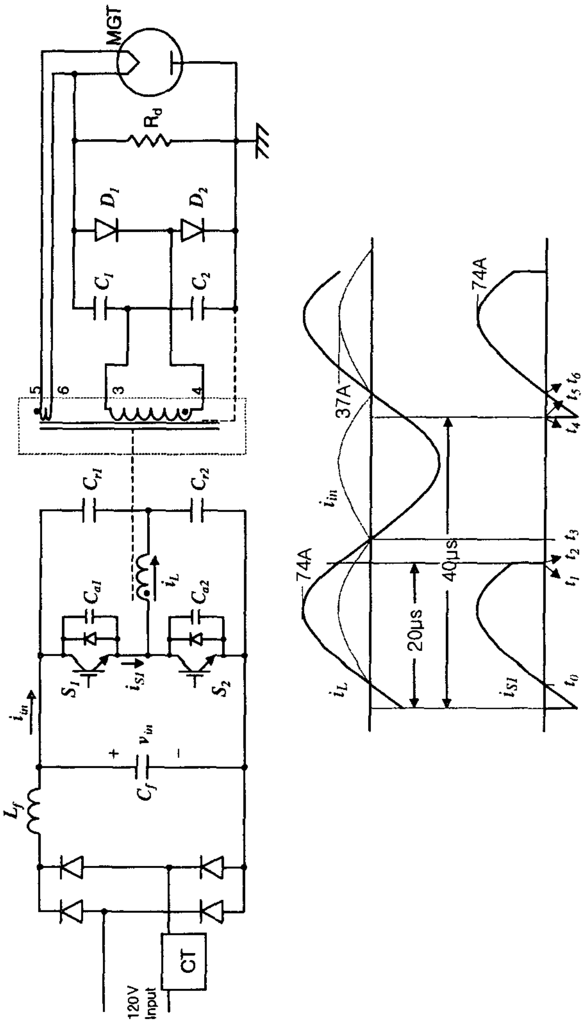

Fig. 3 Circuit Diagram & wave forms of SRHBI

(3) mode 3 ($t_2 \sim t_3$) :

This period is diode turn-on and will proceed so long as transformer primary current is reached up to 0 through resonance. For this period, because switch S_2 has 0 volts, S_2 makes ON in advance. If so, transformer primary current at the moment of zero through main resonance is transform to next mode which is changed current direction.

(4) mode 4 ($t_3 \sim t_4$) :

This period is switch S_2 ON and serial resonance current between transformer primary coil and C_{r1}, C_{r2} is flowed through this switch. So, the current waveform has similar to negative region of sign wave. Before half period of resonance is completed, switch S_2 will be OFF and transform to the second ZVS(Zero Voltage Switching) mode.

(5) mode 5 (t_4~t_5) :

This period is all switches OFF and initial voltage of C_{a1} and C_{a2} at t_4 is V_{in} of input terminal voltage and 0V for each. These initial voltages will exchange each other though a serial resonance between transformer primary coil inductance and C_{a1}, C_{a2}. So, the voltage of C_{a1} and C_{a2} at t_5 will be 0V and V_{in} of input terminal voltage for each. At this time, inverse parallel diode of S_1 will be in forward bias and turn-on, and then this mode will be transformed to next mode

(6) mode 6 (t_5~t_6) :

This period is diode turn-on and will proceed so long as transformer primary current is reached up to 0 through resonance. For this period, because switch S_1 has 0 Volts, the switch makes ON in advance. If so, transformer primary current at the moment of zero through main resonance is transform to the initial mode and a cycle is completed.

The peak value of this current can be investigated when assuming supply wattage 2kW for Inverter circuit at input terminal Cf and clearly rectified sign wave to supply input current i_{in}.

When the input current i_{in} and input voltage V_{in} to supply input terminal C_f is described in Fig. 3, the average input power can be calculated using following formula.

$$P_{in} = \frac{2}{T}\int_0^{T/2} v_{in}\, i_{in} dt$$
$$= \frac{2}{T}\int_0^{T/2} V_P \sin \omega_s t \cdot (V_P \sin \omega_s t \cdot I_P) \sin \omega_r t dt$$

If so, the calculated maximum peak current Ip to supply input terminal C_f is 37A. Because the current of transformer primary coil is double compared to i_{in}, maximum peak current of i_L is 74A as described in Fig. 3.

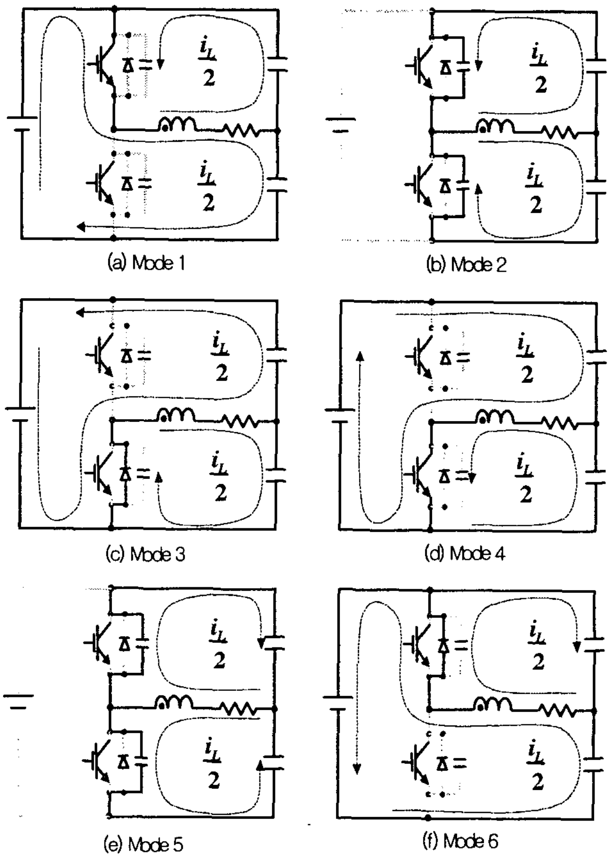

Fig. 4 Current direction of each mode

3.2 Design for HV Transformer(HVT)

We are decided to the core spec. is Isu Ceramic's UTV4671B (effective core area : 2.28㎠) and MGT is Panasonic's 2M261-M32.

In this paper decided final spec. of turns 1:16:350 and its gap is 2mm.

Fig. 5 shows the SRHB Inverter's circuit diagram designed by this paper. Fig. 6 Shows Photograph of the SRHBI type MWO Inverter

4. Experimental Results

A 1.2kW SRHB Inverter has been PC board to verify the operation of the proposed Inverter. Fig. 7~9 shows the MW operating range.

It can be seen that the SRHB Inverter operation time is 6.8[ms], it's wide range of 120Hz phase. Filament current is also suitable measurements 10.42[A] when the MGT generating Microwave.

Operating frequency measurements from 22kHz to 29.8kHz by PFM at the 2kW. and average overall efficiency of 60.1% is achieve.

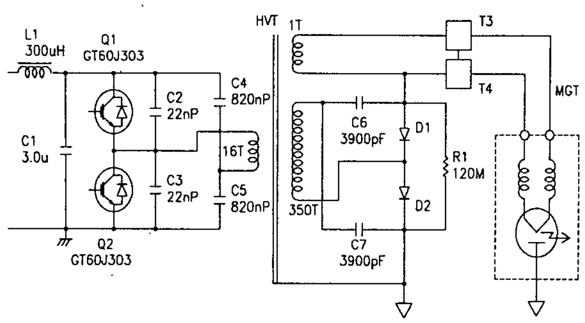

Fig. 5 Designed circuit diagram of SRHBI

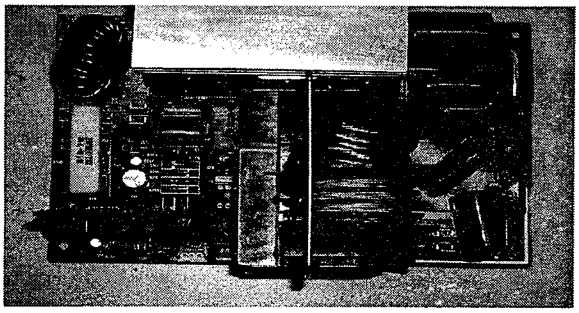

Fig. 6 Photograph of the SRHBI type MWO Inverter

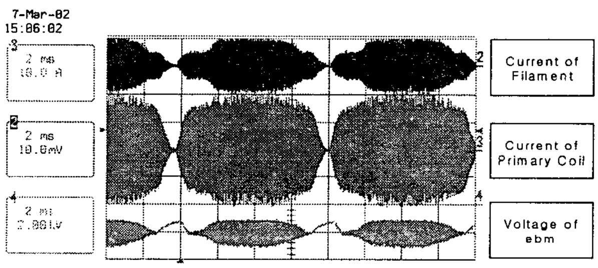

Fig. 7 Waveforms of the SRHBI at the 120V/1.2kW

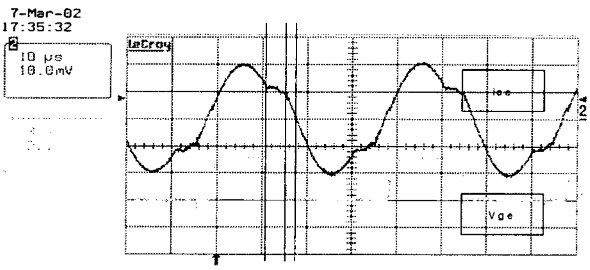

Fig. 8 Voltage waveforms of SW at the low voltage side PFM

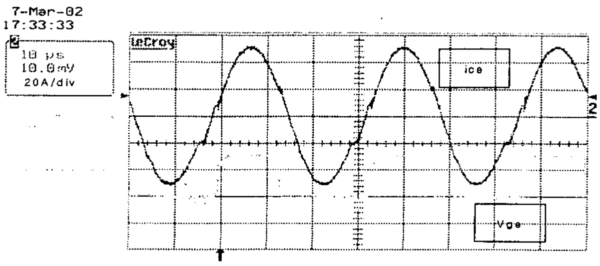

Fig. 9 Voltage waveforms of SW at the high voltage side PFM

5. Conclusion

In this paper SRHB Inverter for 1.2[kW]/120[V] output power MWO power supply and a generalized method for analyzing SRHB Inverter has been presented.

Input current is not exceed 17[Arms] at the 1.2[kW] output power.
Unfortunately we did not analysis of active load of MGT. Therefore the parameters of high voltage parts are designed way of a experimental, so it is necessary to do more studying of be related high voltage capacitor with output power.

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