General-Purpose Induction Heating Inverters

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1. Introduction

This paper introduces Fuji Electric's general-purpose, induction heating inverter series and its main applications in the market. It also introduces a small capacity, thin, drop-in type general-purpose induction heating inverter recently developed for installation in restaurant guest rooms.

2. General-Purpose Induction Heating Inverter Series

Fuji Electric's general-purpose heating inverter is a device which generates high-frequency current for induction heating. The operating frequency is 20 to 50 kHz, enough to cover a wide range of uses.

In addition, to enable smooth operation with various loads, Fuji Electric's original start operation circuit and γ angle control circuit are incorporated in the inverters. The high-speed switching characteristics of IGBT, used in the main circuit power device enable precise control of the heating power, even in the low output region.

In order to avoid generating the input current distortion typically seen in general variable-speed inverters, the capacity of the DC smoothing capacitor is reduced to its minimum requirement, thereby improving the input power factor and suppressing harmonic current. The input voltage and current waveforms and the output current waveform are shown in Fig. 1.

The single-phase power supply inverters has reached an input power factor of 1.0. By modifying the input current waveform into a near sinusoidal waveform and suppressing harmonic current generation, the inverter satisfies the IEC limit for harmonic current. The characteristics of the input harmonic current are shown in Fig. 2.

Figure 3 shows a circuit diagram of the induction heating inverter. Its operation is described below.

A three-phase or single-phase AC supply is rectified and smoothed by the diode bridge and film capacitor, and then converted into high-frequency current by the half-bridge type inverter with IGBTs. The high-frequency current is converted into electromagnetic energy by the heating coil, a part of the resonance circuit, and supplied to the object to be heated. The input circuit is equipped with an EMI filter to suppress line noise within the limit specified by the international special committee on radio interference (CISPR).

On the basis of a command given by the setting

Fig. 1 Input and output waveforms of the single-phase induction heating inverter

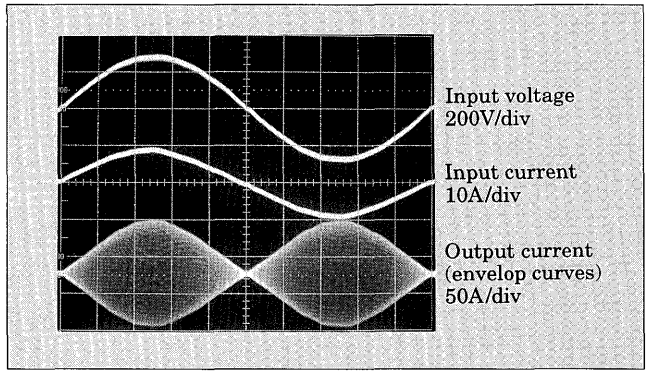


Fig. 2 Characteristics of input harmonic current (single phase input)

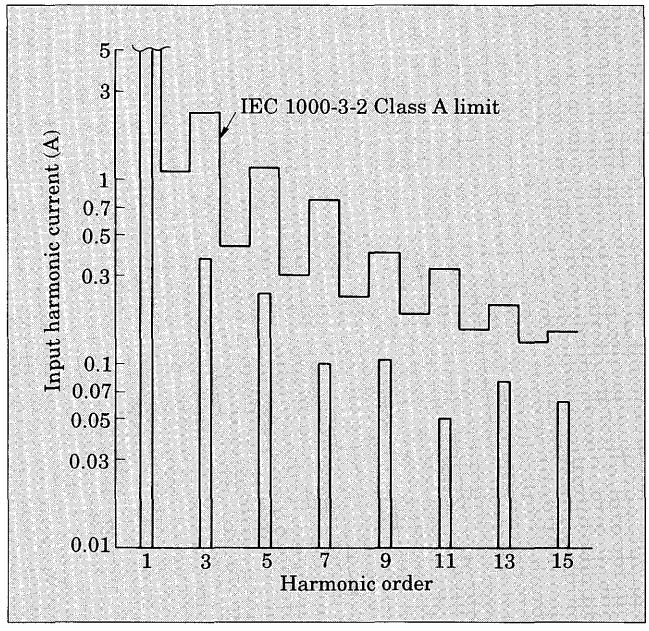


Fig. 3 Circuit diagram of the induction heating inverter

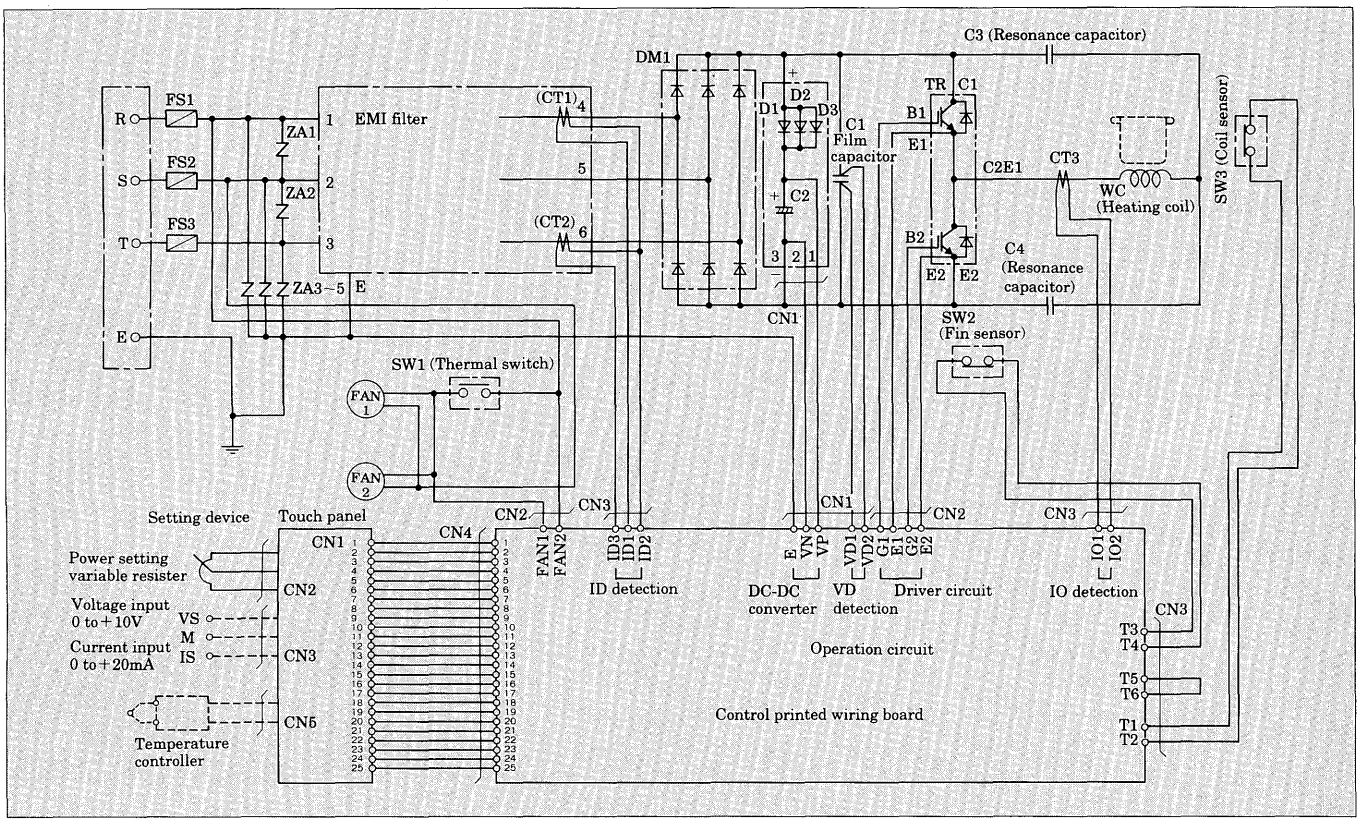


Fig. 4 Output voltage and current waveforms

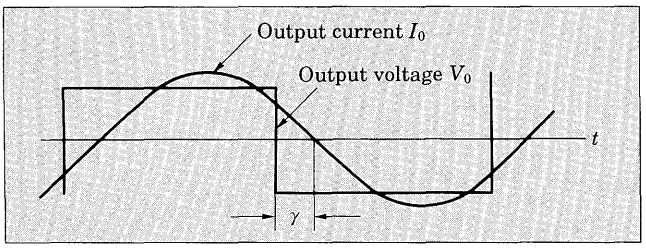
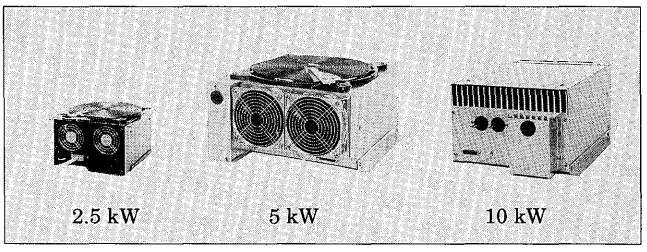


Fig. 5 Exterior views of the standard heating inverters



device, the control system calculates an optimum value for the phase angle γ (using a computation circuit which includes a custom IC), converts it into switching commands, and drives the IGBT.

This control varied the phase angle γ, between inverter output voltage and current shown in Fig. 4, to adjust high-frequency power. The exterior views of some standard heating inverters are shown in Fig. 5, and their specifications, in Table 1.

3. Main Uses of General-Purpose Heating Inverters

The 2.5 to 5.0 kW products are mainly used as the primary heat sources in the kitchen for all types of cooking, including Japanese, western, and Chinese foods. The use of heating inverters for cooking in kitchens and restaurant guest rooms exceeds 80% of all induction heating uses.

The 7.0 to 15.0 kW products were developed mainly for industrial uses such as warming, drying, and the heat treatment of metals.

These heating inverters are based on industrial induction heating inverter technology developed for the industrial heat treatment of metals and designed for general purpose, to be small in size, light in weight, and easy to handle. Industrial applications are expected to increase for these inverters in the future.

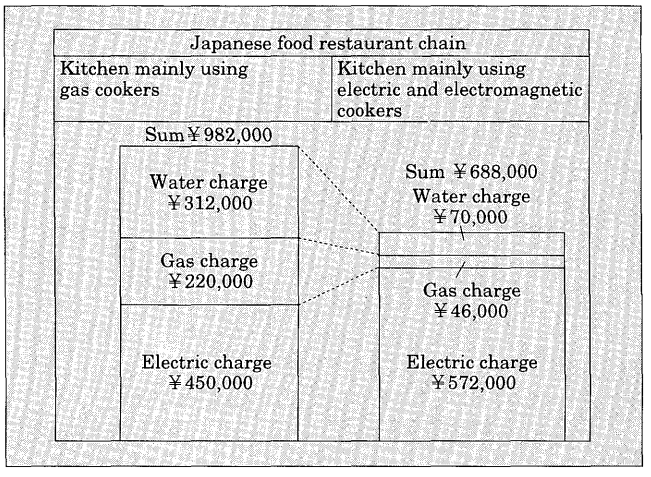
The use of electromagnetic induction heating naturally improves the 3C (Cool, Clean, and Control) conditions of the working environment and also has the advantage of reducing overall initial cost and running cost. Below, the running costs for induction heating and gas heating will be compared when used as cooking heat sources.

When gas heating is used, only about 35% of the heat is used effectively, the rest is spent as exhaust heat to warm the room. Cooling equipment for the room, therefore, will be large in size, high in price, and costly to maintain.

Table 1 Specifications of the standard heating inverters

Model	HFR025F7A-7	HFR030C7K-2	HFR050C7K-2	HFR070C7K-2	HFR100C7K-2	HFR150C7K-2
Supply voltage	200V ± 10%	200/220V ± 10%	200/220V ± 10%	200/220V ± 10%	200/220V ± 10%	200/220V ± 10%
Input power	2.5kW ± 10%	3.0kW ± 10%	5.0kW ± 10%	7.0kW ± 10%	10.02kW ± 10%	15kW ± 10%
Heat efficiency	86% or more	90% or more	92% or more	92% or more	92% or more	92% or more
Appropriate pan diameter	200 to 230mm	280 to 300mm	280 to 300mm	–	–	–
Usable pan materials	Steel, stainless steel attracted by a magnet or 18-8 stainless steel 1 mm or less thick. Note that heating power for 18-8 stainless steel decreases by 20% to 30% .					
Enclosure	Open	Totally enclosed	Totally enclosed	Totally enclosed (Without work coil)	Totally enclosed (Without work coil)	Totally enclosed (Without work coil)
Mass	7kg	12kg	15kg	13kg	15kg	18kg
Electrical Appliance Type Approval No.	㊦81-18927	㊦81-18928	㊦81-20596	–	–	–

Fig. 6 A running cost comparison



On the other hand, when electromagnetic heating is used, more than 90% of the heat is effectively used. Cooling equipment can be small, low-price, and have low maintenance costs. In addition, since the cooking room and kitchen utensils will not become dirty, the amount of water used for cleaning will be greatly reduced.

A comparison of running costs in a chain of Japanese food restaurants is shown in Fig. 6. The result was a cost reduction of about 30%.

4. Small Capacity, Thin, Drop-In Type, General-Purpose Induction Heating Inverter

A 2.5 kW thin, drop-in type, general-purpose heating inverter has recently been developed by Fuji Electric and placed in the market.

A small capacity electromagnetic cooker which was formerly regarded as a household appliance has been remodeled into a small capacity drop-in type heating inverter for use in restaurant guest rooms or commercial kitchens.

This development, based on the same design concept as the previous 2.5 to 15 kW heating inverters, has realized high reliability and long life. The exterior view of the 2.5 kW thin, drop-in type heating inverter is shown in Fig. 7, and the specifications, in Table 2.

Fig. 7 Exterior view of the 2.5 kW thin, drop-in type heating inverter

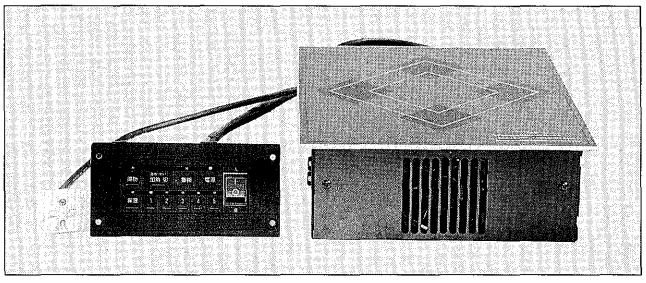


Table 2 Specifications of the 2.5 kW thin, drop-in type heating inverter

Model	HFR025R7A-7
Supply voltage	200/220V ± 10%
Input power	2.5kW ± 10%
Heat efficiency	86% or more
Appropriate pan diameter	ϕ120 to 260 (Optimum diam. ϕ220)
Usable heated materials	Magnetic metals, iron, magnetic stainless steel. (Also can heat 18-8 stainless steel of 1 mm or less in thickness.)
Enclosure and cooling system	Open/forced cooling
Mass	approx. 5.6kg
Electrical Appliance Type Approval No.	㊦81-21517

This product has qualified for UL Recognition and has an Electrical Appliance Type Approval Number.

5. Conclusion

As described above, the use of general-purpose heating inverters is increasing and market requirements are diversifying.

In future, we will continue technical development in this field to meet user demand for optimum heating and to improve the size, functionality, and reliability of heating inverter units. Further guidance and cooperation by the parties concerned will be appreciated.