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High-frequency transistor converters for induction heating

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D. Bondarenko, S. Dzliev, D. Ershov, D. Patanov, I. Tihomirov, P. Chernetsov

St. Petersburg State Electrotechnical University, Russia.

ABSTRACT. The paper deals with a series of transistor converters for induction heating in a frequency range up to 200 kHz, based on voltage inverters. Main parameters of the converters as well as fundamentals of the control of induction technological processes realized by microprocessors are described. The circuits and design of the devices serving for matching of work-coils with the converter are outlined.

INTRODUCTION. Our experience of development, introduction and operation of high frequency technological installations for induction heating with transistor converters has demonstrated the following. The advantages of the new transistor power supplies are not restricted by their high efficiency, light weight, ease of operation, and more flexible control systems. Moreover, their introduction would permit to realize a broad spectrum of new technological processes. The devices for the manual induction brazing of windings of powerful electric machines during their manufacture and repair could be cited as an example. This efficient technology was not possible before the development of small-sized power supplies and induction units.

A variety of technologies using the induction heating motivated the development of flexible adjusted systems with the universal frequency converter supplemented by the unit serving for matching with specific induction systems. The frequency converter structure with the independent key switchboard on power transistors - the voltage or current inverter, supplemented by the programmed control system is best suited in this case. The switched or replaceable matching unit supplements the system.

The use of universal frequency converters essentially simplifies the development of power supply systems for various technological installations, raising their competitiveness. A series of the transistor frequency converters TGI for induction heating described below [1] suits these requirements.

The TGI generators with capacity of 10, 25, 40 and 60 kW work in frequency ranging from 50 to 200 kHz. They served for power supply of various devices of induction heating. Installations for induction brazing, hardening, surfacing, metal heating before plastic deformation, shrink fit of machine parts, butt welding of pipes and tape, bevel welding, stress removal in pipes and metal sheets after welding, drying of painted metal surfaces, etc. could be completed by these generators.

The microprocessor control unit provides measurement and indication of the current power and voltage, as well as the generator frequency. It also provides the indication of the timer parameters, an operating time after switching-on, the diagnostics of causes of switching-off due to the activation of the protection systems, setting of the timer and regulator, communication with the remote computer.

The control unit stabilizes the output power and limits the output current of the converter, using the frequency regulating channel in the AFC mode of output frequency. Due to the maintenance of a soft switching mode of the transistors the efficiency of the TGI generators reaches 96 %.

The generators weight is from 0.5 to 1kg/kW and the volume is from 1.5 to 3dm^3/kW. The microprocessor control units and design, corresponding to the European standard of 19', allow to adjust these generators to different modern technological systems. An external view of the TGI generator 40/100-3 is shown in fig. 1.

For the maintenance of the various technological processes, the programmed control unit of the converter is adjusted to the following control algorithms:

1. Regulation of power, current or temperature at the given level,
2. Change of the current power or temperature in accordance to the given time regularity, and
3. Transition from regulation of one parameter to the other, for instance, the transition from the power stabilization to the temperature stabilization during the accelerated heating.

Figure 1

The maximization of power with the restriction of the output current and temperature of the heated piece from above are sufficient for the operation of all these modes. Moreover, the protection of the converter from overload requires the voltage limiting from above at the compensating capacitor.

STRUCTURE OF THE TECHNOLOGICAL INSTALLATION WITH THE TGI GENERATOR. The structure of the technological installation for induction heating based on the transistor TGI generators is given in fig. 2. Apart from the generator, the installation includes the induction system (IS), the matching unit (CU) and a personal computer.

The TGI generator consists of the power supply unit and the control system (CS) which, in its turn, consists of the invariant part providing the generator operation, and the adjusted part based on the microcontroller. The power supply unit consists of the uncontrolled rectifier B, the capacitor filter F, and the transistor voltage inverter with frequency control.

The circuit of the power supply unit of the installation is given in fig. 3, where C1 is the filter, C2 is the blocking capacitor, C3 is the compensating capacitor, and Li, Ri is the circuit for work-coils replacement..

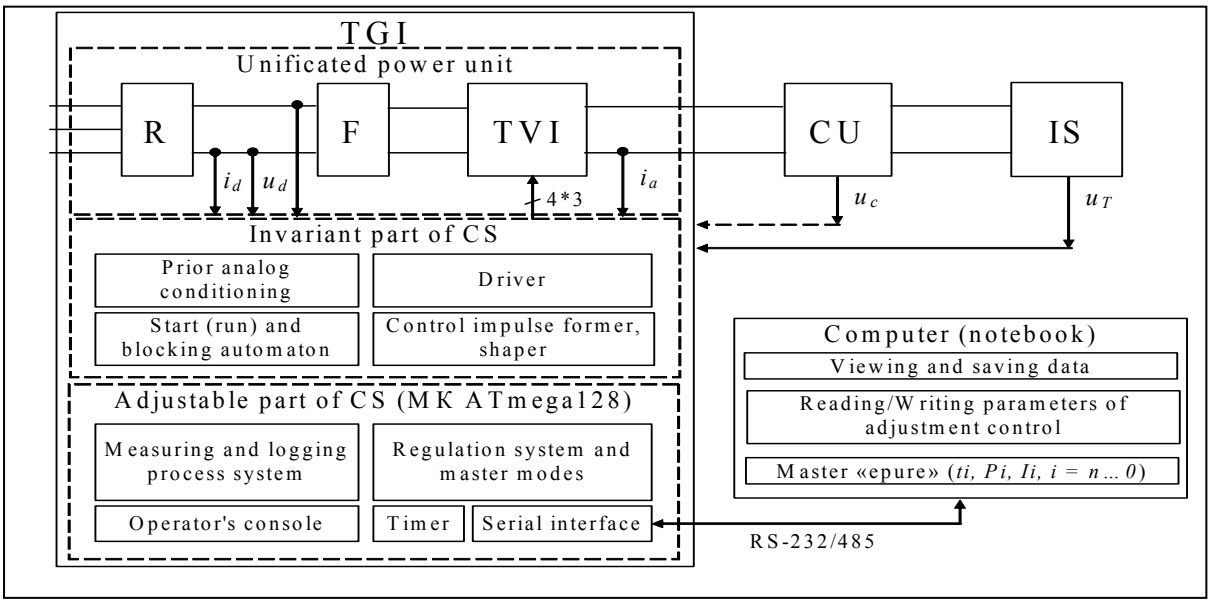

Figure 2

The invariant CS unit based on the analog and digital microcircuits carries out the following ordinary control functions with required high speed of response and reliability:

- Formation and distribution of control pulses providing low switching losses,
- Amplification of control pulses, galvanic isolation, the control of power drops, the discharge - source of power transistors (the driver functions),
- Preliminary analog processing of signals from transducers of a current (*id, ia*), voltage (*ud, uc*), temperature *(T),* etc., and

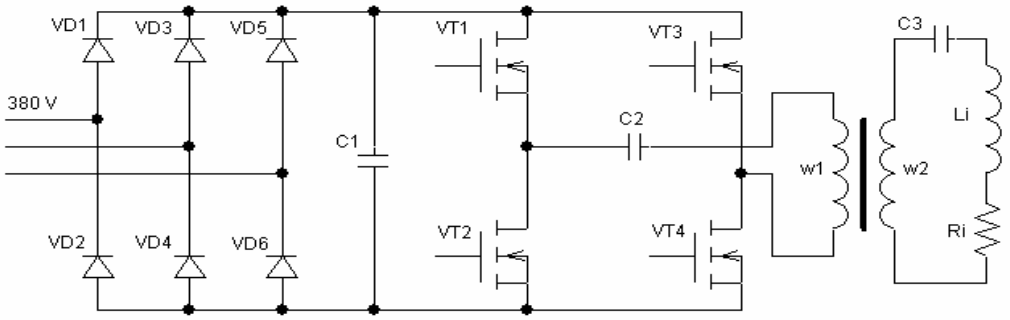

Figure 3

- Regular switching on and off of the generation, identification and recording of emergency situations (current excess, voltage deviation, overheat of the power unit, failures in the systems of water and air cooling, etc.) and protective switching off.

The microcontroller ATmega128-16 (Atmel) is in the core of the adjusted part CS. It carries out the following functions:

1. Adjustment on the chosen control mode, including:
- Direct frequency control, and
- Power stabilization with restrictions on frequency, output current, voltage at the matching capacitor and temperature of a heated part,

2. Restriction of the operating time (the timer with the minimal step up to ti = 0.01 s) or energy contribution (the power integral $\sum P_{di}\, t_i$),

3. Automatic storage of the operating time and settings,

4. Measurement, registration and indication of some electric and non-electric parameters of the TGI operation, and

5. Connection with a personal computer using the successive communication channel (RS-232/485), supported by the special software, while realizing the following modes:

- storage the information about the technological process,
- program input for the generator operation, for instance, as a sequence of the time *ti* , power *Pdi*, current *Iai,* and temperature *Ti* settings, and
- calibration and automatic calibration of measurement and indication channels, adjustment of parameters and functions of the timer.

The adjustments are partly set by producers according to the consumer requirements, partly set by users.

The use of a computer is not necessary while it could serve for automatic data processing in the study of new technological processes, re-adjustment of control algorithms, cyclogram input and storage in the energetically independent memory of the CS TGI.

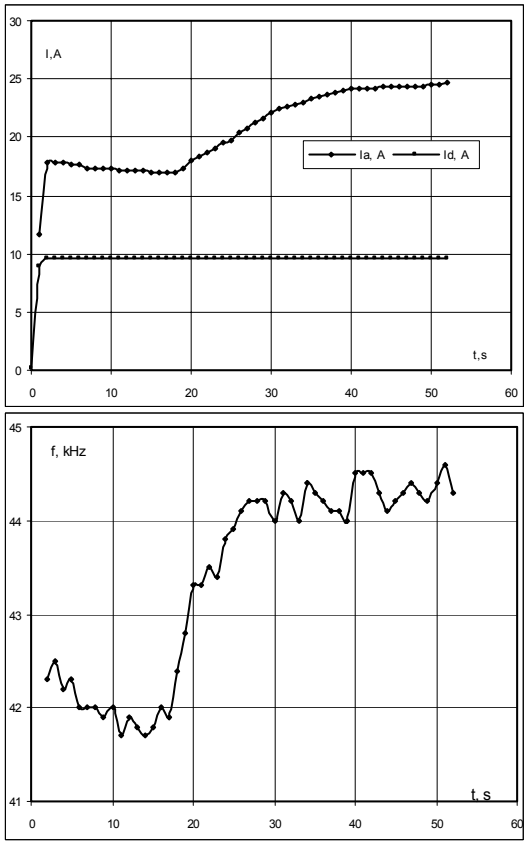

Figure 4

Figure 5

Figure 6

Figure 4 displays diagrams of change of the rectifier current *Id*, the output current of the inverter *Ia*, and output frequency of the inverter *f* . These were registered by a computer during the heating of a ferromagnetic part while brazing of a hard alloy tip under the stabilization of power mode. With a direct current of the rectifier the output current of the converter changes in 1.5 times due to the change of specific resistance and the loss of magnetic properties of the heated steel. The diagram demonstrates that 1.5 allowance of the output current of the generator is required to maintain a constant power during heating of the magnetic steel with temperature exceeding the Curie point.

The changes in output frequency of the generator, providing stabilization of the converter power in the technological process, lie within narrow limits from 42 up to 44.5 kHz, which rest the heating process essentially unaffected.

EXAMPLES OF USE. The induction heating of the shroud ring of a turbo-generator using the device with the TGI 40/100 generator is given in fig. 5. The heating time of the shroud for its removal from shrink fit varies from 40 to 60 minutes depending on the turbo-generator type. Figure 6 demonstrates the brazing of stator winding of a motor. Small size of the heating unit and work-coils allows to braze closely spaced winding leads without deformation.

CONCLUSION. The transistor TGI generators could be used as universal power supplies for various technological installations of induction heating due to the programmed control unit, the frequency independent power circuit and problem-oriented software.

REFERENCES

[1] S. Dzliev, H. Conrad. Induction soldering of cooper buses. Elektrowarme international. Heft 3/2001, September, p.p. 98 – 102.
