



# CONVERTER OF FREQUENCY AND NUMBER OF PHASES FOR FLASH-BUTT WELDING OF RAILS

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The aim of the work is experimental verification of possibility of using the thyristor frequency converter with direct connection for 37.5 Hz for power supply of two-phase flash-butt welding machine from three-phase mains for its uniform loading. For experimental verification and tests the converter was designed according to the circuit with two three-phase full-wave controlled rectifiers connected in an antiparallel mode. The industrial tests were conducted in welding of steel R65 rails using continuous and pulsating flashing during two years at the rail welding enterprise. It was found that the quality of welded joints met the technical specifications. The analysis of plots of changes of effective values of phase currents showed that difference of these values did not exceed  $\pm 2\%$ . At the same time the phase currents were 20 % lower than the current at the load. Thus, the pilot tests of the frequency converter for 37.5 Hz showed its possibility and rationality for application for flash-butt welding, in particular, of railroad rails due to uniform loading of three-phase mains. At that the efficiency of using converter can be significantly increased by applying it in the flash-butt welding machine power transformer, designed for 37.5 Hz. 7 Ref., 3 Figures.

**Keywords:** *flash-butt welding of rails, thyristor frequency converter, uniform loading of three-phase mains*

For flash-butt welding of the railroad rails the stationary and suspended welding machines are used, which basically have two different circuits of electric power [1, 2]: from single-phase (two-phase) alternating current mains of 50 Hz (60 Hz) frequency, and from three-phase mains and source of rectified voltage.

The single-phase (two-phase) machines have the most simple and the cheapest circuit of power supply. The machines with a rectifier in the secondary circuit are much more complicated and expensive both in their manufacture as well as in operation [3]. They have a lower efficiency factor due to significant losses at the rectifier in the secondary circuit, but due to power consumption from three phases they surpass the machines of alternating current in terms of providing quality of the mains being used (GOST 13109–97). To provide this value, which is important for nowadays, in the machines of alternating current the converter of frequency and a number of phases with direct connection (hereinafter – converter) may be used.

In works [1, 2] it was shown that such converters of low frequency (about several hertz) found application in resistance welding and were at the first time designed by «Sciaky». However, this converter should operate with welding transformer, which has many times increased weight

and dimensions as compared to the machines of industrial frequency, and cannot be used for power supply of the existing single-phase resistance machines for 50 Hz.

In work [1] it is shown that the converter with a direct connection can be applied for power supply of the single-phase resistance welding machines, if the frequency of voltage at its output will be increased to 30 Hz and the value of voltage decreased [2]. It is known that the converter of frequency and a number of phases with direct connection can generate voltage only of certain frequencies. It is shown in work [4] that except of 30 Hz frequency for power supply of the resistance welding machines the converter with output voltage of 37.5 Hz may be used. The increase of frequency of output voltage improves the conditions of its use for welding transformers of industrial frequency, in particular, the requirement of reducing the value of generated voltage and, which is most important, achieving the uniform loading of phases.

The aim of the work is the experimental verification of possibility of using a thyristor frequency converter with direct connection at 37.5 Hz for power supply of two-phase flash-butt welding machine from three-phase mains for its uniform loading.

In flash-butt welding of rails the technology with programmed change of basic parameters is used, including voltage between the edges of welded parts, which is equal to voltage at the

output of welding transformer [5]. Since minimum voltage, at which the stable flashing is possible, depends on heating of welded parts, at the beginning of welding a high voltage is required and almost the same voltage must be at the final stage of welding. Thus, the time intervals of the transformer operation with higher voltage amount to 10–30 % of the total duration of welding and the heat losses in the transformer increase negligibly.

There is also a high probability of sharp increase in the load to electrical power mains. This is connected with the fact that decrease in frequency results in increase of working induction, which can reach saturation induction, and magnetizing current can reach very high values in accordance with nonlinearity of magnetization curve for transformer steels. In this case, even a short-term increase in supply current of welding machine may result in its emergency stop by circuit breaker. Therefore, the use of 37.5 Hz in the frequency converter is more preferable unlike 30 Hz.

For experimental verification and testing the converter with output voltage with frequency of 37.5 Hz was designed and assembled according to the circuit with two three-phase full-wave controlled rectifiers connected in an anti-parallel mode [4, 6, 7]. It is designed for rated output voltage of 400 V, rated current of 1000 A at the duty cycle of 100 %.

The frequency converter consists of the unit of thyristor rectifiers, switching unit of thyristors, unit of thyristors protection, computer control system and sensors of phase currents  $I_A$ ,  $I_B$ ,  $I_C$ , welding current  $I_w$ , output voltage of converter  $U_w$ , and temperature of casings of thyristors  $T$ , °C (Figure 1). The protection unit of the thyristors realizes the control of values of phase currents and at the values of more than 1500 A disconnects the control circuits from the input of the switching unit of thyristors. The response time of protection is 2 ms. However, the switched on thyristor cannot be instantly disconnected from the control circuit. Therefore, to protect the thyristors the quick-break fuses Fu 1, 2 and 3 are also used.

The converter control system of 75 Hz frequency measures the welding current, i.e. the value of current in each separate pulse. This value is used to calculate the signal of control movement speed of mobile column of welding machine. In addition, the converter control system measures also the output voltage of frequency converter and stabilizes the preset value of voltage, controls the temperature of thyristors of power

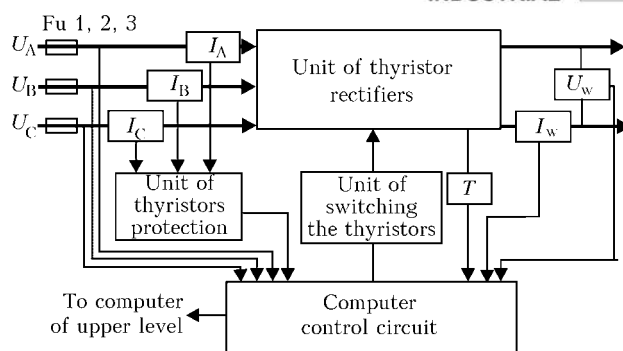


Figure 1. Schematic diagram of converter

rectifiers and stops welding at exceeding the allowable value.

The ranges of measurement of welding current are 10–1000 and 200–2000 A, the range of preset voltage at the output of converter is 200–400 V, the given error of measurement of welding current and voltage stabilization is less than 3 %, the rate of data transfer to serial channel is 19600 baud. The serial communication channel is used to link the control converter system with control system of the upper level of welding machine – reception of the value of preset voltage and transmission of the measured current and diagnostic messages.

The control system of upper level is assembled on the basis of industrial controller Siemens SIMATIC S7-300 with processor CPU314C-2 PtP. The main function of this system is the control of welding process in real time and control according to the preset cyclogram.

To evaluate the required decrease of value of output voltage of the converter the characteristics of open-circuit current of the welding transformer of flash-butt welding machine K-1000 was studied. Due to the effect of saturation of the welding transformer at low voltage frequency the open-circuit current grows significantly (Figure 2), which leads to a great overheating of the primary circuit of welding transformer and power cables of welding machine,

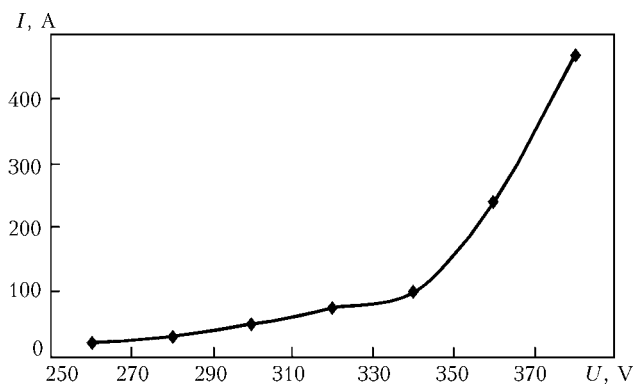
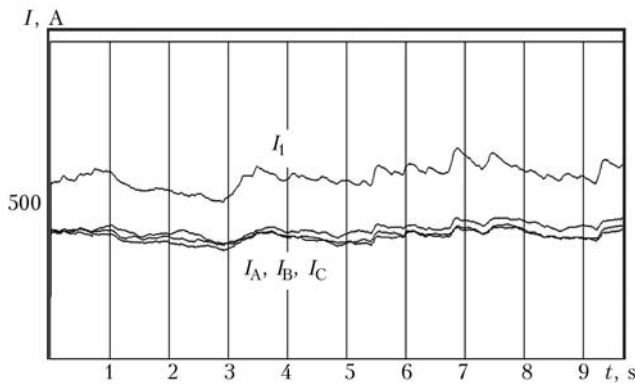


Figure 2. Dependence of open-circuit current on input voltage for welding transformers of machines K-1000 at power supply from converter of  $f = 37.5$  Hz



**Figure 3.** Oscillograms of currents  $I_A$ ,  $I_B$ ,  $I_C$  in phases A, B, C and current  $I_1$  in the primary circuit of welding transformer during welding of rails in K-1000 machine using the converter of frequency and number of phases

and may result in their premature wear and accident. In further tests during welding of specimens and full-scale products the voltage was pre-set up to 340 V. As far as the maximum effective voltage at the output of the converter during its power supply from mains of 380 V is 416 V, for its reducing the autotransformer of machine K-1000 was used.

The converter passed industrial tests in welding of rails within almost two years at the rail welding enterprise. The technology of welding of rails R65 was practiced using continuous and pulsating flash. At the same time, the selection of modes and welding of specimens of new and used repaired rails of steel M76 (production of «Azovstal») and used repaired rails E76F «Evraz» production (Nizhny Tagil Metallurgical Works, Russia) was carried out. The quality of welding was controlled by mechanical tests for a static three-point bending of specimens of welded butts by values of strength and ductility, as well as by ultrasonic flaw detection method, according to the approved standard documents of Ukraine. It was found that the quality of welded joints met the technical conditions of TU U 27.1-000334045-1353:2007. At the same time, the reliability of converter meets the industrial conditions. At the final stage of testing, welding of rail sections was carried out, which were mounted to the main track of railway. Both in the first and second cases, the quality of welded products met their technical requirements.

To evaluate the uniformity of loading the phases of three-phase mains, a continuous registration of phase currents was carried out with sampling rate of 128 measurements over the period of mains using measuring complex SATEK EDL 175XR N822584. Also current sensors

FLUKE i3000s flex were used, which were connected to the phases of cable input of 0.4 kV of the welding machine cabinet. The analysis of plots of effective values of phase currents showed that the difference between these two values of phase currents did not exceed  $\pm 2\%$ . At the same time, phase currents were 20% lower than current at the load (at the output of source) (Figure 3), which, in its turn, allows reducing the load to power substation of the transformer for each phase, and therefore, increasing its lifetime before repair; connecting additional consumers of electric power energy without increasing the power of power transformer of the substation; eliminating imbalance of phase voltages and improving the working conditions of three-phase electrical devices and, in the first turn, asynchronous motors, which increases their service life and improving the quality of the consumed electric power.

### Conclusions

1. The pilot industrial tests of the frequency converter for 37.5 Hz showed the possibility and rationality of its application for flash-butt welding, in particular, of rails due to uniform loading of three-phase mains.

2. The efficiency of use of the converter can be significantly increased by using the power transformer, designed for 37.5 Hz, in flash-butt welding machines.

1. Lebedev, V.K., Pismenny, A.A. (2001) Power systems of resistance welding machines. *The Paton Welding J.*, **11**, 28–32.
2. Lebedev, V.K., Pismenny, A.A. (1998) Improvement of power systems of resistance welding machines. In: *Welding and related technologies into the 21st century*, 130–136.
3. Kuchuk-Yatsenko, S.I., Rudenko, P.M., Gavrish, V.S. et al. (2015) Comparative evaluation of power and technological characteristics in continuous flash-butt welding of thick-walled parts at direct and alternating current. *The Paton Welding J.*, **1**, 11–17.
4. Rudenko, P.M., Gavrish, V.S. (2013) Thyristor direct converters for supply of resistance welding machines. *Ibid.*, **8**, 54–56.
5. Kuchuk-Yatsenko, S.I., Lebedev, V.K. (1976) *Flash-butt welding*. Kiev: Naukova Dumka.
6. Kuchuk-Yatsenko, S.I., Gavrish, V.S., Rudenko, P.M. et al. *Method of electric supply of single-phase resistance machines of alternating current*. Pat. 86279 Ukraine. Int. Cl. B23K 11/24. Publ. 10.04.2009.
7. Kuchuk-Yatsenko, S.I., Gavrish, V.S., Rudenko, P.M. et al. *Method of electric supply of welding transformer of single-phase resistance machines of alternating current*. Pat. 100064 Ukraine. Int. Cl. B23K 11/24. Publ. 12.11.2012.

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