Development of the Electronic Generators of the Ultrasonic Technological Apparatuses

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***Abstract* – Article is devoted to the development of ultrasonic generators. Discusses options for controlling the amplitude of mechanical vibrations.**

***Index Terms* – Ultrasound, generator, the amplitude of mechanical oscillations.**

I. INTRODUCTION

THE ULTRASONIC generator is one of the most important components of the ultrasonic technological apparatus, it provides power supply of the ultrasonic vibrating system maintaining optimum mode of its operation.

II. THE STRUCTURE OF THE ULTRASONIC GENERATOR

The ultrasonic generator is the complex electronic device combining both power modules and measuring circuits with controlling microprocessor systems. The main block diagram of the ultrasonic generator [2] is shown in Fig. 1.

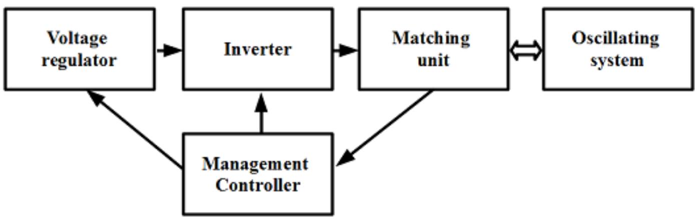

Fig. 1. Main block diagram of the ultrasonic generator

The main tasks performed by the generator are the transformation of industrial network power (220V 50Hz) into voltage suitable for power supply of the piezoelectric transducer of the ultrasonic vibrating system. As the ultrasonic vibrating system is the resonant load influenced by processed medium, it is necessary to maintain frequency of output voltage depending on changing conditions of the ultrasonic vibrating system operation. The microprocessor control unit on the base of the algorithms included in it is responsible for the search and maintenance of the operating frequency of the ultrasonic vibrating system. The second parameter determining the efficiency of ultrasonic action is the amplitude of mechanical vibrations. The control of amplitude of mechanical vibrations is realized by change of power supply voltage of the ultrasonic vibrating system [1].

III. CONTROL OF VIBRATION AMPLITUDE

Stability of amplitude of mechanical vibrations of the working ending of the ultrasonic vibrating system is one of the most important parameters influencing on technological process. It is caused by both the stability of input energy during ultrasonic action and the repeatability (at the series of actions). For different technological processes there are some requirements to the quality of maintenance of the amplitude of mechanical vibrations.

A. Influence On Liquid Media

One of the processes, which is not demanding to the stabilization of vibration amplitude, is the process of liquid medium treatment [7] due to its inertia and as a rule rather long time of action. Nevertheless at the processing of small volumes (tubes) it is necessary to reduce the level of pulsation of vibration amplitude for the decrease of splashing of processed material. In the case of liquid treatment under variable pressure we use compensation of influence of variable pressure.

B. Dimensional Processing

During dimensional processing of brittle materials [6] there is a need to provide not only stabile amplitude, but an amplitude profile (dependence of amplitude on the depth of drilling). Instability of vibration amplitude may lead to the formation of splits and quality deterioration of processed surface.

C. Ultrasonic Welding of Thermoplastic Materials

The process of ultrasonic welding [4] is the most particular about the quality of maintenance of amplitude of mechanical vibrations. The amplitude of mechanical vibrations is the main parameter influencing the quality of formed welding seam. Besides the stability of the amplitude of mechanical vibrations the ultrasonic welding imposes strict requirements of processing rate (rate of increase and decrease of vibration amplitude) due to process speed of welding seam formation (0.1 – 0.5 sec) [4]. The process of welding seam formation requires higher amplitudes (20 – 100 micron), which are close to maximum possible values for applied titanium alloys. All listed above demand special requirements to the control of vibration amplitude such as high speed, stability of maintenance of specified amplitude and small overcorrection because of possible destruction of welding tool by high vibration amplitude.

The thyristor voltage regulators traditionally applied as actuating mechanisms cannot provide the requirements to the quality of amplitude control of mechanical vibrations due to inertia and high pulsation level inherent to them.

The inertia of the thyristor regulators is caused by the necessity to apply relatively large filtering volumes at the output of the regulator.

To determine required capacitance of the filtering capacitor is possible from the equation (1) [8].

$$2\pi f \cdot C_{out} >> \tfrac{1}{R}. \qquad (1)$$

The only method of the decrease of regulator inertia is to reduce filtering volume and other conditions being equal it is possible at the increase of operating frequency of the regulator. It can be achieved by using pulse down converter (chopper) as a regulator [5] with operating frequency of transformation of more than 20 kHz. Such frequency increase allows reduce filtering volume in 10 – 100 times that increases speed of the regulator as a whole.

The application of pulse converter as a regulator requires supply of rectified and preferably stabilized voltage to its input in this connection there is a need to use large filtering volumes at the output of the rectifier that as a thyristor regulator worsens operation mode of the rectifier and leads to distortion of current supplied from the network [5].

Owing to growing demands to quality of current consumed from the network the modern electronic equipment contains the corrector of power factor that lets not only reduce distortion of current consumed from the network, but also stabilize power supply voltage of the regulator.

The quality of consumed current is regulated by the State standard [3] and for the ultrasonic equipment with consumed current of up to 16 A the data are given in Tab. I.

TABLE I
THE QUALITY OF CONSUMED CURRENT FOR THE ULTRASONIC EQUIPMENT WITH CONSUMED CURRENT OF UP TO 16 A

№ of harmonic component	Maximum possible value of the harmonic component of current
odd	
3	2.3
5	1.14
7	0.77
9	0.4
11	0.33
even	
2	1.08
4	0.43
6	0.3

Consumption of current from the network at the application of the thyristor regulator is shown in Tab. II.

TABLE II
CONSUMPTION OF CURRENT AT THE APPLICATION OF THE THYRISTOR REGULATOR, POWER CONSUMED IS 240W

№ of harmonic component	Current consumed from the network, A
1	1.25
2	0.01
3	1.17
4	0.02
5	1.123

Consumption of current from the network at the application of the pulse regulator with active corrector of the power factor is shown in Tab. III.

TABLE III
CONSUMPTION OF CURRENT AT THE APPLICATION OF THE PULSE REGULATOR WITH ACTIVE POWER FACTOR CORRECTOR, POWER CONSUMED IS 315W

№ of harmonic component	Current consumed from the network, A *
1	1.45
2	0.002
3	0.08
4	0.001
5	0.077

As it is evident from Tab. II and Tab. III the use of the corrector of the power factor allows essentially decrease amplitude of higher harmonics in the current consumed from the network.

The application of more qualitative voltage regulator along with updated control algorithms lets increase electro-acoustic efficiency from 63% at the generators with the thyristor regulator up to 67% at the generators with the pulse voltage regulator during the processing of water solutions.

IV. FEATURES OF PROGRAM IMPLEMENTATIONS OF THE AMPLITUDE CONTROL ALGORITHMS IN THE ULTRASONIC GENERATORS

A. *The Generators With the Thyristor Regulator*

Due to low speed of the regulator the intermediate variant between the proportional and two-position regulator is optimum.

Proportional control mode in the ultrasonic apparatuses (especially intended for welding of thermoplastic materials) is used quite limited. At the first switching-on of the apparatus or at abrupt load changes on the vibrating system the step of power change can be rather large. As a result there is an additional load on the elements of the power regulator. Moreover due to high inertia of the regulator it is practically inevitable the appearance of amplitude modulation at the output of the ultrasonic apparatus.

That is why; change step of the current power value is usually made fixed. At that at power decrease the step is set larger, as short amplitude excess can lead to sufficient deterioration of performed process. The step may depend on the value of the difference between current and required level of amplitude, but no more than 2 – 3 magnitudes of steps are normally used.

Necessity to use analog comparator for emergency switching-off of the ultrasonic apparatus in the case of extremely quick change of vibration amplitude. In this case the thyristor regulator is closed, but residual charge of the capacitors is sufficient for the operation during 1 second.

Necessity of synchronization with the phase of supply-line voltage. It is essential for phase method of voltage regulation. If mains voltage is extremely noisy (interference from powerful industrial equipment), it can affect the stability of output voltage and respectively amplitude of mechanical vibrations.

B. *The Generators With the Pulse Generator*

As a main control mode it is preferable to use pulse lowering regulator that provides quick achievement of required vibration amplitude, maintenance of constant amplitude level at abrupt changes of acoustic load.

Due to high speed of the regulator there is no need to use analog comparator, as abrupt splashes of amplitude do not appear independent on the situation.

The synchronization with the network is not required, that increases reliability of the ultrasonic apparatus at poor quality of voltage.

V. CONCLUSION

The application of modern schematic solutions combined with the optimization of control algorithms in the ultrasonic generators allows improve their operation characteristics. The use of power factor correctors lets not only reduce distortion of current consumed from the network, but also decrease influence of change of voltage in the supply network. The application of pulse regulators of voltage increases speed of growth of mechanical vibration amplitude and stability of its maintenance at the specified level under changing internal conditions.

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