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DEVELOPMENT OF THE METHOD OF COMPENSATING OF DISTORTIONS OF OUTPUT SIGNAL OF AMPLIFIER WITH NON-LINEAR LOAD

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Abstract—*The method of suppression of nonlinear distortion is considered. Distortion alternating voltage of amplifier of generator-calibrator is caused by the non-linear load of controllers quality of power and electric meters. Suppressor of non-linear distortion is developed and investigated. The block diagram and the algorithm are presented. The simulation of the device in the circuit simulator is offer.*

Index terms—Generator-calibrator; electric power energy; indexes of quality; amplifier.

I. INTRODUCTION

Constant growth of electricity consumption leads not only to increase tariffs, but also to increase the number of meters and quality control, further measuring instruments (MI). Also, increased demands on measurement accuracy. Thus, each such unit requires periodic checking which is carried out using specialized current source and voltage generator-calibrator (GC) reproducing alternating current (AC) network. All modern MI are electronic devices and need power supply. Although there are a great variety of them, they get power to lines measuring phase voltages. Electronic circle of power supplies are non-linear load (NL) for output voltage amplifier GC. Non-linear load is the cause harmonic distortion of the output voltage fundamental frequency due to the addition of higher harmonics, as result – deterioration in the quality of the test signal (Fig. 1) and makes an error in the calibration MI [2].

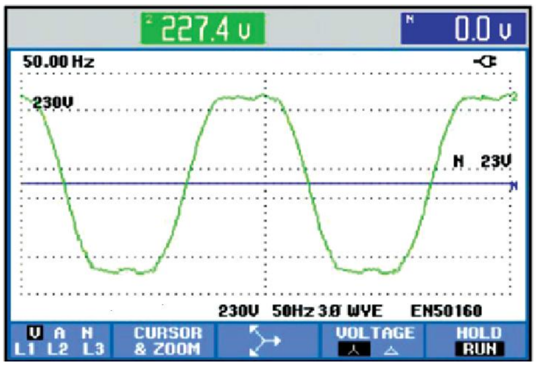

Fig. 1. The distortion signal caused by non-linear load

The sine wave distortion factor (or THD) voltage curve should not exceed 0.5% according to GOST 13109–97 with GOST 22261–94 considering. In [1] observed that GC producers not guarantee reproduction test signals corresponding quality when working with NL. Overcome the problem several possible ways. This new GC using high-voltage output DAC [3] or hybrid amplifiers with sophisticated circuitry [6]. Whether upgrading existing equipment in metrology and certification centers and enterprises, as suggested below. Make it easier and cheaper.

Research showed that this issue is relevant in the electric power long, especially abroad. Switched power supply of radio, frequency converters of electric motors, electric transport are typical NL for supply network. To reduce distortion sine wave voltage curve applied active harmonic conditioners (AHC), based on active filters that are known from the 70s.

Active harmonic conditioners analyzes harmonic current that creates NL and injects to the network in the opposite phase. There may be parallel, sequential and combined type.

Contain in its structure DSP (digital signal processor) and powerful PWM inverters [5]. The biggest development and application of have become in Japan [4], as part of electric power where voltage distortion factor improve to 1.1 %.

In Europe, for home uses are available AHC like devices [7] which reduces distortion caused by household appliances (computers, TV sets, etc.) to 2.9 %.

II. DESCRIPTION OF SUPPRESSOR OF NON-LINEAR DISTORTION

Proposed solutions with electricity use in metrology is the principle of consistent use AHC, but without the use of DSP processor and inverter. The idea of using an ideal sine wave signal generator and a device for subtracting the harmonic distortion the AC, caused by the nonlinear load of traction consumers, discussed in [1]. Also, there is indicated that an introduction in a working network of any source of power, however small power, can affect the correct function of the individual elements, so scheme of information-measuring system of monitoring of quality of electric energy in which there is no reference signal generator the was developed.

In proposed device made comparisons signal on output load with sinusoidal reference, which is used as a reference voltage generator (RVG) of calibrator and suppression of harmonics is made at the connection point NL from which the feedback is taken. Therefore, scheme is safe and effective for use in metrology equipment. Selected harmonic signal is amplified by the amplifier and added to the output, causing suppression of distorting voltage harmonics. Block diagram of suppressor of non-linear distortion (SND) is shown in Fig. 2.

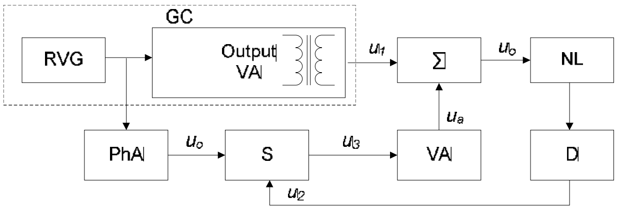

Fig. 2. Block diagram of suppressor of non-linear distortion

The reference signal from the RVG of calibrator passes through a phase adjuster (PhA) to the input device subtractor (S), and the other input receive the signal from the voltage divider (D) connected to the NL. Subtractor is compare these signals with considering phasing as a result – obtained separate harmonic voltage supplied to the voltage amplifier (VA). The voltage signal from amplifier with opposite phase is fed to the summator, where correction signal add with the output voltage signal from GC. The phasing is done once when debugging SND in phase adjuster. The signal is adjusted on phase shift angle fundamental harmonic signal coming from the load through the divider needed to leveling the amplitude of the reference signal and the signal from NL. The adder – transformer significantly less power than the output in the GC.

III. Mathematical model of SND

Output voltage GC

$$u_1 = \sum_{k=1}^{\infty} U_{1k} \sin(k\omega t + \varphi_{1k}),$$

where k is the number of harmonic components; U_{1k} is the peak value of kth harmonic component; $\omega = 2\pi f_1$ is the angular frequency; f_1 is the frequency 1st harmonic alternating voltage; φ_{1k} is the initial phase shift angle kth voltage harmonic component.

Output voltage of divider

$$u_2 = \sum_{k=1}^{\infty} U_{2k} \sin(k\omega t + \varphi_{2k}) = K_d u_1 = K_d \sum_{k=1}^{\infty} U_{1k} \sin(k\omega t + \varphi_{1k}),$$

where K_d is the dividing ratio of divider.

Reference output voltage of phase adjuster

$$u_o = U_r \sin(\omega t + \varphi_o),$$

U_r, φ_o is the peak voltage, the starting phase angle of the reference signal, respectively. According to the requirements of work SND the amplitude of the reference voltage and its initial angle should be equal to the amplitude, and phase shift angle output divider signal $U_r = U_{21} = K_d U_{11}$, $\varphi_o = \varphi_{21}$.

Then the output voltage of the subtractor

$$u_3 = u_2 - u_o = \sum_{k=2}^{\infty} U_{2k} \sin(k\omega t + \varphi_{2k})$$

$$= K_d \sum_{k=2}^{\infty} U_{1k} \sin(k\omega t + \varphi_{1k}).$$

The voltage at the amplifier output voltage

$$u_a = -u_3 K_d = -K_a K_d \sum_{k=2}^{\infty} U_{1k} \sin(k\omega t + \varphi_{1k}),$$

where K_a is the gain amplifier.

The voltage at the output of the adder

$$u_o = u_1 + u_a = \sum_{k=1}^{\infty} U_{1k} \sin(k\omega t + \varphi_{1k}) - K_{ad} K_a K_d \sum_{k=2}^{\infty} U_{1k} \sin(k\omega t + \varphi_{1k}).$$

K_{ad} is the transformation ratio of voltage adder, chosen from the condition $K_{ad} = 1/(K_a K_d)$, then

$$u_o = U_{11} \sin(k\omega t + \varphi_{11}).$$

Thus, on the output summator is only the main (1st) harmonic voltage.

The mathematical model is somewhat simplified because do not take into account the frequency characteristics of the circuit elements. Its development to full potential if coefficients in the relationships expressed by the ratio of impedances, which will use it for circuit simulation using mathematical environments. Not sophisticated analysis of this model show that the effectiveness of reducing harmonics depends on the accuracy and stability elements, configuration of divider, subtractor, amplifier, precision phasing in PhA.

IV. Evaluation of SND

To assess the effectiveness of reduction of harmonic distortion SND simplified circuit model without SND (Fig. 3) and with it (Fig. 4) were modeled in an environment Electronics Workbench.

The diagram in Fig. 3 show generator TSU6804 represented RVG V1 and V2, output VA with the transformer T1. In the properties T1 are specified the real value of the input and output resistance and number of turns. Elements of MI are meters TSE6827I or NIK2102, representing NL – rectifying diode bridge D1, resistance R1 and capacitance C1. In Fig. 3 is shown the distortion of the output voltage harmonic components and distortion ratio (total harmonic distortion) at 6.99 %.

The diagram of the SND is shown in Fig. 4.

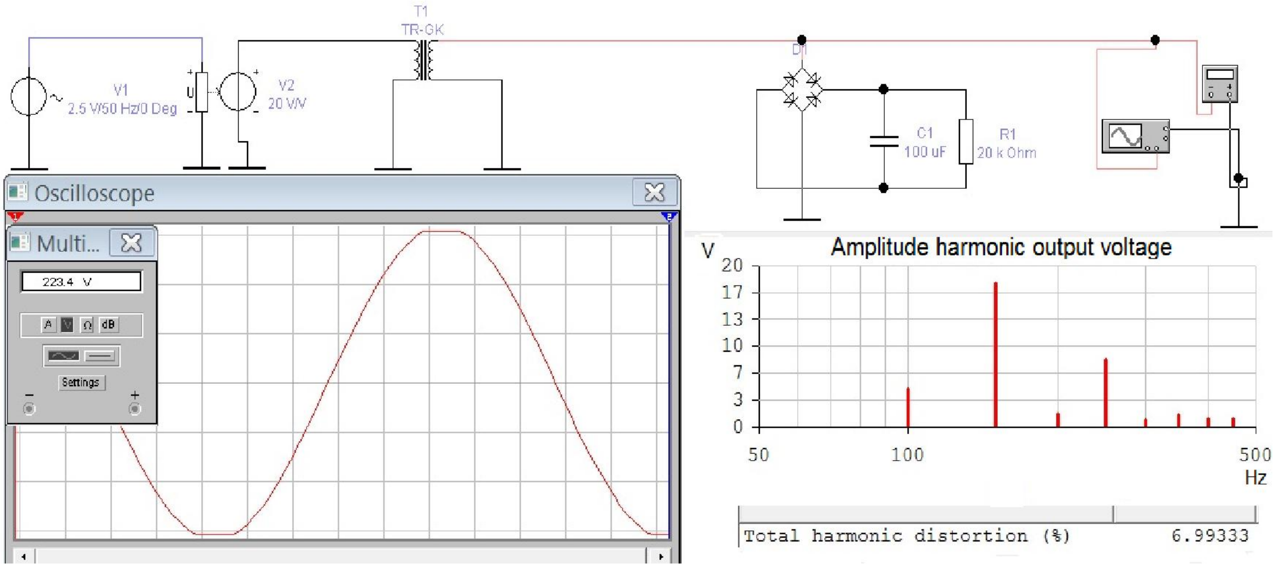

Fig. 3. Form output signal, amplitude harmonic of output voltage, THD curve voltage

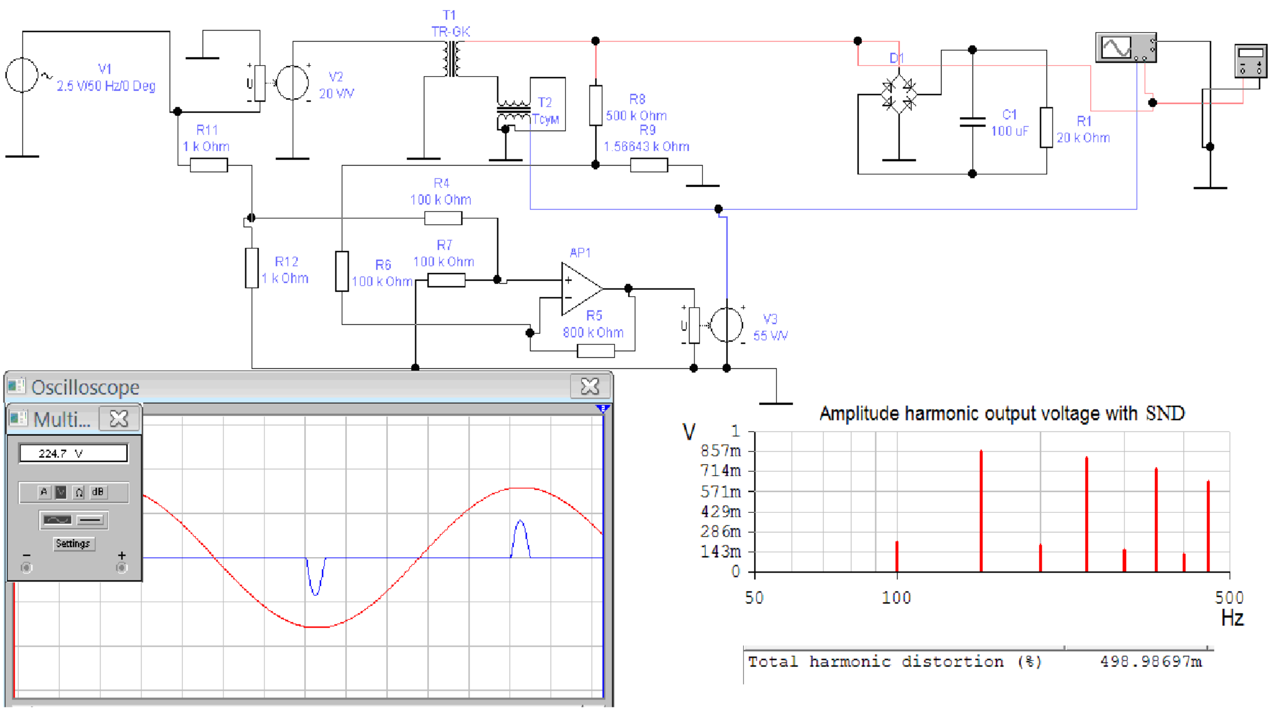

Fig. 4. Output and correcting signal, amplitude harmonic of output voltage, THD voltage curve with SND

Where T2 is the transformer summator, R8, R9 are resistors divider; R4, R5, R6, R7, R11, R12, AP1 are resistors and an operational amplifier of subtractor; V3 is the voltage amplifier. The phase adjuster not applied, because the model has not phase shift. The corrected signal and correcting the level of residual harmonics (amplitude less 1 V) are shown in Fig. 4. Simulation shows distortion reduction to an acceptable level 0.499% or 14 times, confirming the effectiveness of this method and the suppressor of non-linear distortion. It is easy to see that the result was a reduction of distortions of signal more effectively than in electricity by ACH.

Also, the experimental sample was studied. The experimental results confirmed the data obtained by simulation. This allowed creating the source of voltage and current DNST-3, which reproduces three-phase network (Fig. 5). Classical PWM amplifier circuits were used and SND in voltage channels were applied.

Fig. 5. Voltage and current source DNST-3

CONCLUSION

The method applied in SND is confirmed effectiveness by computer simulations and laboratory tests on the sample. Evidence of this is reduction the level of harmonics to allowed value. It can be used for modernization and manufacturing voltage amplifiers of GC, which will work with non-linear load of MI. That will reduce the calibration error.

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Ю. Ф. Тесик, Р. М. Мороз. Розвиток метода компенсації вихідного сигналу підсилювача з нелінійним навантаженням

Запропоновано спосіб подавлення гармонічних спотворень. Розроблено та досліджено пристрій, що дозволяє зменшити спотворення підсилювача генератора-калібратора змінної напруги, які спричинені нелінійним навантаженням від приладів обліку та контролю якості електроенергії. Приведено структурну схему і алгоритм роботи. Проведено моделювання пристрою в схемному симуляторі.

Ключові слова: генератор-калібратор; електроенергія; показники якості; підсилювач.

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Ю. Ф. Тесик, Р. Н. Мороз. Развитие метода компенсации искажений выходного сигнала усилителя с нелинейной нагрузкой

Рассмотрен метод подавления нелинейных искажений. Разработано и исследовано устройство, позволяющее уменьшить искажения усилителя генератора-калибратора переменного напряжения, которые вызванные нелинейной нагрузкой от приборов учета и контроля качества электроэнергии. Приведены структурная схема и алгоритм работы. Проведено моделирования устройства в схемном симуляторе.

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