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SPECTRAL ANALYSIS OF THE BIPOLAR POWER SUPPLY OF A MOBILE INTEGRATING EQUIPMENT FOR MEASURING FORCES AND TORQUES WITH STRAIN GAUGES SENSORS[1]

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Abstract: *In this paper a study of the pulsations, random and / or noise signals, in the bipolar feeding voltage of the operating amplifiers of an integrated measuring transducer in the composition of mobile equipment for measuring forces and torques is presented. Spectral analysis was carried out and the spectral density determined for the specified bandwidth of 600 Hz - 120 kHz by simulating the operation of the transducer with an exemplary resistive decade ± 0.5Ω. The results obtained are the basis for the development of a prototype measuring transducer.*

Keywords: *Integrating Equipment, Measurement, Spectral analysis, Spectral density, Transducer*

INTRODUCTION

A Mobile Measuring Integration Stand is designed to measure forces and torques in field conditions (Stoyanov, S., & Zaharieva S., 2017). For the purpose a two-sided integration strain gauge transformer with resistance variation into frequency deviation was used including an operational amplifier (OA) working on the ramp right transformation method (Stoyanov, S., 2016). It has its own power supply system with an inverter unit and the corresponding rectifying and filtering circuits.

In operation, the constant voltage from the battery is converted into pulses resembling a modified sinewave - Fig. 1 (Stoyanov, S., & Vasilev, R., & Zaharieva S., 2017). Upon rectifying and filtering the voltage that feeds the transducer's operational amplifiers a few significant parameters should be followed: the pulsation of the rectified voltage, the inherent noise produced from the integral stabilizers, as well as the random and noise signals generated by the relaxation generator.

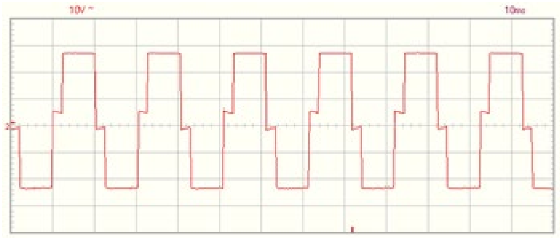

Fig.1. Output pulses from the inverter unit.

To ensure the accuracy of the measuring transducer, it is necessary to suppress the noise in the measuring circuits that are directly affected by the random and noise signals in the feeding voltage. This is explaind with the fact that the strain gauge measuring sensors are supplied with alternating voltage at a frequency equal to the frequency of the relaxation generator.

INVESTIGATION

1. Block diagram

The equipment used in this survey and respective wiring are shown in Fig. 2.

[1] Докладът е представен на пленарната сесия на 26 октомври 2018 с оригинално заглавие на български език: СПЕКТРАЛЕН АНАЛИЗ НА ДВУПОЛЯРНОТО ЗАХРАНВАЩО НАПРЕЖЕНИЕ НА МОБИЛЕН ИНТЕГРИРАЩ СТЕНД ЗА ИЗМЕРВАНЕ НА СИЛИ И МОМЕНТИ С ТЕНЗОСЪПРОТИВИТЕЛНИ ДАТЧИЦИ

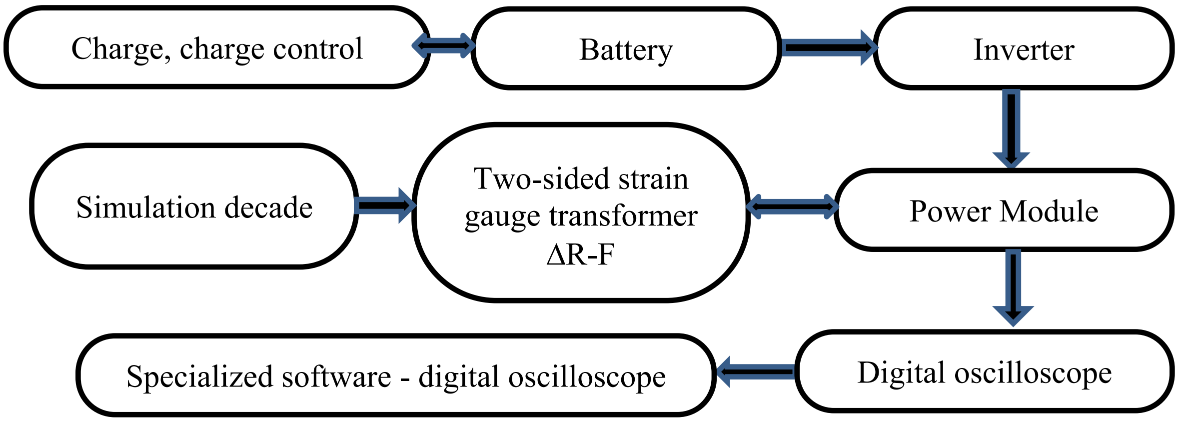

Fig.2. Block diagram of the used equipment

The power supply is provided with a LAVA PS9-12, 12V, 9Ah battery. It is in the range of 6 ÷ 8W and the current in the primary circuit is 0.5 ÷ 0.7A. Battery charge control is realized by means of a Batteries tester - 80127 in Standby use 13,6 ÷ 13,8V, and Cycle use 14,5 ÷ 14,9V. A HL300 Power Inverter unit is implied with parameters: Input voltage DC 11 ÷ 15V, Output voltage 220 ÷ 240V, Maximum continuous power 300W. The output signals are visualized using a PSCU1000 Velleman two-channel digital oscilloscope and original PC-Lab2000SETM software - Fig.3.

Fig.3. A mobile stand.

2. Spectral analysis

For the accurate determination of the pulsation of the feeding voltage a spectral analysis is performed - Fig. 4 (Stoyanov, S., & Vasilev, R., & Zaharieva S., 2017). A Spectrum Analyzer included as a component of the PC-Lab2000SETM software of the German company Velleman is used for the purpose. The pulses of the feeding voltage and their harmonics were expected to be at low frequencies so the analyzer was set to an upper frequency band of 600Hz with horizontal and vertical scaling of 10Hz and 10mV, respectively.

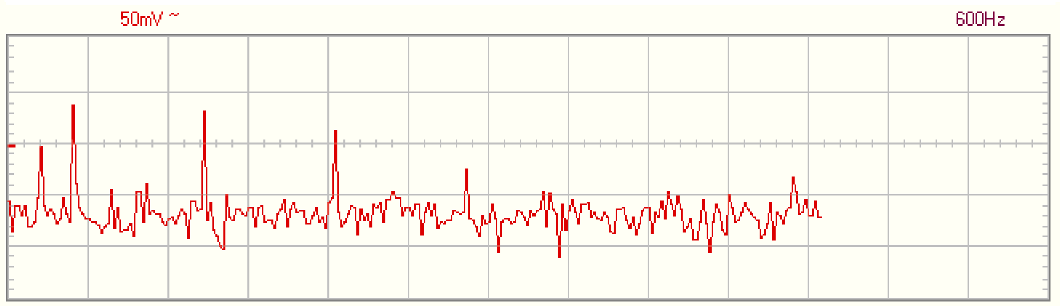

Fig.4. Decomposition of the pulses of the feeding voltage of the OA operating with an inverter.

The resulting signal, seen in Fig. 4, was processed using the FFT (Fast Fourier Transform) method and the Hamming function, which is prefered for nearby sinusoidal signals or modified ones. In the graphic the individual harmonics are clearly visible at low frequencies.

The pulsation coefficient is defined as the ratio of the amplitude of the first harmonic $U_{(1)}$, according to Fig. 4, and the mean value of the rectified voltage U_0 (Stefanov, N., 1985).

$$K_n = \frac{U_{(1)}}{U_o}.100\% = \frac{0.09}{30}.100 = 0.3\% \qquad (1)$$

For rectifiers implied in power supply modules of electronic devices the permissible values of the pulsation coefficient are chosen within the range of 0.003-0.1% (Kitaev, V., 1993). (Stefanov, N., 1991).

The inherent noise in the output signal of the integral stabilizers (Output Noise) is 90µV in the frequency band from 10 Hz to 100 kHz at 25^0C (http://www.hep.upenn.edu). This is about 1000 times less than the received amplitude of the first harmonic, so that it can be neglected.

To reduce the pulsation coefficient, it is also necessary to examine the frequency generated by the relaxation generator. In addition to the inherent noise, pulses and harmonics from the electronic system of the inverter may occur in the feeding voltage

This research can be performed by determining the spectral noise density in the feeding voltage at the initial frequency of the converter 1.22 kHz.

3. Determination of the spectral density

Spectral density as a measurement parameter is used to measure the density of random or noise signals. The spectral density is normalized at bandwidth 1Hz. This mode of operation gives an idea of how the frequency spectrum will look like if each frequency component occupies a bandwidth of 1Hz at any point in the frequency range.

Due to the different noise bands, it is necessary to study the spectral density at different frequencies as in FFT the width of the samples is changed and the frequency resolution.

The Spectral Density tool from the Spectrum Analyzer of the PC-Lab2000SETM software (by the German company Velleman) is used. Herein FFT transformation and Hamming function are also applied.

Fast Fourier Transform (FFT) implied in the software gives the possibility to work with several different values of the signal: the maximal amplitude values at each frequency over time – Maximum; the actual root-mean square values of the variable component - RMS Average (used to study the noise level) and Vector Average values (the last reduces the incidental and nonphase noise).

The RMS Average is used herein to estimate the noise voltage in the power source for the OA and to accurately assess the highest amplitude noise voltages and their distribution in the corresponding Vector Average frequency band.

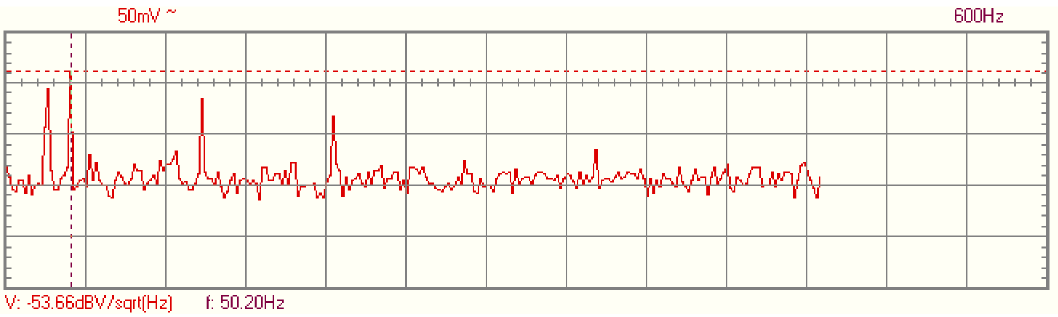

Fig.5. Spectrum of the noise signal in the 600 Hz band.

In Fig. 5 is a noise analysis oscillogram at 600Hz, which shows the distribution of the noise amplitudes on the ordinate as a function of frequency (on the abscissa). At 50.2Hz frequency, the spectral density of the voltage is determined:

$$V=V_{SdbV}= -53,66 \text{ dBV/sqrt[Hz]}. \quad (2)$$

За определяне на напрежението V_S, като спектрална величина, нормирана при широчина на честотната лента 1Hz се използва следната формула:

To determine the voltage Vs, the spectral magnitude is normalized considering 1Hz bandwidth, according to the formula:

$V_s = 10^{\frac{V_{SdBv}}{20}}$=0,002075V/$\sqrt{f}$ (3)

Определянето на шумовото напрежение за дадена честотна лента се извършва по следната формула:

The noise voltages at a given frequency band are specified as follows:

$V_{rms} = V_s.\sqrt{f}$, where f if the frequency bandwidth. (4)

За честотна лента 50,2 Hz шумовото напрежение е $V_{rms} = 0{,}0147V$ –Таблица 1.
For frequency band 50.2 Hz the noise voltage is V_rms = 0.0147V -Table 1.

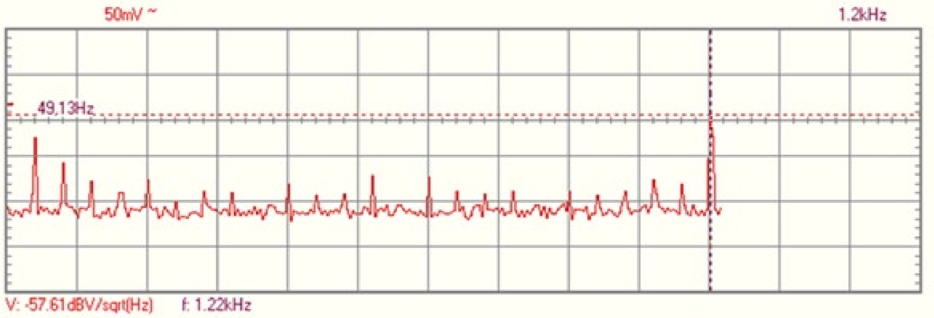

Fig.6. Spectrum of the noise signal in the 1200 Hz band.

In the band 1200Hz - Fig.6 there is a high amplitude pulse corresponding to the initial oscillation frequency of the relaxation generator of the transducer. In the 3000 Hz band, there is also a distinct pulse with a frequency of 1.22 kHz, a first harmonic at 2.44 kHz - Fig.7 and a second harmonic at 4.88 kHz - Fig.8

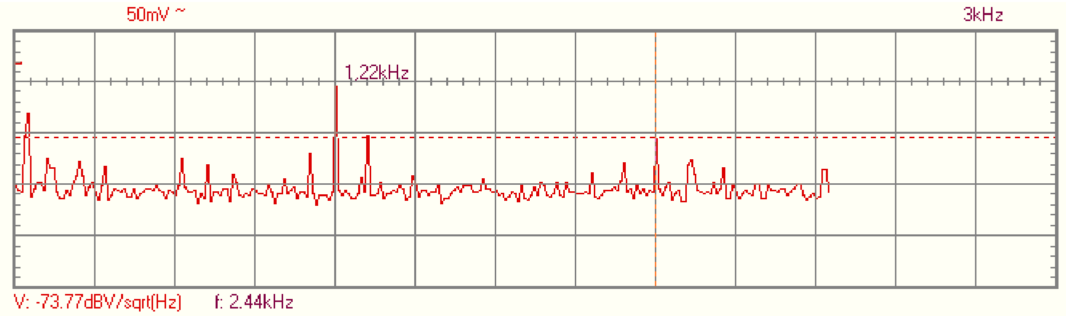

Fig.7. Spectrum of the noise signal in the 3000 Hz band

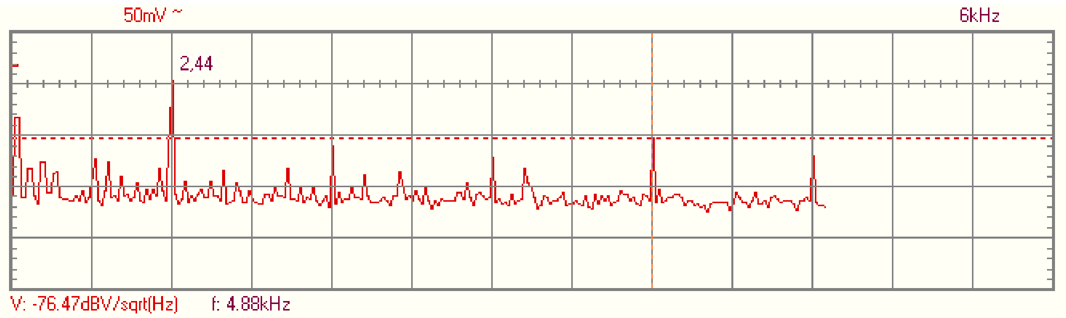

Fig.8. Spectrum of the noise signal in the 6 kHz band

The parameters of the third, fourth and fifth harmonics can be defined according to Figures 9, 10 and 11, respectively. After processing the data, it is seen that their influence progressively decreases; the noise voltages are insignificant and they are in the order of 10 to 45 times smaller in relation to the base frequency noise voltages.

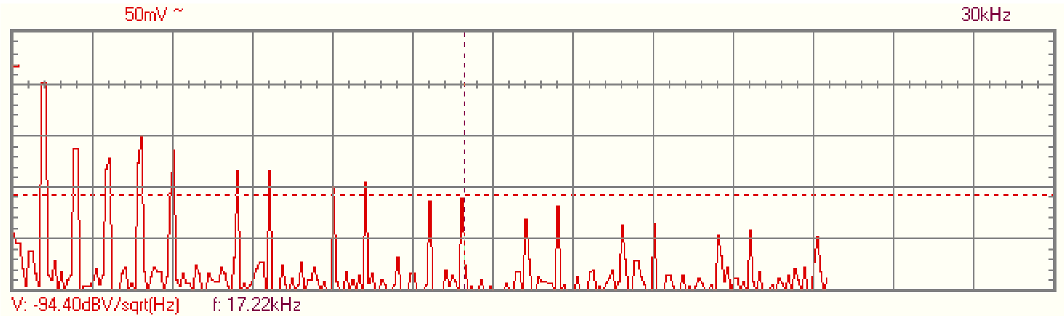

Fig.9. Spectrum of the noise signal in the 30 kHz band

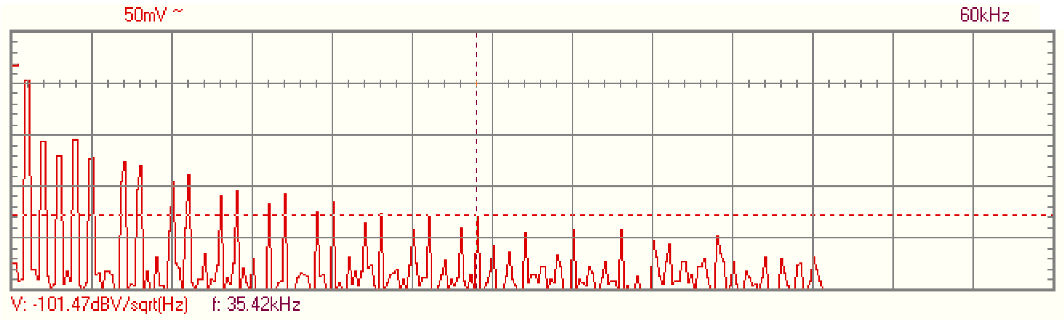

Fig.10. Spectrum of the noise signal in the 60 kHz band

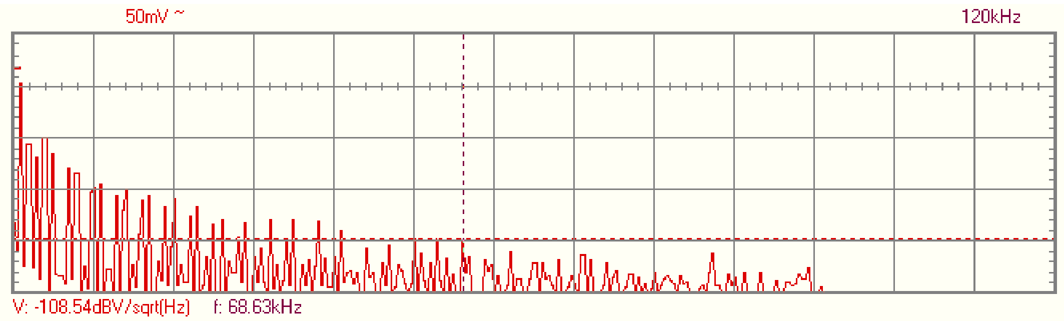

Fig.11. Spectrum of the noise signal in the 120 kHz band

It can be seen in Figure 11 that the study of sixth, seventh, and so forth higher harmonics is pointless due to the low noise level, which is more than 50 times less than the base noise at 1.22 kHz.

In Table 1, in column 1, the frequency band of the graphs is given, in column 2 the frequency surveyed by the given frequency band, in column 3, the spectral density of the voltage which the program determines automatically, in column 4 the calculated noise voltage by (3) as a spectral magnitude, in column 5 the calculated noise (4) for the given frequency, and in column 6 the calculated noise voltage (4) normalized for the given frequency band.

Table1. Received and calculated results

F_{line} [Hz]	F_i [Hz]	V [dB]	Vs [mV]	V_{rms} [mV]	$V_{rms\ fline}$ [mV]
1	2	3	4	5	6
600	50,2	-53,66	2,075	14,701	50,825
1200	1220	-57,61	1,317	45,992	45,613
3000	1220	-63,77	0,648	22,630	35,486

3000	2440	-73,77	0,205	10,120	11,222
6000	2440	-66,47	0,475	23,453	36,777
6000	4880	-76,47	0,150	10,488	11,630
30000	9770	-87,84	0,041	4,008	7,024
30000	17220	-94,4	0,019	2,500	3,300
60000	35420	-101,47	0,008	1,589	2,068
120000	68630	-108,54	0,004	0,980	1,296

CONCLUSIONS

1. Spectral analysis was performed and the spectral density of a two-sided integrating measuring transducer, based on the ramp right conversion method, was determined in the composition of mobile measuring equipment.
2. The pulse of the supply voltage from the inverter and the influence of the generated frequency from the converter's relaxation generator are investigated.
3. The noise voltages of the harmonics are determined in the respective frequency ranges that have the greatest impact on the transducer performance.
4. The results obtained are the basis for calculating and including the required number of filters when designing the PCB.

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