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DIGITAL MEASUREMENT SYSTEM OF ELECTROMAGNETIC DISTURBANCES AND AUDIBLE NOISE OF MARINE FREQUENCY CONTROLLED AC DRIVES

Jacek Wyszkowski (1), *Ludwik Spiralski* (2), *Romuald Winter* (3)

(1) Gdynia Maritime University, Poland, (2) Gdańsk University of Technology, Poland
(3) ASTAT El Ltd, Poznań, Poland

Abstract – Digital measurement system of electromagnetic disturbances and audible noise of marine drive systems with frequency converters is described. This measurement system allows establishing the synonymous and rational correlation, between electromagnetic disturbances in AC motor supply line and audible noise of the drive system. Thanks to this method, the audible noise reduction can be obtained by attenuation of motor electrical supply harmonics.

Keywords: frequency converter, electrical harmonic disturbances, audible noise

1. INTRODUCTION

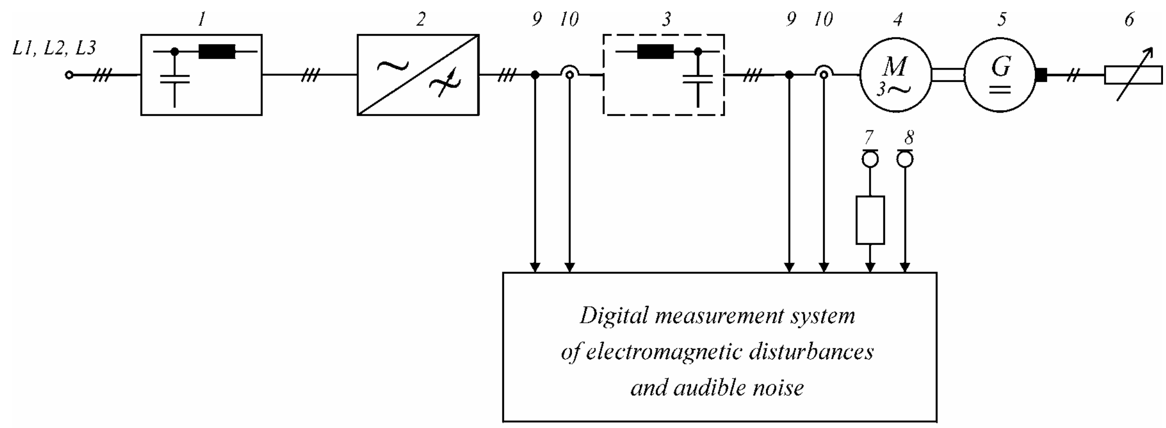
In the recent years a lot of frequency converters were applied at seagoing ships, in various drive systems with squirrel-cage motors. The output voltage frequency of these converters can be adjusted in the wide range up to hundreds Hz. Such converters push out formerly used power electronic converters used with DC motors and AC slip-ring motors [1].

Now they are also applied in the drives, where the speed was not controlled before, for instance in marine centrifugal fans and pumps, of which capacity and pressure was changed using inefficient methods, like reducing flow or by-pass valves.

Frequency converters bring energy savings and real practical benefits. But the frequency converters, which consist of the diode rectifier bridge and inverter bridge with IGBT power transistors, have some disadvantages. When they are on, they generate electromagnetic disturbances in the wide frequency range. This happens because of the rectifier diodes and inverter transistors' commutation, which can be switched with the frequency from 2 kHz to 15 kHz. Those disturbances that are conducted to the system supply net, also to the supply line of the motor, and emitted to the space, increase the audible noise caused by the drive system [2, 3].

2. DIGITAL MEASUREMENT SYSTEM

The authors propose to use digital measurement system, which allows establishing the synonymous and rational correlation between electromagnetic disturbances in AC motor supply line and audible noise of the drive system.



1 - RFI filter, 2 - frequency conventer, 3 - optional sinusoidal output filter, 4 - induction motor, 5 - DC generator, 6 - adjustable resistor, 7 - sound level meter, 8 - mircophone, 9 - voltage transducer, 10 - current transducer

Fig. 1. The block diagram of the laboratory drive system

TABLE 1 Technical data of the laboratory drive system components

Technical data	RFI Filter	Frequency converter		Sinusoidal output filter	Induction motor	DC generator
		Input parameters	Output parameters			
Manufacturer	REO Inductive Components, Germany	CONTROL TECHNIQUES, U.K.		SCHAFFNER, Switzerland	Fabrica de Motorae Electrice Pitesti, Romania	KOMEL, Poland
Type	No 304 32/2	UNI 2401		FN 5020-25-33	N 132 / S4	PZ8 b 54 a
Nominal power	-	5.5 kW		max. 17.3 kW	5.5 kW	3.5 kW
Nominal voltage	3 Ph 480 V	3Ph 380/480 V	3Ph 380/480 V	max. 3Ph 440 V	3Ph 380 V Δ	230V
Nominal current	3x16 A	13.7A	12.0 A	25 A	11.5 A	15.2 A
Nominal frequency	50/60 Hz	50/60 Hz	0÷400 Hz	max. 600 Hz	50 Hz	-
Switching frequency	-	PWM 3, 4.5, 6, 9, 12 kHz		6 ÷ 15 kHz	-	-
Nominal speed	-	-		-	1440 r.p.m	1450 r.p.m.

The block diagram of the laboratory drive system is shown in Fig. 1. and the digital measurement system in Fig. 2.
LEM analog current and voltage isolating sensors are connected to digital oscilloscope. The oscilloscope digitises voltage and current waveforms and next the acquired data is passed to PC hard disc.

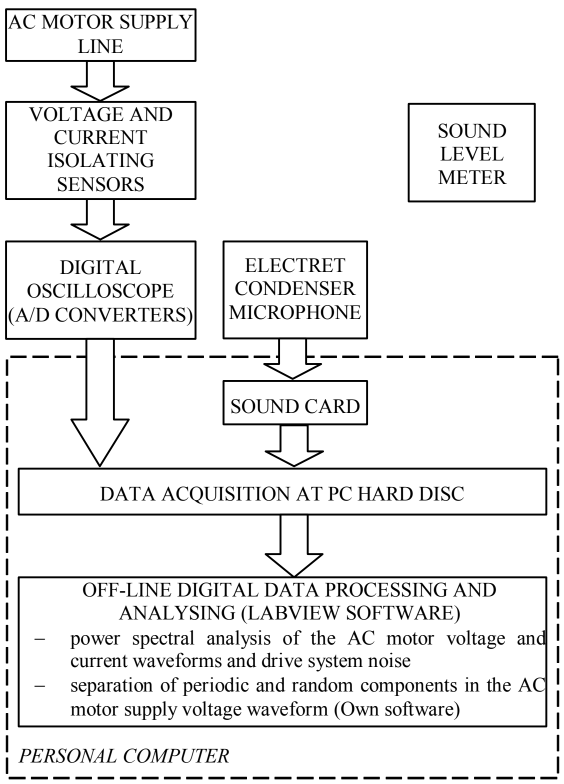


Fig.2. Block diagram of digital measurement system

The electret condenser microphone is used to record the noise of the drive system. Using computer software, *off-line* power spectral analysis of acquired waveforms and separation of periodic and random components in the motor supply voltage is performed.

The algorithm for separation of periodic and random components in the motor supply voltage is shown in Fig.3. [4].

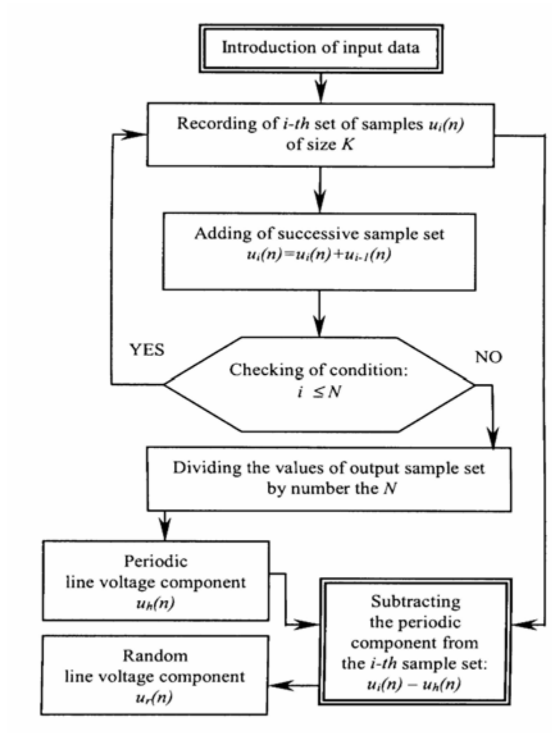


Fig. 3. The algorithm for separation of periodic and random components in the motor supply voltage

3. LABORATORY EXPERIMENTS

The experiments with the model of marine drive system with frequency converter were performed at laboratories of Department of Ship Automatic Control at Gdynia Maritime University.

At the first stage of the tests, 5.5 kW squirrel cage asynchronous motor was connected directly to the output of the typical manufactured frequency converter. The drive system was supplied with 3x380 V, through the RFI (Radio Frequency Interference) filter. At the second stage of the tests, to confirm the thesis of correlation between harmonics contents in motor current waveform and acoustic noise of the motor, the sinusoidal LC passive filter was connected at the output of the frequency converter.

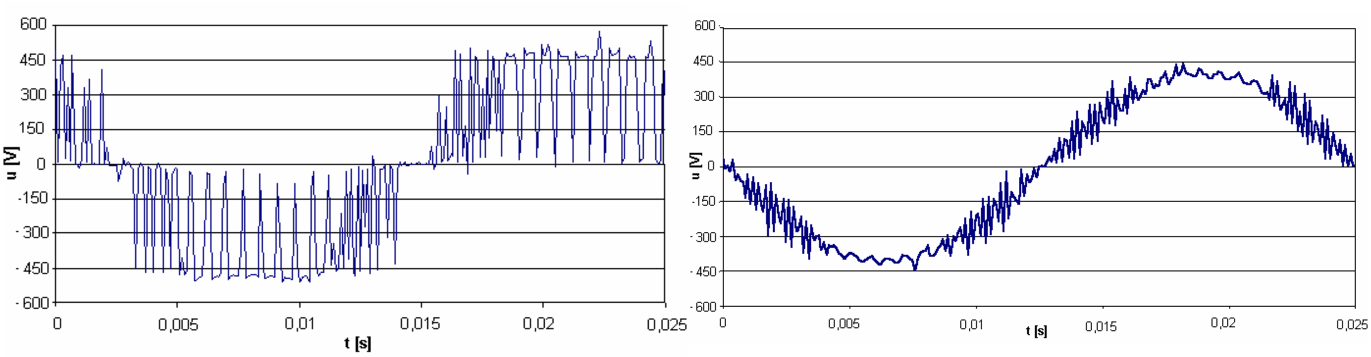
During all tests, the motor was loaded by DC generator with adjustable resistor, and the AC motor current was set to 8 A.

Technical data of the laboratory drive system components are listed in Table 1.

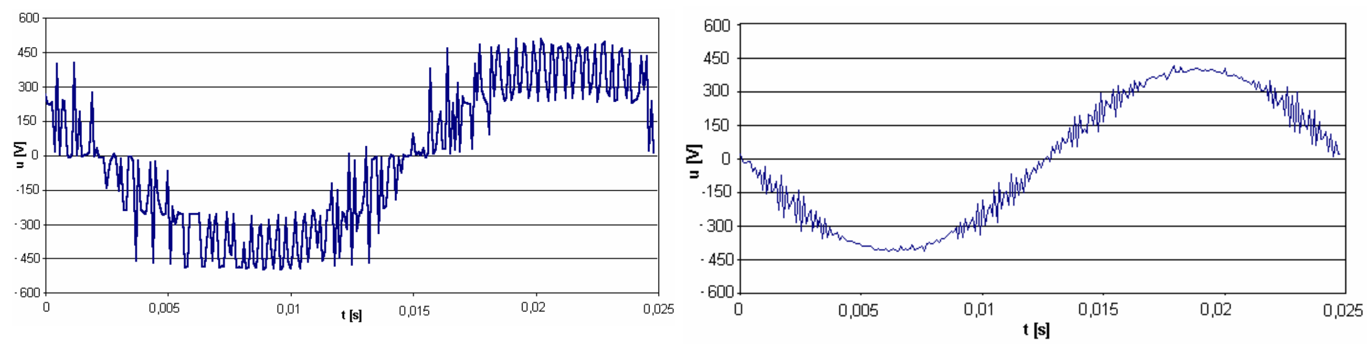
Because the extent of this paper is limited, the results are performed for only one case – for the motor voltage frequency f_{out} = 40 Hz and switching frequency of inverter transistors f_{sw} = 6 kHz.

AC motor voltage waveforms are shown in Fig. 4, in the left column for the case when the motor was supplied directly from the frequency converter and in right column when the output LC passive filter was applied. In Fig. 4(b) voltage periodic components and in Fig. 4(c) voltage random components are performed, which were calculated using algorithm shown in Fig. 3.

a)



b)



c)

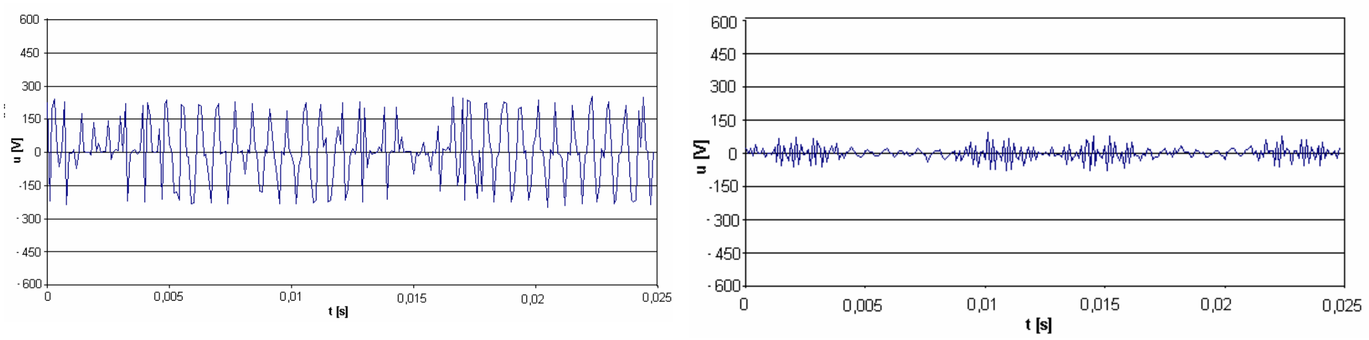


Fig. 4. The waveforms observed in the drive system for f_{out} = 40 Hz and f_{sw} = 6 kHz, in the left column without output filter and in the right column with the filter: a) motor voltage, b) motor voltage periodic component, c) motor voltage random component

When analysing these figures and taking into account the PWM (Pulse Width Modulation) method of inverter control, it can be stated that voltage random components result from the fluctuations of inverter switching (carrier) frequency, which have high influence on the transient states in this process. It was observed, that using passive LC output filters, electromagnetic disturbances in the AC motor supply line were decreased, and also random components of the voltage, what leads to drive system noise reduction.
More detailed results of the actually performed tests and studies will be presented during Congress.

The problems arising with use of frequency converters in marine systems are the subjects of research/scientific works at Department of Ship Automatic Control of Gdynia Maritime University, in co-operation with Department of Measuring Instrumentation of Gdańsk University of Technology [5].

4. CONCLUSION

Research works undertaken by the authors, with the presented in this paper digital measurement and analysing system, lead to final defining of assumptions on the project of adaptive filter, which would be connected between the frequency converter and the motor. Such a filter with controlled, variable frequency characteristics, dependent on converter output voltage frequency and switching frequency, would attenuate motor supply voltage harmonics and this way audible noise of the drive system.

In the near future the modification of digital measurement system is planned; the much modern 16-bit A/D converters will be applied in the place of 8-bit ones.

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Authors:
M.Sc. Jacek Wyszkowski, Department of Ship Automatic Control, Gdynia Maritime University, ul. Morska 83, 81-225 Gdynia, Poland, phone: (+48 58) 6901256, fax: (+48 58) 6219938, e-mail: jacekw@am.gdynia.pl

Prof. Ludwik Spiralski, Department of Measuring Instrumentation, Gdańsk University of Technology, ul. Narutowicza 11/12, 80-952 Gdańsk, Poland, phone: (+48 58) 3471504, fax: (+48 58) 3416132, email: kapsz@pg.gda.pl

M.Sc. Romuald Winter, ASTAT *El* Ltd., Schaffner's EMC measurement and engineering service, ul. Dąbrowskiego 461, 60-451 Poznań, Poland, phone: (+48 61) 8488871, fax: (+48 61) 8488276, e-mail: R.Winter@astat.com.pl