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ASSESSMENT OF THE ELECTRIC POWER QUALITY ON THE POLISH FISHING BOATS

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Abstract:
Power quality is an important problem for electrical systems. Electricity receivers should operate at nominal conditions. Each deviation from nominal values may cause the malfunction of electrical devices, decreasing their durability and permanently damage the appliance. The importance of electric power quality for technical systems and individual electrical devices on fishing boats is fundamental. Utilization of equipment powered by electrical energy with a reduced quality resulting in economical losses and the treat to the screw's safety.
Researches of the electrical energy's quality were carried out almost any type of fishing boats. This article presents the results of researches concerning the quality of electrical energy performed on a representative type of fishing boats. It shortly evaluates the results of tests and suggests solutions to improve the power quality parameters.

Key words: *electrical power quality, electrical energy system of fishing boats, quality parameters of electrical energy, passive filter*

INTRODUCTION

In comparison to low-voltage networks commonly found on land (TN type), the marine network, including electrical network in fishing boats, is specific. In order to ensure the continuous power supply of important receivers of fishing boats, the network with an isolated neutral point (IT type) is used. This network is a "soft" network, because powers of autonomous power sources are comparable with the power of the largest electrical energy loads. Changes in load on this network (turning on and off of the high power loads) cause changes of voltage parameters. Together with the development of technology, there is an increase in the number and power of receivers installed on fishing boats.

The main sources of electrical energy in energy systems on fishing boats is an autonomous diesel generator (DG) and a shaft generator (SG). The commonly used generator is a synchronous generator.

An example of a schematic diagram of the electricity system for fishing boats with the use of DG and SG is presented in Figure 1. Diesel generator (DG) and shift generator (SG) supply separated loads. SG usually powers higher power loads (for example, RSW cooling system). Parallel operation of two generating sources is not expected. There is a possibility to connect the fishing boat's electrical network to the terrestrial network on all units.

The high quality of electrical energy generated, transmitted and utilized in marine systems has a decisive impact on the safety and economy of fishing boats' exploitation.

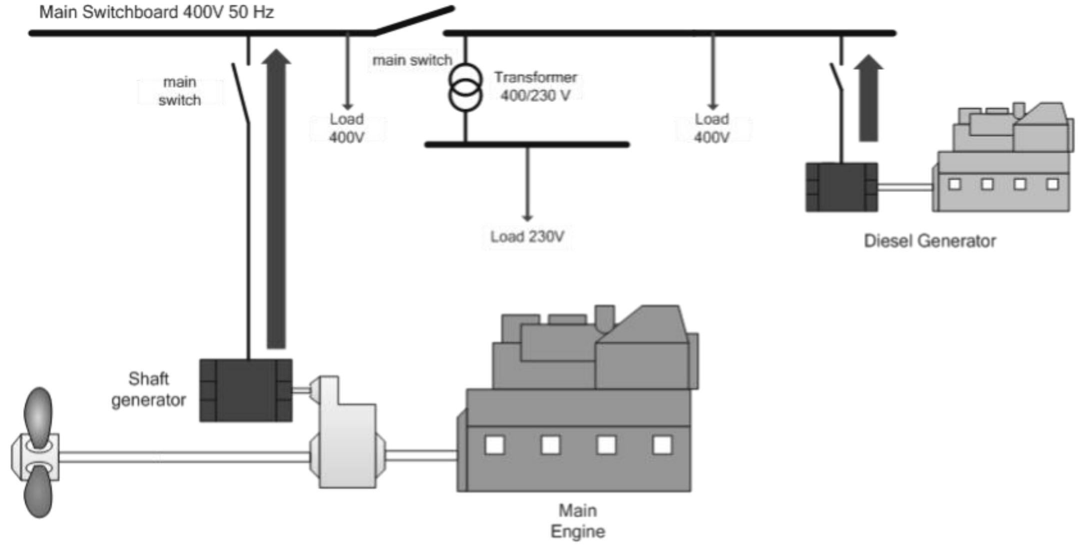

Fig. 1 Schematic diagram of a typical electric energy system for fishing boats

QUALITY OF ELECTRICITY ON FISHING BOATS AND ITS IMPACT ON RECEPTIONS

Electrical energy is degraded under the electromagnetic disturbances. Uncontrolled disturbances of electrical energy occurring on fishing boats can cause interferences, failures (contributing to economic losses). The most common problem is the presence of changes in voltage values, frequency and voltage unbalance [4].

Voltage parameters (mainly the voltage and frequency level) change due to the receptions of electrical energy, but above all during the change of the sea's status (it especially concerns the shaft generator).

Quality of electrical energy can be defined as a set of parameters describing properties of the electricity supply process and characterizing the voltage [1]. Qualitative parameters serve to describe the quality of electrical energy.

Appropriate quality of electrical energy in marine ships (including also fishing boats) is defined by classification societies and international organizations. Limit values of electricity's quality parameters for watercraft are determined in IEC (International Electrotechnical Commission) documents and presented in Table 1 [3].

Table 1
Limit values of electricity's quality parameters for watercraft

Parameter	Permissible value
Steady-state voltage deviations	+6% -10%
Voltage momentary deviation	+20% -20%
Phase to phase voltage unbalance (continuous)	3%
Steady-state frequency deviations	+5% -5%
Frequency momentary deviations	+10% -10%
Total harmonic distortion THD	5%
A single distortion (any harmonic greater than)	3%
Voltage transients recovery time	1.5s
Frequency transients recovery time	5s

Momentary voltage deviation from nominal values is particularly important for the safety of marine technical systems, while long-term deviations are mainly connected with economic costs [5].

The impact of individual parameters on different receptions of electrical energy is important. There may be mentioned the most important sources:

– electric motors by changing the torque (correlation of torque and tension is especially important when starting cage asynchronous motors. During the motor's operation, it has an effect on the stiffness of motor's mechanical characteristics). Wear of motor bearings, engine overheating,
– transformers – changes of the magnetic field, the deterioration of the power factor, overheating of transformers,
– contractors and relays – change of the magnetic field's power causes a malfunction,
– light sources – light flickering, reducing the efficiency and durability of light sources,
– supply lines – increased losses in lines, the aging of cable insulation,
– electronic devices – interferences in the work of appliances.

RESEARCHES OF ELECTRICAL ENERGY QUALITY PARAMETERS FOR A REPRESENTATIVE MARINE FISHING BOAT

Operational Program "Sustainable Development of Fisheries and Coastal Fishing Areas 2007-2013" included measurements of electric power quality on the majority types of Polish fishing boats. This article presented an analysis for one type of boat.

Moreover, it described measurements and recording of electrical network parameters. Measurements were carried out using a power quality analyzer with the Certificate Class (Class A) Wally A3 consistent with IEC 61000-4-30 [2]. Researches were performed in different stages of the fishing boat's operation, i.e.: stoppage in the port, maneuvers, sea sailing, trawling. The paper shows the results of measurements of electrical ship network for sealing and trawling, where the load of diesel generators was the greatest and changing. Measurements were carried on the main switchboard.

Steady-state voltage deviations and voltage momentary deviation

Figure 2 presents processes of phase-to-phase voltages recorded while sailing and trawling. Limits values of voltages in accordance with the IEC regulations (Table 1) are marked.

Steady-state frequency deviations and frequency momentary deviation

Figure 3 presents the frequency of voltage recorded while sailing and trawling. Limit value of frequency in accordance with the IEC regulations (Table 1) is marked.

Total harmonic distortion (THD_U%)

Figure 4 presents the change of THDU recorded while sealing and trawling. Limit value of THDU in accordance with the IEC regulations (Tab. 1) is marked.

A single distortion (any harmonic greater than)

Figure 5 shows values of voltage's particular harmonics in the highest value of THDU. It presents a limit value for individual harmonics in accordance with the IEC provisions (Table 1).

Phase to phase voltage unbalance (continuous)

Indicator of voltage asymmetry is calculated according to the method of symmetrical components [6]. This indicator is determined on the basis of formula (1) in accordance with the standard [2]:

$$U_{ASYM}\,\% = \sqrt{\frac{1-\sqrt{3-6\cdot\beta}}{1+\sqrt{3-6\cdot\beta}}}\cdot 100\% \qquad (1)$$

where:

$$\beta = \frac{U_{AB}^{\,4} + U_{BC}^{\,4} + U_{CA}^{\,4}}{\left(U_{AB}^{\,2} + U_{BC}^{\,2} + U_{CA}^{\,2}\right)^2}$$

U_{AB}, U_{BC}, U_{CA} - effective value of the first harmonic

Figure 6 shows an indicator of voltage asymmetry calculated on the basis of formula (1). The limit value of the indicator in accordance with IEC regulations (Table 1) is marked.

Voltage transients recovery time

Figure 7 presents the time course of voltage when switching on a big receiver and the return of a temporary component of the voltage to the nominal value. Moreover, it shows the maximum return time of transients according to the ICE (Table 1).

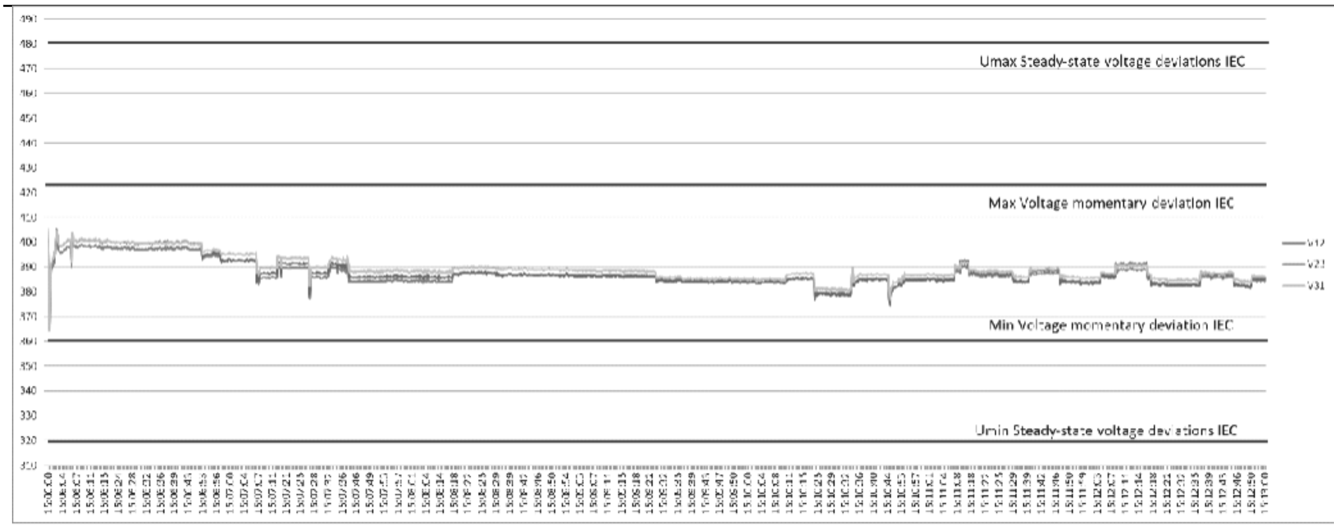

Fig. 2 Processes of phase-to-phase voltages. The nominal value of UN = 400 V

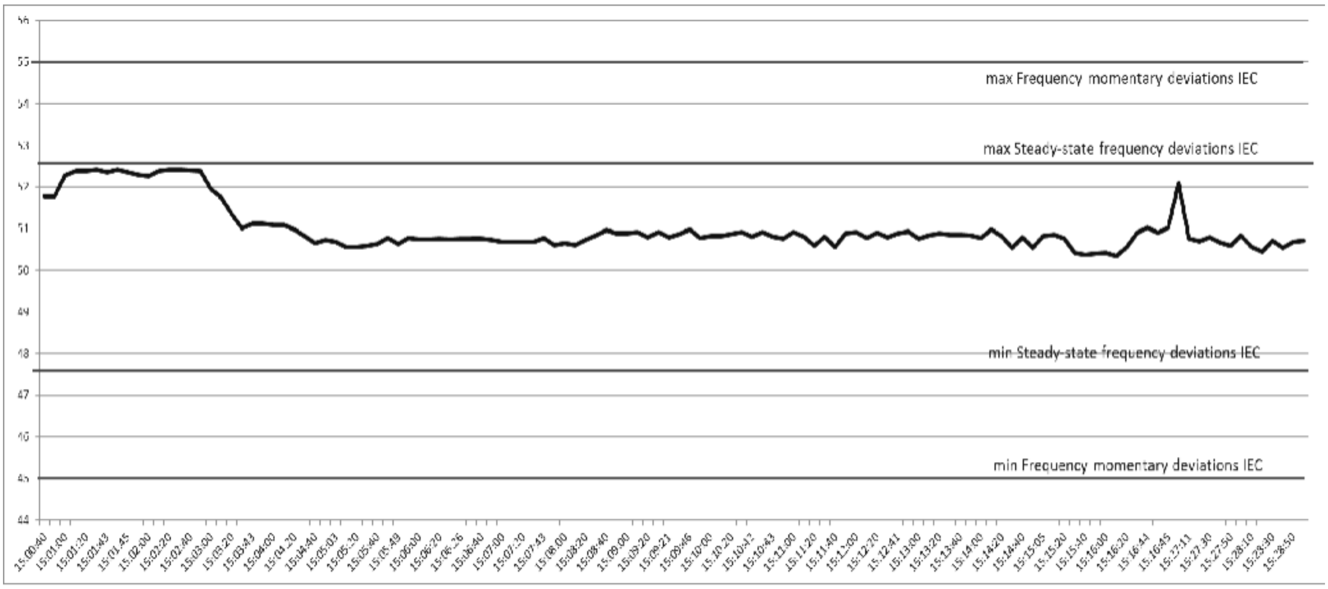

Fig. 3 Frequency of the voltage. The nominal value fN = 50 Hz

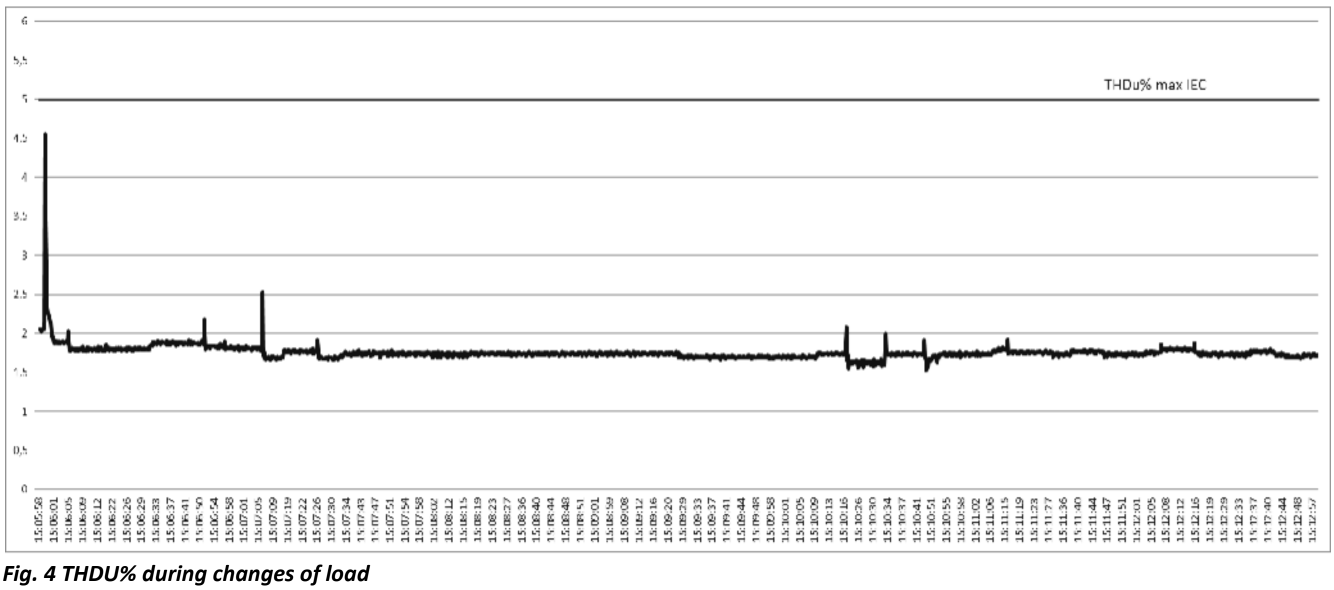

Fig. 4 THDU% during changes of load

When analyzing the quality of electrical energy obtained from measurements (Figures from 2 to 7) it can be concluded that the vast majority of parameters is within the limits permissible by the ICE standard. Long-term and short-term deviations do not exceed the limit values.

Asymmetry of voltages during changes in load does not exceed the values approved by the standard. Return time of voltage transients practically does not exceed the standard. General distortions of THDU% in the voltage have values less than the maximum value of ICE standard, but harmonic 7 exceeds the acceptable value.

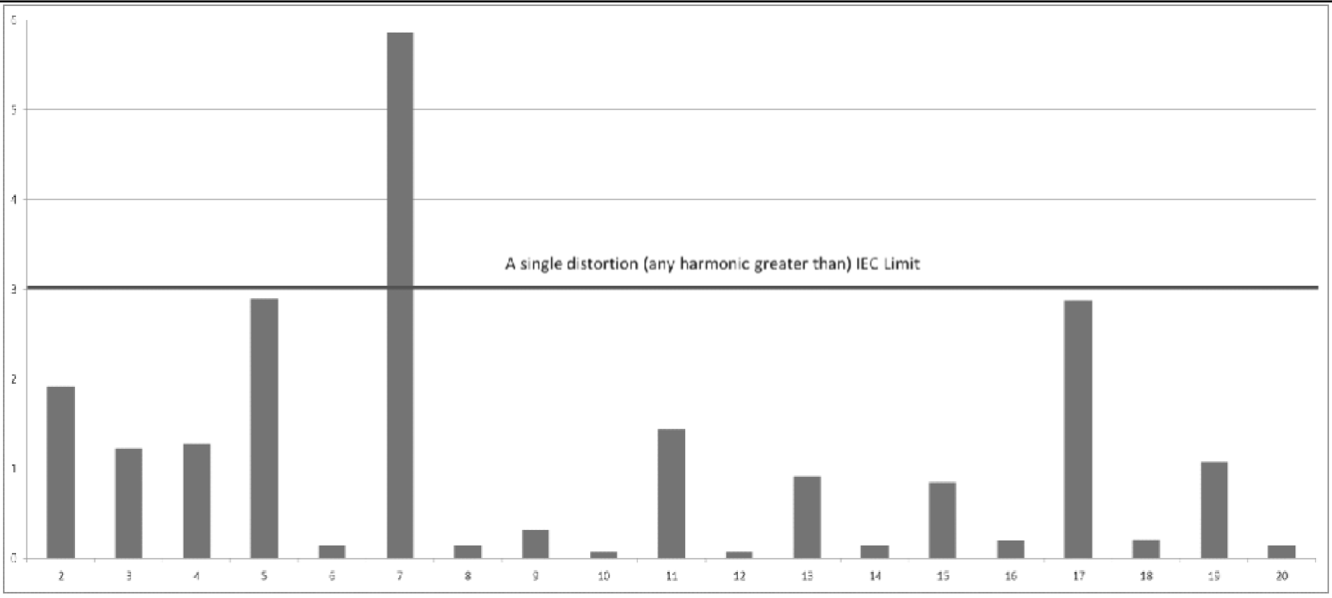

Fig. 5 Individual harmonics of voltage in the power supply

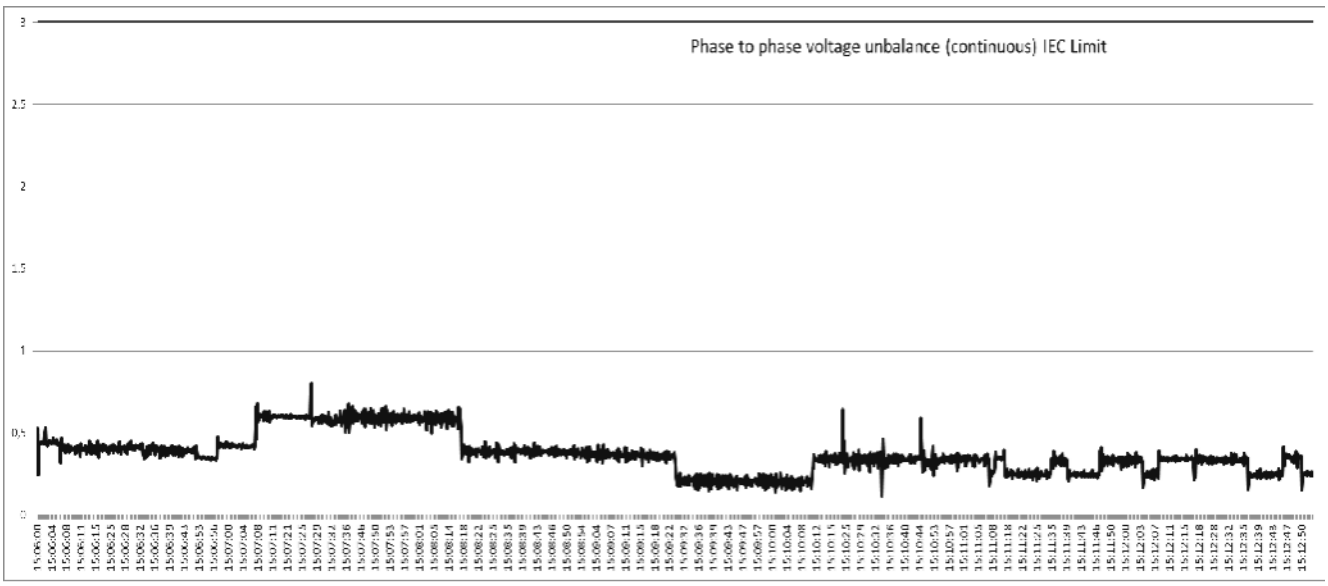

Fig. 6 Indicator of voltage asymmetry

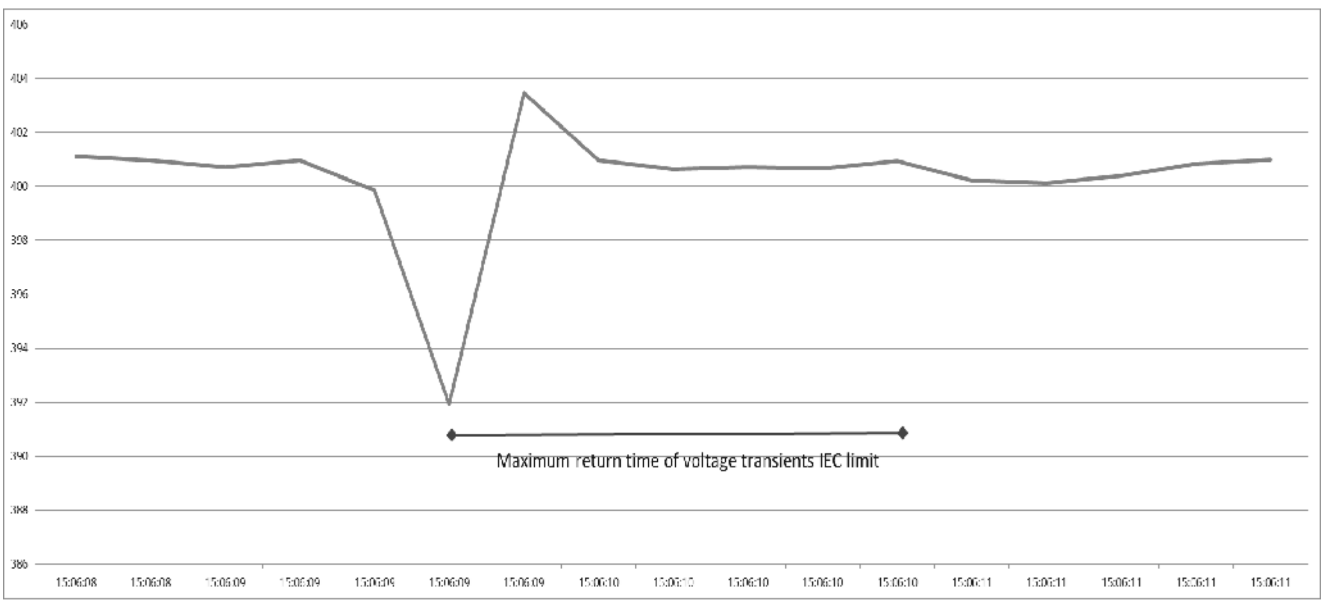

Fig. 7 Return of the voltage transient component

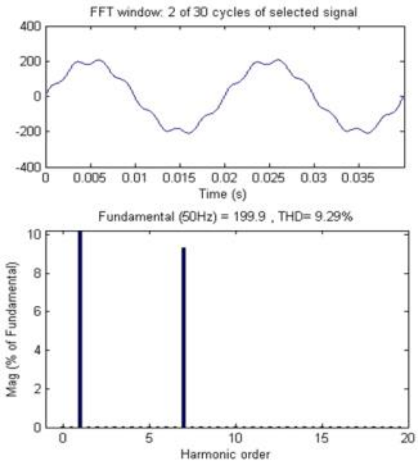

Fig. 8a Voltage waveform and harmonics spectrum without use of the passive filter

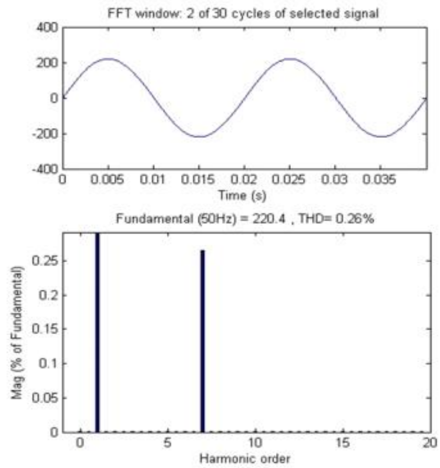

Fig. 8b Voltage waveform and harmonics spectrum with use of the passive filter

COMPENSATION OF THE PARTICULAR HARMONICS

As stated only one parameter power quality measurements obtained value exceeded the value limit – 7th harmonic. According to the ICE, an acceptable value is 3% (Table 1), and the value of harmonic 7 was almost doubly exceeded and it amounted to 5.87%.

In order to reduce the value of a single harmonic, the best solution is to use a passive filter. Passive filters are systems made up of branches of serially connected capacitors and chokes. What is more, they are parallel connected to rails of the supply network and matched to the resonance frequency of the selected harmonic. The use of passive filter for compensation of more harmonics is possible by inclusion of a few passive filters in a combined system to the electricity network. In this case, it would be advisable to use the passive filter, which compensates the spectrum of harmonics.

In the discussed case, the passive filter was selected to compensate the harmonic 7 (for harmonic 7, the resultant reactance of the filter is equal to zero). Simulation tests with the use of MATLAB-SIMULINK program were carried out. The results of these researches are presented in Fig. 8.

Obtained results confirm the effectiveness of the use of passive filter. Harmonic capacity factor in the network disturbed by harmonic 7 without a passive filter is $THD_U\% = 9.29\%$ (Fig. 8a). After switching on the filter, the harmonic capacity factor drops to $THD_U\% = 0.26\%$ (Fig. 8b).

The discussed fishing boat should have a combined filter (and additionally two passive filters for harmonic 5 and 17) in order to improve the $THD_U\%$.

During the activation of different high power receptions, there can be dynamic changes of individual harmonics. In appropriate sections of the main switchboard, it would be suitable to use active filters.

CONCLUSIONS

Quality of electrical energy, even in such small units like fishing boats, is primarily connected with the safety of systems and the durability of devices. Commonly used control and monitoring appliances, which are more and more popular on modern fishing boats, are threatened by the low quality of electrical energy.

Each modernization of electrical systems on fishing boards should be confirmed by measurements of the electrical energy's quality. An example can be one of boats with the DC/AC converter for portable on-board equipment. Output voltage of inverters was trapezoidal ($THD_U\%$ over 40%) and no on-board appliance could not work.

When assessing the results of electrical energy quality's measurements for the representative and described fishing boat, it can be concluded that the majority of qualitative parameters is within the limits prescribed by the IEC regulations. The only parameter that was exceeded is a value of the single voltage harmonic. Proposed solution for the compensation of a single harmonic is the use of a passive filter.

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