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# A new concept of harmonic current detection for shunt active power filters control

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ABSTRACT

The paper deals with measurement and control aspects of active power filtering in ship systems. The main focus of the paper is concentrated on improvement of harmonic current measurement algorithms based on $i_p$–$i_q$ method with application of low-pass filter (LPF) module and, alternatively, on $i_p$–$i_q$ method with application of mean value module.



## 1. Introduction

The problem of power quality in marine networks has gained its due significance over the last few years. This results from some accidents, like malfunctions of important systems, black-outs or even fires. The accidents were due to inappropriate level of power quality in ship systems. One of the solutions for improving electrical power quality in ships systems, especially with non-linear and non-stationary loads is an application of the correcting and filtering systems. These non-linear loads cause distorted line load currents, which through the voltage drop on the generator and line impedances are subsequently transferred into distorted voltage supply on the bus bars of main and auxiliary switchboards in the ship electrical power systems. For the purpose of this paper, it was assumed that this distorted current is called harmonic current, since it contains mainly harmonics, although authors are fully aware that interharmonic components can be present as well. A necessary condition of effective operation of the ship electric power systems is to control and limit of the harmonic current impact on the whole system operation. This can be carried out by e.g. active power filters. This results in the necessity of fast and an adequate detection of analyzed, usually significantly distorted load current waveforms. A concept of ship electrical power system equipped with the power quality improvement modules is shown in Fig. 1.

An example solution consisting of parallel active power filter with power factor correction, series active power filter and set of passive power filters (so – called Combined APFCC – active power filtering correction circuit and SAPF/PF – series active power filter/passive filter), dedicated to simultaneous reactive power compensation and mitigation of higher harmonics, has been described in [1]. Further research carried out under a Polish – Chinese joint project led to the conclusion, that a basic part of the proposed filtering and correcting system is shunt active power filter and improvement of its properties is critical for solving the problem of power quality improvement. Taking into account the well known configuration of this filter and related procedures of its control [2,3] the authors proposed a progress on the way of more precise measurement of load harmonic current and improved APF (active power filter) control. The problem of improving APF control is presented in [4] based on compensating current waveform by optimization of current tracing algorithm in active power filter, based on Space Vector Pulse Width Modulation (SVPWM) method. So, in this paper only a problem of detecting of harmonic current for APF control is considered.

The paper is organized as follows. Firstly, the main features of the ship electrical power system are presented. In Section 2 the physical model of ship power system

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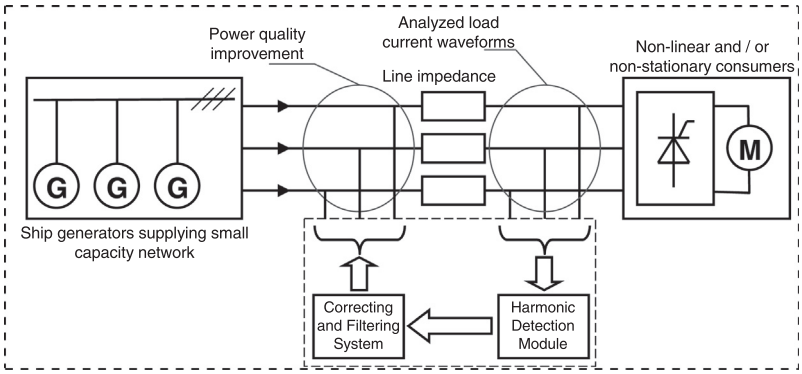


**Fig. 1.** Ship electrical power network with power quality correction system.

equipped with shunt active power filter, corresponding to an isolated power network is described. This model was used for preliminary experimental research, to choose a method of distorted load current measurement and generation of compensation current by active power filter. Afterwards, in Section 3 a concept of improvement of harmonic current measurement algorithm is discussed. In this section the main ideas, block diagrams, and short mathematical analysis for measurement of harmonic current with traditional and improved $i_p$–$i_q$ algorithm, respectively are presented. Section 4 covers a discussion of the results of simulation, corresponding to the two previously mentioned algorithms. Simulation was carried out using Matlab/Simulink environment, applied for the configuration of ship electrical system resulting from Fig. 2. A comparison of two analyzed algorithms is based on two criteria: low level of the waveform distortion and time of response of harmonic detection for the active power filtering. The former was analyzed by using Mathcad environment. Finally, the conclusions and indications for the future research are formulated in Section 5.

## 2. Model of the ship electrical power system

A block diagram of the physical model of ship power system equipped with shunt active power filter is depicted in Fig. 2.

Application of active power filter in the configuration of the system shown in Fig. 2 is connected with two basic problems: measurement of distorted load current (including an identification of its waveform) and generation of appropriate compensation current by active power filter. A supply side of the considered system was realized, by means of an appropriately selected voltage controller and transformer as overland electrical power separator and the made the electric network connected to the transformer to be an model of an isolated small capacity network, together with a non-linear load of resistive–inductive character. This physical model corresponds to an isolated power network, like a ship network. In the preliminary research for solving the first problem, the current component filtering method and alternatively wavelet transform method were considered. On the other hand, for solving the second problem, the space vector pulse width modulation control strategy and the fuzzy-sliding mode control strategy as an alternative possibility for generation of appropriate compensation current of APF were considered. Finally, for further investigations, taking into account the experimental research results a method of harmonic current measurement based on the current component filtering and active power filter control strategy based on the space vector pulse width modulation concept were chosen. The designed shunt active power filter was able to fulfill the task of harmonic current suppression and keep the current on the network side approximately sinusoidal.

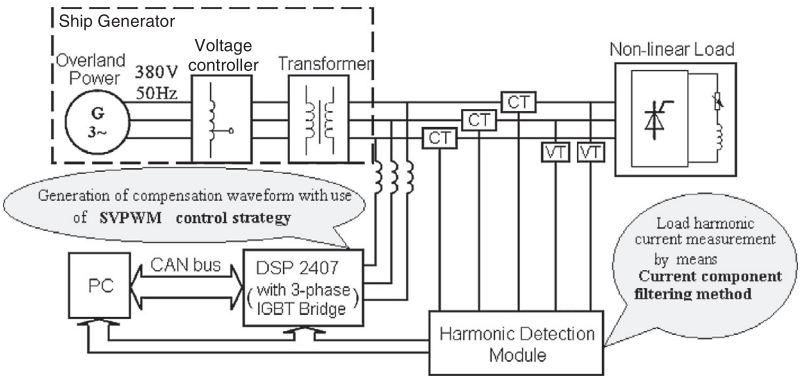


**Fig. 2.** Physical model of ship electrical power system equipped with active power filtering system.