Management Systems in Production Engineering

2014, No 4 (16), pp 179-183

DOI 10.12914/MSPE-07-04-2014

QUALITY OF SUPPLY GUARANTEED IN SYSTEMS OF SHORE SUPPLY CONNECTION OF SHIPS MOORING IN A PORT

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Abstract:
Increased sea transport with a constantly growing demand by ships for electric power means higher emission of pollutions generated by ships to the atmosphere.To turn off automatic generator sets which are the main source of air pollution emissions by ships mooring in the port a ship has to be connected to the power land network.
Quality of electric power supplied from the land is of a great importance connected with security of the work of naval systems and economical ship functioning. Complicated computer steering systems more and more frequently used on ships are very sensitive to disturbances and require energy supply of a very high quality.
In this article basic information about quality of electric power supplied to the ship from the land network and chosen ways of its improvement are presented.

Key words: *"shore to ship" system, electrical power quality, Total Harmonic Distortion, conversion of electrical energy*

INTRODUCTION

All over the world the interest in ways of reducing a negative influence of ships mooring in ports on a natural habitat is increasing. It is necessary to find solutions to this problem.

The main source of air pollution emissions by ships mooring in ports are naval generator sets called Diesel – Generator.

In most cases electric power is supplied from automatic generator sets (AE) which consist of a piston internal combustion engine and a synchronous generator. Tests of exhaust emissions carried out in ports and their surroundings lead to the conclusion that sea vessels are the main source of exhaust emissions such as: nitric oxide (NOx), sulfur dioxide (SO_2) and particulates (PM) [1]. Exhaust emission from land sources (industrial plants, cars, trains) was drastically reduced within the last two decades by implementing rigorous norms of exhaust emissions, using clear fuels and installing devices which limit pollution emission. Pollution generated by ships mooring in the ports is unacceptable. Making use of electric power from land network by ships mooring in the ports allows turning off automatic generator sets while considerably limiting air pollution emission.

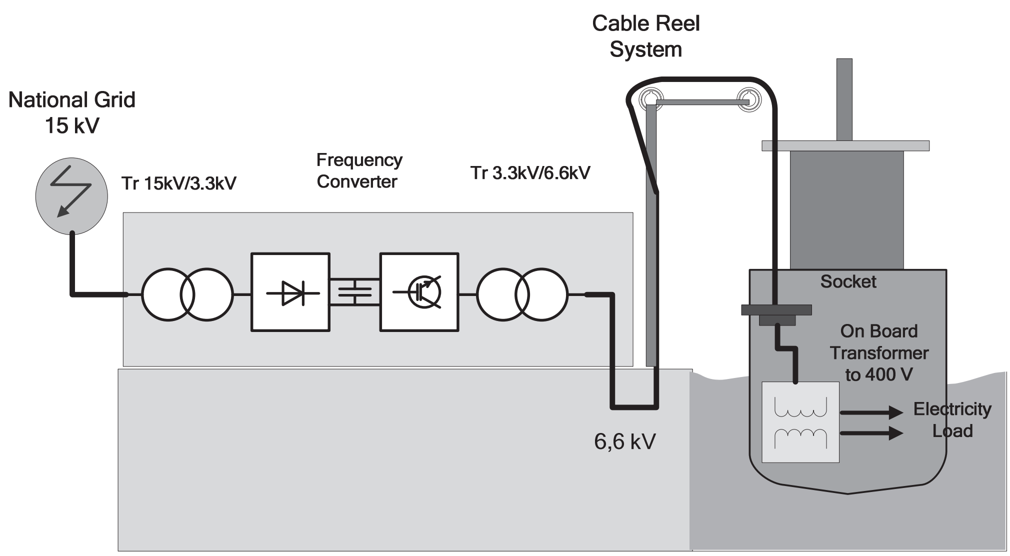

Fig. 1 The scheme of vessel electric supply system configuration (STS) based on IEC

The technical problem of such a solution is connected with using electric networks with different nominal parameters on the ships as well as the lack of standardization of parameters of power land networks in the world [2]. Matching voltage levels of the land network to the power ship network is made by network transformers. The main problem is matching the frequency of 60 Hz (around 65% of ships) and 50 Hz (around 35% of ships). The frequency of land networks depends on world regions and equals mostly 50 Hz in Europe, Africa and a large part of Asia and 60 Hz on the American continent. Frequency converters are used to match frequencies of ship and land networks.

It has been a priority to guarantee a full compatibility between electric ship and land network. The international system standardization allows universality of using the system, that is, it allows building a system which makes it possible to use shore connection for most types of ships. In July 2012 IEC/ISO/IEEE 80005-1 document titled INTERNATIONAL STANDARD Utility connections in port – Part 1: High Voltage Shore Connection (HVSC) Systems – General requirements [3] was published. It describes HVSC systems on the ship deck and on the land so that it was possible to supply electric power to the ship from the land. Figure 1 presents the configuration of the Shore to Ship (STS) system– power shore connection to the ship based on assumptions developed by IEC[1].

Electric power quality supplied from the land to the ship has a great significance connected with security of ship system work and economical ship functioning.

ELECTRIC POWER QUALITY IN STS SYSTEMS

Electric power quality can be defined as a set of parameters which describes the properties of the process of supplying electric power determining uninterruption of power supply and characterizing voltage [4, 5]. To describe electric power quality, quality parameters are used which can be divided into two groups: parameters connected with supply continuity and with voltage distortion against the basic harmonic. The basic quality parameters are:

– Voltage fluctuations
– Voltage distortions
– Voltage asymmetry
– Long-term and short-term voltage decreases and increases
– Voltage dip
– Long-term and short term blackout
– Overvoltages

Temporary deterioration of energy power quality has a special importance for security of technical ship system work, while long-term deterioration is mostly connected with economic costs [6].

Electric power receivers on the ship are very sensitive to supply voltage changes – its deviations from rated values.

Voltage distortion has an influence on:

– electric engine work (electromagnetic parasitic torques, overheating and permanent damage of bearings)
– electric wires (active power losses, voltage drops),
– control and measurement instruments ("false" alarms, uncontrolled shutdowns).

Voltage fluctuations have an influence on:

– electric engine work (change of the electromagnetic moment, wear of engine parts and a powered device),
– luminous receivers (change of luminous efficiency),
– power-supply devices (damage of valves),
– contactors and relays (contact sparks, uncontrolled shutdowns).

Voltage deviations have an influence on:

– electric engine work (overcurrent, temperature rise, difficulties in moving),
– luminous receivers (decrease in durability of discharge lamps)
– heaters (efficiency decrease, faster wear).

Deterioration of parameters of electric power quality in STS systems is connected both with the supply network (most of all non-linear current and temporary characteristics of semiconductor elements of a frequency converter) like with non-linear receptions of energy which supplies ship devices. The chosen ways of its improvements are presented in the article.

VOLTAGE DISTORTION

Voltage distortion for power networks is defined by THD – total harmonic distortion – indicator of harmonic contents. The voltage indicator of harmonic contents presents the following dependencies (1) [6]:

$$THD_U = \frac{\sqrt{\sum_{h=2}^{30} U_h^2}}{U_1} \cdot 100\% \quad (1)$$

were:

U_1- RMS value of the fundamental voltage,
U_h- RMS value of voltage harmonic h.

In connection with high saturation of ship systems with complicated and sensitive to voltage disturbances automation there is a tendency to limit THD_U to 5% (e.g. Lloyd's Register of Shipping < 5%).

In the STS system the main source of high supply voltages harmonic in process is the inverter in the frequency converter configuration. To limit the higher harmonic the following are commonly used:

– Passive filters – parallel LC circuits matched to the chosen harmonic
– Active filters – serial inverter systems (voltage filtration) or parallel inverter systems (current filtration)
– Hybrid filters – installation of passive and active filters simultaneously.

In the article the other way of limiting the higher harmonic was proposed – a multilevel inverter. Power of classical two-level transistor converters built on the basis of IBT transistors is limited by technological aspects. IGBT transistors preserve current commutation up to 1.8 kA and are built for maximum voltage up to 4.5 kV. Using multilevel transistor systems allows reducing requirements on a voltage class of connectors. Currently, in multilevel inverter systems the most popular one is the NPC (neutral-point clamped) inverter. The topology of NPC inverter is based on a division of voltage of the link circuit into three or more degrees with the use of a capacitive divider. A zero pole of "N" supply voltage is a reference point of output phase voltages. Figure 2 presents a topology of two-level inverter (Fig. 2a) and five-level NPC (Fig. 2b).

[1] International Electrotechnical Commission

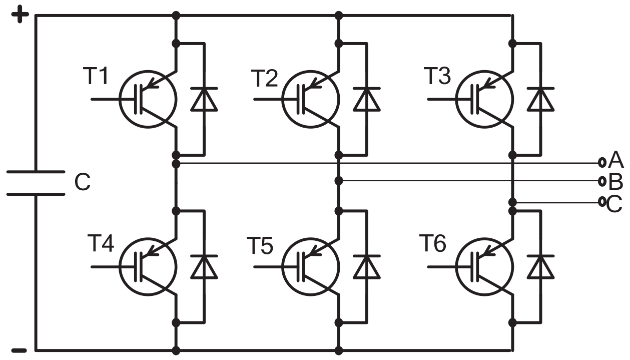

Fig. 2a The topology of three-phase two level inverter NPC

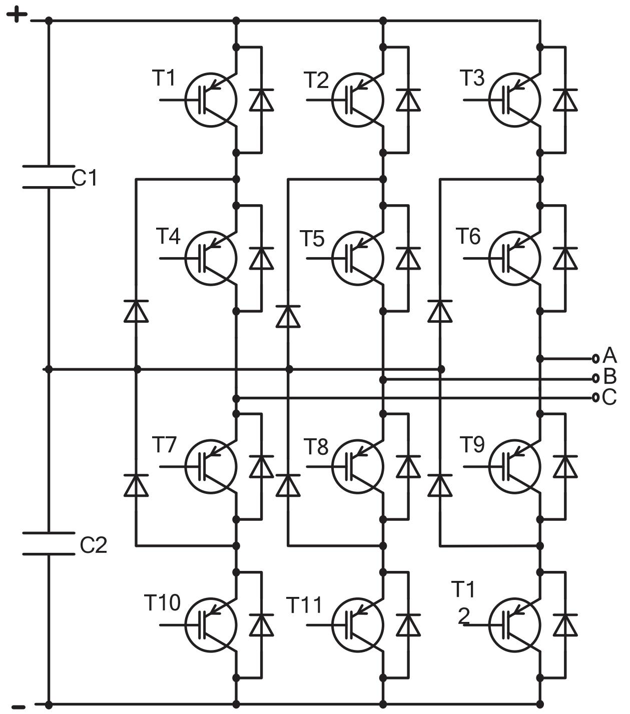

Fig. 2bThe topology of three-phase five-level inverter NPC

Figure 3a and 3b show the processes in the classical (two-level) five-level inverter system and obtained in simulation tests with the use of the MATLAB program. Tests were carried out for the same inverter parameters (link voltage, sampling frequency, inverter output inductance). Processes presented are for one voltage phase.

Test results show the improvement of supply voltage quality with the increase of inverter levels (for 2-level THD = 3.36%, and for 5-level THD = 1.84%).

VOLTAGE ASYMMETRY

The main reason of asymmetry of three-phase voltages is asymmetric load in individual phases. Receivers in ship networks are treated as symmetric ones which is not quite true. Asymmetric receivers of high power are installed on ships. The important group are tank and system heaters which often work like two-phase ones. Load asymmetry can be considerable and changeable in time. The lack of supply voltage symmetry mostly causes additional energy losses in asynchronous cage motors which can cause the increase in temperature and overheating.

In STS systems voltage asymmetry signifies especially when one frequency converter supplies few ships in the port. In the article the way of asymmetry improvement with the using shunt active filter (SAF) was presented.

Total apparent power (S) is a geometric sum of active power P, reactive power Q and asymmetrical power D [7]:

$$S^2 = P^2 + Q^2 + D^2 \qquad (2)$$

The task of SAF active filter is to generate reactive components of currents to the electric network. Thanks to the suitable transform of three-phase coordinates one can set components of load active currents, and as a result, compensation of reactive components of current. In inverter steering systems conversion of size of instantaneous three-phase a, b, c (voltage or currents) to equivalent rotating Cartesian two-phase system d, q, 0 is commonly used [8, 9]. Using the Park transform leads to the error of setting an active component of current in the case of current asymmetry. The error can be eliminated by the rotating system of three p, q, r coordinates [10]. Transformation of d, q, 0 coordinates system and p, q ,r coordinate system is according to the equation (1):

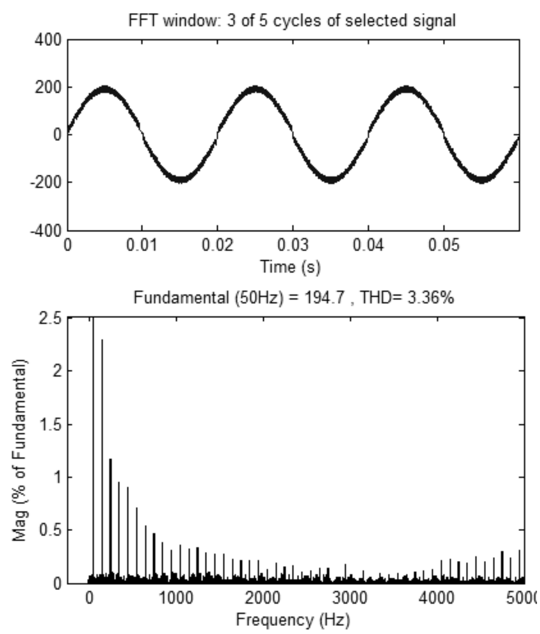

Fig. 3a The course of voltage single-phase two level inverter and harmonic

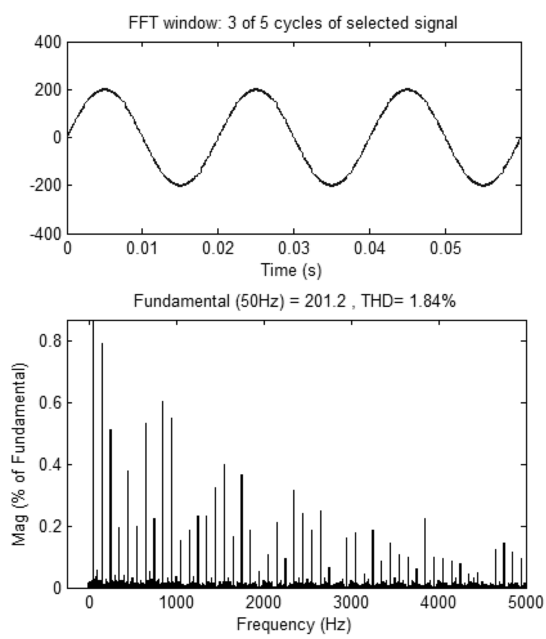

Fig. 3b The course of voltage single-phase five level inverter and harmonic

$$\begin{bmatrix} u_p \\ u_q \\ u_r \end{bmatrix} = \begin{bmatrix} \frac{u_d}{u_{d0}} & 0 & \frac{u_0}{u_{d0}} \\ 0 & 1 & 0 \\ -\frac{u_0}{u_{d0}} & 0 & \frac{u_d}{u_{d0}} \end{bmatrix} \cdot \begin{bmatrix} u_d \\ u_q \\ u_0 \end{bmatrix} \quad (3)$$

where:

$$u_{d0} = \sqrt{u_d^2 + u_0^2}$$

A schematic diagram of the STS system with the SAF filter which eliminates load current asymmetry is presented in picture (Fig. 4).

The system presented on picture (Fig. 4), was implemented in the MATLAB-SIMULINK simulation program. Picture (Fig. 5, 6), shows the results.

CONCLUSIONS

The quality of electricity supplied to ships in the STS system is primarily related to safety marine systems. Most at risk for poor quality of electricity are commonly used control devices and control. Proposed in the article selection methods to improve the power quality allow you to improve the safety and economics.

The use of multilevel inverters in the system STS significantly improves THD voltages, increasing class contrived voltage frequency converters.

The use of STS systems filter SAF allows disabling of output current the converter asymmetry, and hence improve the power quality parameter which is the voltage asymmetry.

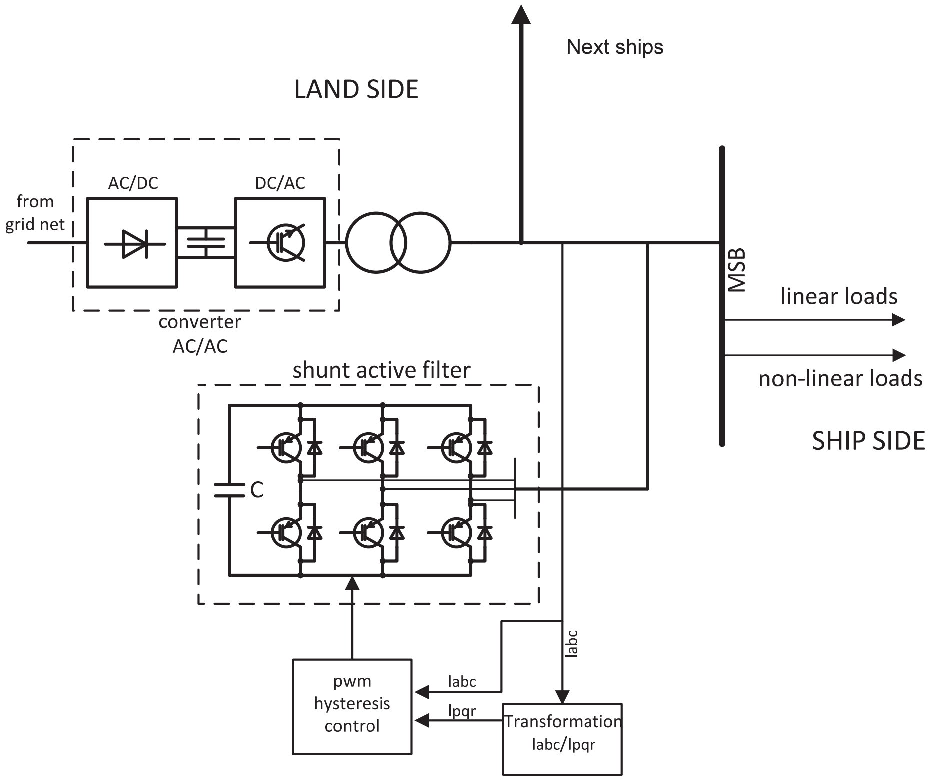

Fig. 4 The scheme of STS system with the SAF

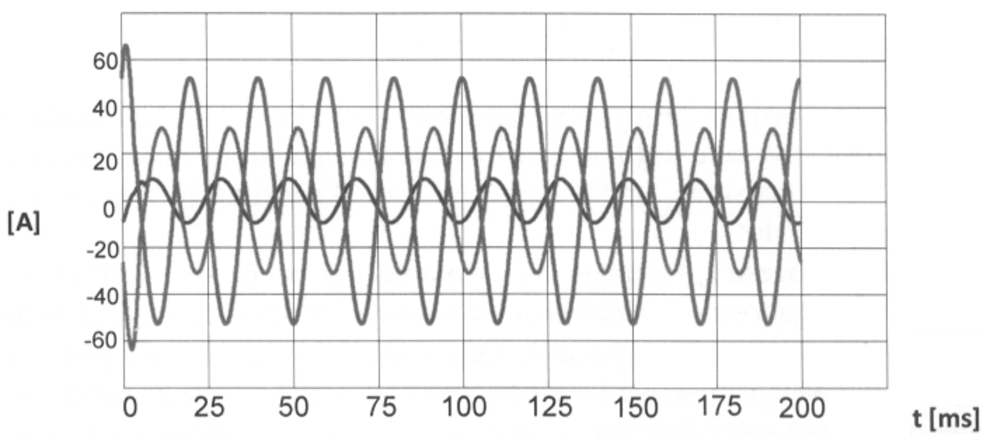

Fig. 5 The current in the STS network at the maximum asymmetry in the load

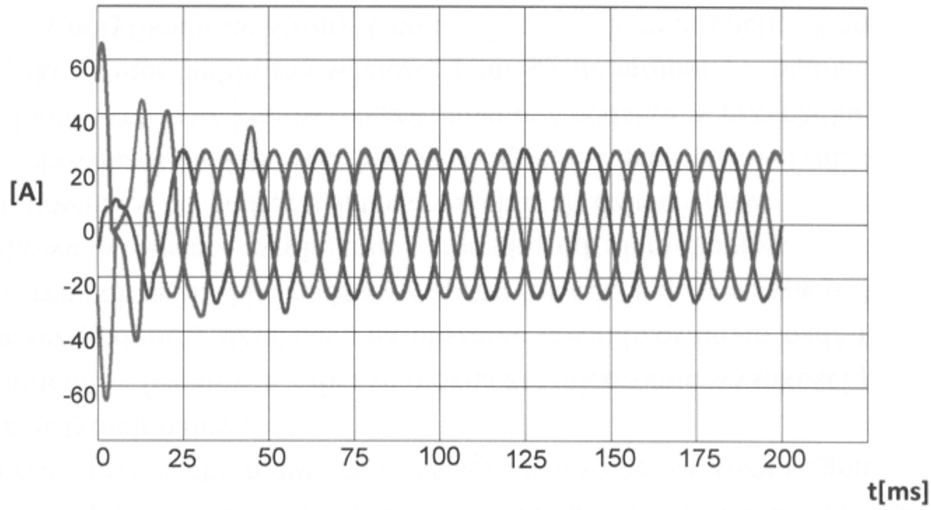

Fig. 6 The current in the STS network with SAF

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