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Quality of the Ship Electric Power at Transients in Converter Fed AC Motor Drives

Abstract – The paper is devoted to the analysis of electromechanical transients in converter fed AC motor drives and their impacts on quality of the ship electrical power. The analysis begins with an idealized model of the ship power system on base of which the important analytical expressions for the induction motor (IM) start up transients are deduced. Two methods of transient suppression are described.

Key words – Power quality, ship, transient, soft start, induction motor.

1. INTRODUCTION

A ship electrical power system is featured by stand alone generator station of commensurable with load output power and by relatively high short-circuit impedance. At these conditions the increase of load currents results in voltage sags, distortion of the supply voltage waveform and the growth of harmonic contents [1, 5]. At the same time this system includes a lot of nonlinear loads, such as high power electromagnetic installations (transformer, AC motors drives, etc.) and power electronic converters (AC/DC, DC/AC types). Power quality and compatibility of the system are also deteriorated due to start up processes and intermittent mode of high power AC motor drives operation (cranes, pumps, fans, compressors, etc).

At present there are two main approaches to ship electric power conditioning [5]: the first one is based on installing the additional power electronic converters (e.g. active filters, power factor correctors, compensators); the second group sticks to suppression of power system disturbances at the root by means of advanced control strategy of the electrical and electronic equipment including soft starters for the AC machines, soft switching converters and active rectifiers. The paper deals with the second group of problems and aims at suppression of undesirable transients by means of advanced control of power electronic converters.

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2. BLOCK-SCHEME AND EQUIVALENT CIRCUITS OF SHIP ELECTRICAL POWER SYSTEM

The problems of electromagnetic compatibility (EMC), interference (EMI) emissions and power quality (PQ) are interrelated between themselves, e.g. electromechanical transients in converter fed drives are accompanied with high harmonic emission and voltage sags in the ship electric power system (Fig.1).

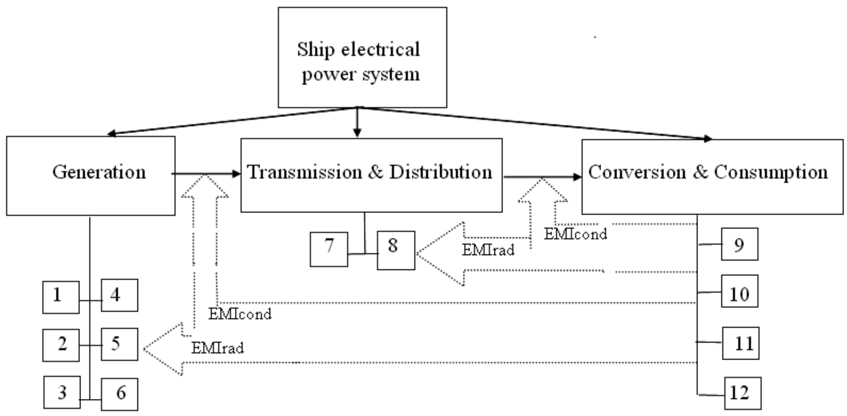

Fig.1. General block-scheme of the ship electrical power system.

A ship electrical power system (SEPS) has a lot of nonlinear loads (# 9-12 in Fig.1), such as transformers, AC motors drives, power electronic converters that results in conductive and radiation EMI and distortion of the ship voltage waveform. Having reached the ship electrical generator station EMI influences sensitive automatic control systems and deteriorates or damages operation of fuelling (1), lubrication (2) and cooling (3) units, micro-controllers (4,5) and computer network (6).

The ship electromechanical transients result in stator current inrushes, voltage sags and brownouts. To discover the physical phenomena of transient we analyze first the SEPS with help of an ideal linear equivalent circuit (Fig. 2a). To analyze concrete performances of the ship power quality it is necessary to proceed from an ideal to a more adequate model as nonlinear equivalent circuit (Fig. 2b) with the integrated short-circuit impedance Z_i and the submodels of frequency converter (FC) and the IM motor drive.

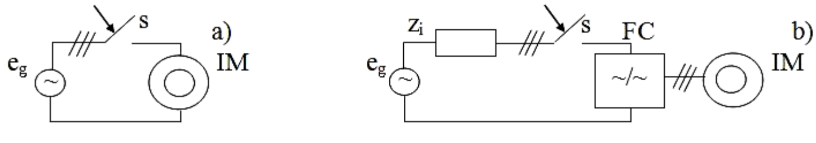

Fig. 2. Ideal linear (a) and updated nonlinear (b) equivalent circuits of the SEPS.

Below the comprehensive analysis of current and torque transient begins with investigation of across-the-line start up of the IM.

3. TRANSIENT ANALYSIS OF THE IM START

The mathematical model of the IM in *abc* reference frame is adequate and convenient for analysis of electrical drive systems with different parameters and states, including arbitrary stator voltage waveforms, different modes of symmetrical and asymmetrical operation and both steady state and transient [2-4]. Results of computer simulation and calculation of the IM transients at across-the-line start up are presented in Fig. 3.

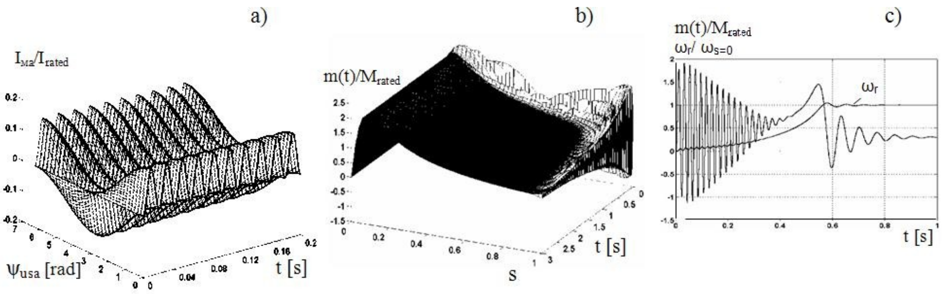

Fig.3. Transients in the IM at across-the-line start up.

Fig.3a displays the 3D set transients of per unit magnetizing current in phase "a" of the standstill IM at different instants ψ_{usa} of the grid voltage impressed. If the voltage is impressed to the stator of rotating IM at given different slips "s" we receive 3D set of torque transients (Fig.3b). The light color in this figure corresponds to transient and black surface to area of steady state. Calculated electromechanical transient of IM drive start up is shown in Fig. 3c.

Fig.4a displays transient of the IM start up with frequency control ($f=a\cdot t$) given zero initial conditions $f(0)=u(0)=0$ and the IM loaded by dry friction torque $M_{st}=0.3M_{rated}$ and by a moment of inertia $J=J_r$. Time of run up is fixed by $t=2.5$ s.

The main reason of transient during the IM start up with two described ways of control is a long transient of the IM magnetizing current. For transient suppression there are two available methods. The first one is based on the pre-excitation of standstill IM and the second – on the separate (asymmetrical) switching on the stator windings [5].

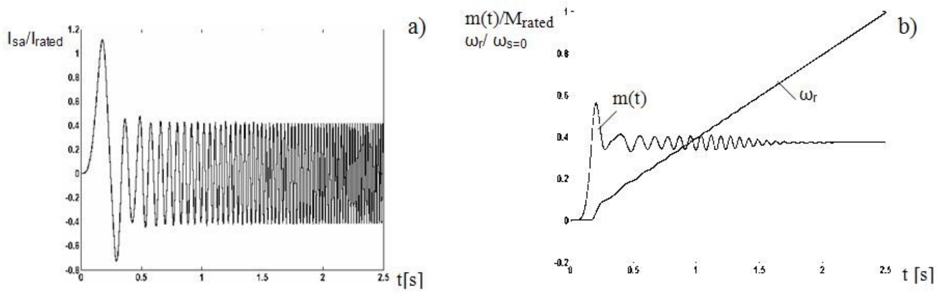

Fig. 4. Per unit stator current (a), torque and speed
(b) time diagram of the IM start up transient at v/f control.

The method of asymmetrical switching on (MAS) the stator phase windings is conprehansively discussed in the paper.

CONCLUSIONS

1.The ship electrical power system is featured by stand alone generator station of commensurable with load output power, by relatively high short-circuit impedance and nonlinear load circuits. Transients during the IM drive start up and intermittent mode of operation deteriorate power quality very strongly, resulting to deep voltage sags and brownouts, increasing harmonic contents and instability of the ship power system on whole.
2.The deeper sag the longer start up process and longer impact on power system, so the power quality may deteriorate avalanchely down to loss of the SEPS stability.
3.To suppress transients during AC motor start up two methods are available. The first one is based on the pre-excitation of standstill IM, and the second - on separate switching on the stator windings to the grid.
4.To analyze power quality of the complicated ship power system it is reasonable to proceed from ideal to a more adequate model as an equivalent nonlinear circuit compiled with the integrated short-circuit impedance and mathematical submodels of power converters and motor drives.

4. REFERENCES

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