PERFORMANCE OF SHUNT ACTIVE FILTER IN ALL-ELECTRIC SHIP (AES)

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Abstract: The problem of harmonic power quality, which has increased lately on the continental grid is expected to deteriorate on shipboard installations, too, after the advent of electric propulsion and other All Electric ship (AES) schemes where the harmonic pollutant power electronic devices dominate. This work aims to investigate the application of the emerging technologies of active filters. It deals with the design, analysis and simulation of an active power filter, capable to suppress the harmonic currents in the phases of an electrical AES system, feeding non-linear loads. The compensating strategy uses a PWM source converter based on the generalised instantaneous power theory . A phase locked loop (PLL) is designed to allow proper operation under distorted and unbalanced voltage. The simulations results show the performance of the proposed shunt active filter in All Electric ship (AES) schemes.

Key-Words: Harmonics, power quality, Active power filter, Voltage Source Inverter, PLL.

1 Introduction

During the last years there has been a deterioration to the problem of the harmonic distortion, observed in voltage and current, in the electrical plants of modern all-electric ship [1].The use of electric propulsion in marine applications provides significant advantages over traditional mechanical solutions. Such supply networks are however, amongst the most demanding in term of power quality and harmonic mitigation due to the variation in term of frequency and short circuit power.

The problem is expected to deteriorate in the future constructions due to the extensive use of devices with power electronics and perspective of implementing electric propulsion utilising power pollutant converters feeding innovative A.C motors as implied by all Electric Ship (AES) concept. Evidently having a good power quality on electric energy system of an AES should be the ultimate objective, considering its impact on all electrified and electronic subsystems including automation and control ones**.**

The electric system of AES comprise a reduced number of generators and an increased number of non-linear loads., which inject non-sinusoidal currents in the electrical network and generates harmonic and reactive currents. The' impact of harmonic voltage and/ or current distortion on electric energy system cover a wide range of phenomena [2],[3]:

- Extra heating losses in electric machinery and cable wiring .
- Failure of equipment sensitive to harmonics.
- Excitation of resonance phenomena resulting to significant overvoltage and /or overcurrents
- energy efficiency and harmful to other appliances.

Conventionally, passive filters have been used to eliminate line current harmonics, but the performances of this solution is strongly dependent on the mains impedance at the harmonic frequencies [4]. To ensure passive filters do not enter into resonance, it is usually necessary to include relatively high levels resistive damping in such applications given the wide short circuit power and frequency variations. This increases equipment losses which is obviously undesirable in any application but particularly in marine context.

In order to overcome these problems, the active power filter relatively well-researched in recent years, is quite promising approach for treating the disturbances on AES.

In this article an active filter operating in a current controlled mode is proposed. Moreover, we propose a PLL with high performances and good results are obtained when the main voltage are strongly unbalanced and contain harmonics**.**

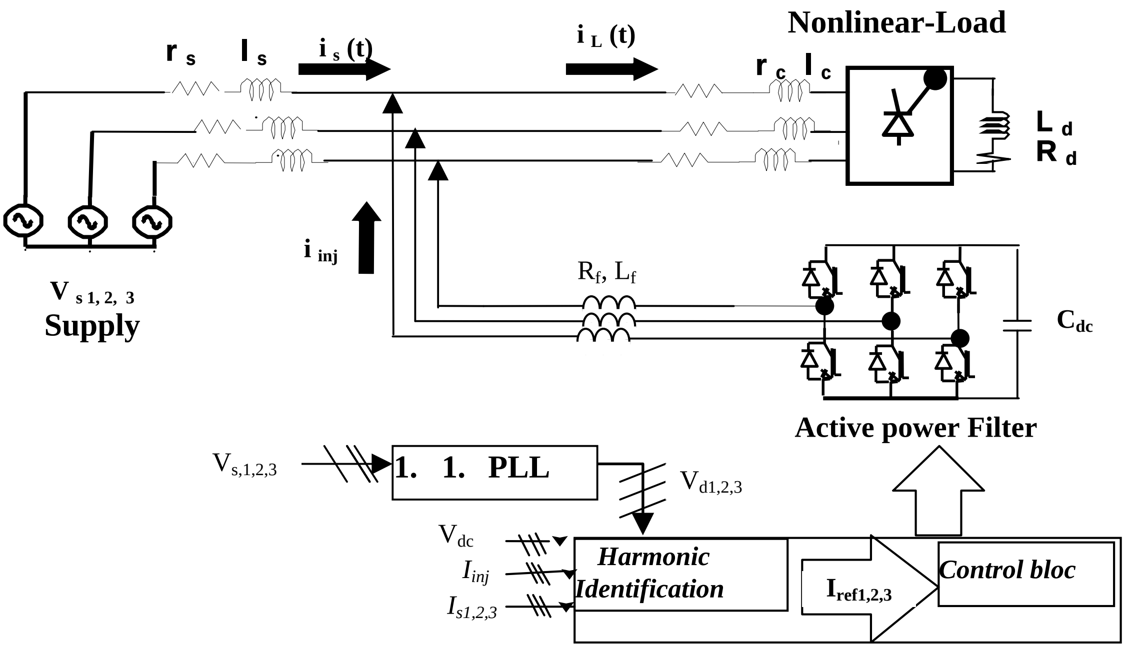

Fig. 1 Basic Scheme of Active power filter

2 Shunt active power filter

Fig.1 shows a power system with a shunt active filter and a non-linear load. The active filter uses an inverter and a first order L-Type filter. The inverter is controlled in pulse width modulation mode (PWM) with the storage capacitor as a voltage source . Different methods for disturbing current identification have been developed [5], [6]. The method using instantaneous power has been chosen in this paper in order to compensate the current harmonics. In this method, as shown in Fig. 2, the perturbing currents (harmonic, reactive and negative components) are separated from the fundamental direct current component.

Thus, a fundamental direct voltage reference is required. If the network voltage reference is disturbed, the non fundamental direct voltage components introduce an undesired instantaneous power component. Consequently, the harmonic current reference will be wrong. A three phase direct system at fundamental frequency is required. Its magnitude and phase shift can be of any value but a minimum magnitude voltage reference is required for the storage capacity recharging. Thus, we propose a PLL (Phase Locked Loop) in order to components) are separated from the fundamental direct current component.

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3 Control strategy description

The generalised theory of the instantaneous power can be written in the α-β-0 co-ordinate system as:

$$\begin{bmatrix} v_{s\alpha} \\ v_{s\beta} \end{bmatrix} = \sqrt{\frac{2}{3}} . \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_{s1} \\ v_{s2} \\ v_{s3} \end{bmatrix} \quad (1)$$

and the currents

$$\begin{bmatrix} i_{c\alpha} \\ i_{c\beta} \end{bmatrix} = \sqrt{\frac{2}{3}} . \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{c1} \\ i_{c2} \\ i_{c3} \end{bmatrix} \quad (2)$$

The instantaneous power components p, q and p_0 are expressed by:

$$\begin{pmatrix} p \\ q \end{pmatrix} = \begin{pmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{pmatrix} \begin{pmatrix} i_\alpha \\ i_\beta \end{pmatrix} \quad \text{and} \quad p_0 = v_0 i_0 \qquad (3)$$

Where:

p: Instantaneous real power
q: Instantaneous imaginary power
p_0: Instantaneous zero sequence power

To calculate the reference compensation currents in the α-β-0 coordinates, the expression (3) is inverted, and the powers to be compensated ($\tilde{p} - \bar{p}_0$ and q) are used:

$$\begin{pmatrix} i^*_{C\alpha} \\ i^*_{C\beta} \end{pmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{pmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{pmatrix} . \begin{pmatrix} \tilde{p} - \bar{p}_0 \\ \tilde{q} \end{pmatrix} \qquad (4)$$

where:

$\tilde{p}$ (t) :alternative instantaneous real power

$\tilde{q}$ (t) alternative instantaneous imaginary power

In order to obtain the reference current in the a-b-c coordinates the inverse of the transformation in expression (3) is applied.

$$\begin{bmatrix} i_{c1} \\ i_{c2} \\ i_{c3} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{c\alpha} \\ i_{c\beta} \end{bmatrix} \qquad (5)$$

By this approach when applied to unbalanced load condition and sinusoidal current required, the block diagram of fig. 2 presents the procedure in this cas

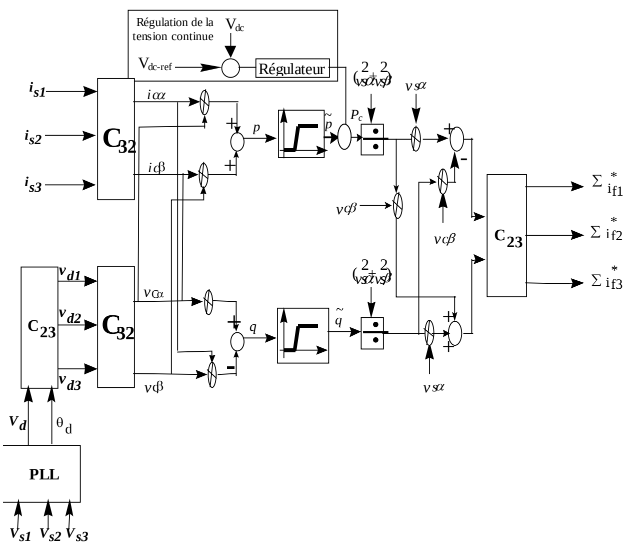

Fig. 2. Current references identification

4 The PLL

The phase voltages v_a, v_b and v_c at load terminal are mainly composed of positive sequence components, but can be unbalanced with negative and zero sequence components at fundamental frequency and can contain harmonics. The detection of the fundamental positive sequence component of v_a, v_b and v_c is necessary if the shunt active filter has to compensate load currents. The positive sequence detector uses a PLL (Phase-looked loop) circuit looked to the fundamental frequency of the system voltage. The design of the PLL should allow proper operation under distorted and unbalanced voltage waveform. The PLL circuit that is used is illustrated in Figure.3 .The PLL allows control of estimated phase angle $\hat{\theta}$ with respect to the angle θ of mains voltage.The PLL will be looked out of the supply voltages when $\Delta\theta = (\theta - \hat{\theta})$ is equal zero. In this case $V_{sd} = 0$ and V_{sq} gives the RMS voltage.

Moreover, we use a self tuning filter for extracting harmonics. The self tuning filter allows to make insensible the PLL to the disturbances and filtering correctly in α-βaxis [9].

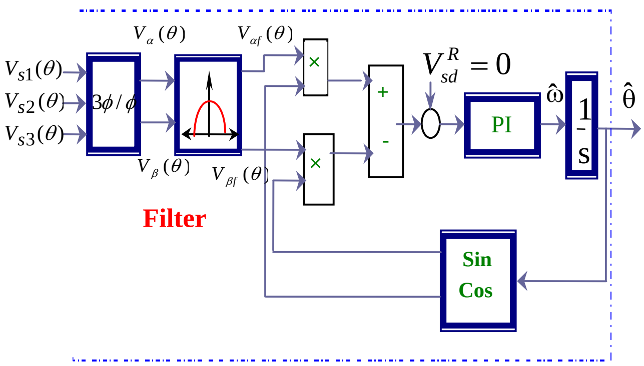

Fig.3 The PLL circuit.

5 Simulation results

The efficiency of the filter has been tested through the simulation using Matlab “simulink and power system blockset”. The response of control strategy (and overall active power filter) is studied by switching a non linear load made up of a six pulse thyristor rectifier which supplies a 400 kVA R_d-L_d series, with the commutation angle: α=30°, under the following parameters:

Ac source 240V/50Hz, R_s=1.1mΩ, L_s=37.6µH, R_c=4.3mΩ , L_c=68.67µH R_d=0.8Ω, L_d=2.2mH. L_f=100µH et R_f=5m

Figure.4 presents the network voltage inα-β axis as can be seen thevoltage are unbalanced and not sinusoidal. By the use of self tuning filter, they become sinusoidal, balanced and without phase figure .5 .Fig. 7 shows a number of selected simulation results of utility harmonics compensation which have been realised on the described model. Corresponding spectrums before and after compensation are given in fig.8 . The THD of the line current source was 27.88% before compensation is reduced into 3.51% by the shunt active power filter

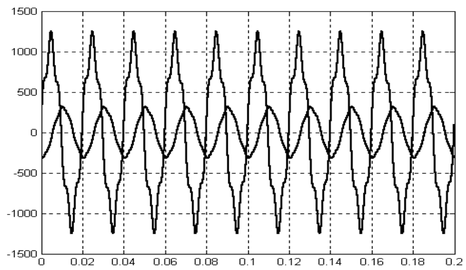

Fig.4 V_α et V_β Voltage of the network under unbalanced conditions

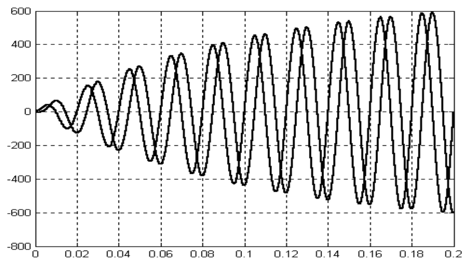

Fig . 5 V_α et V_β Voltage of the network after filtring

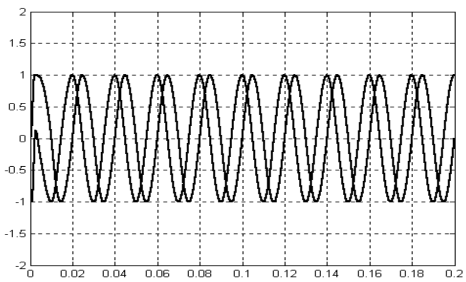

Fig. 6 The synthetic sine and cosine generated by the PLL

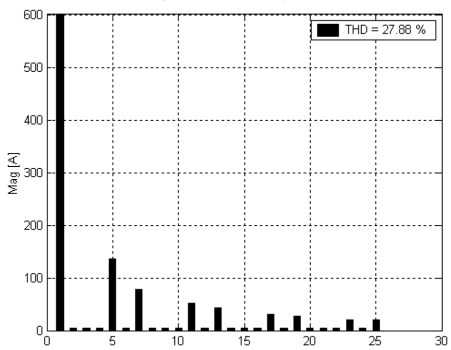

Fig. 7 a) Current spectrum before compensation

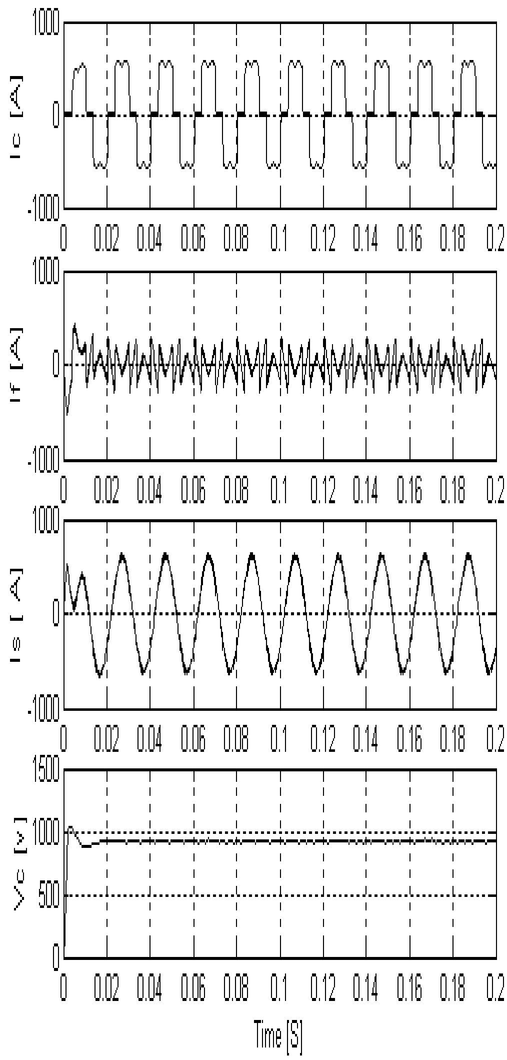

Fig.7 b) Load and source current wave form, I_{LA}: Load current, I_f: compensation current in phase A I_s: line current, Vdc: Capacitor voltage

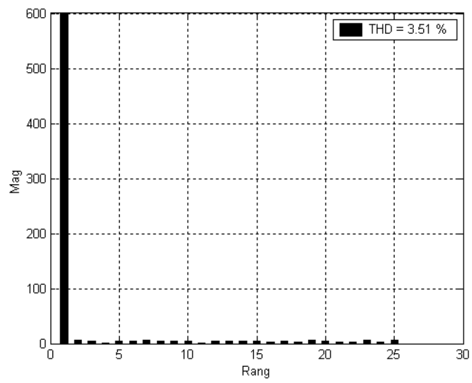

Fig. 7 c) Current spectrum after compensation

6 Conclusion

In this paper, a shunt active filter based on PWM voltage source inverter is proposed for compensating current harmonics, even under a distorted voltage using a PLL is detailed.

The general model for the proposed scheme is obtained and analysed using instantaneous power identification method .It has been shown that the line current can be controlled to leads to a sinusoidal current in the ac source and consequently no voltage harmonic distortion due to the internal impedance may occur. The validity of the modelling, analysis and control method of the proposed shunt active filter is proved by the computer simulation. Simulation results show that the shunt active power filter is capable of compensating the harmonics generated by nonlinear load in distribution system. In conclusion, shunt active power filter is feasible means power conditioning for marine power system, particularly when applied to condition the low voltage AES ship service section of a marine electrical system.

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