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AC Filter Capacitor 에 따른 진상 전류 보상 회로를 갖는 3ϕ PWM AC/DC 컨버터

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Three Phase PWM AC/DC Converter with Leading Current Compensation Control

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Abstract

This paper proposes a novel PWM technique for a three phase current fed type converters. A minor loop compensation method is introduced to compensate leading current and to minimize input line current (Iu) distortion resulting from the resonance between AC filter capacitor and source inductance of power system.

This PWM converter has excellent characterics as next. The control system is simply designed, and the operation with unity power factor can be easily obtained by automatic compensating the leading current of the filter circuit. Also, the three phase sinusoidal input current can be obtained.

Introduction

In recent years, many PWM AC/DC converter schemes have been proposed in order to solve the problem of the excessive harmonic current generation in the utility systems. The harmonics are typically caused by the controlled or uncontrolled line-commutate rectifiers. The PWM AC/DC converter consists of the boost inductor(Lb) and the switching element as shown in fig.1, and offers distinct advantage over the conventional rectifiers in terms of unity power factor, bi-directional power flow capability, low harmonics components in line current and low ripple in output voltage.

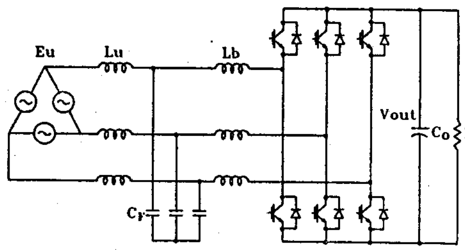

Fig.1 PWM AC/DC Converter

However, when the AC/DC converter is operated at a constant high switching frequency, the value of the boost inductor(Lb) is designed relatively small. Therefore, the effect of the source inductance must be seriously considered because the voltage distortion at the AC terminal due to PWM switching is generated as shown in fig.5.

To solve this problem, AC filter capacitor is needed to absorb the switching voltage and current ripple. Fig.2 shows the single phase equivalent circuit of the AC filter circuit. The transfer function from the converter current (Ip) to the line current (Iu) is given as following.

$$\frac{I_u(s)}{I_p(s)} = \frac{\frac{1}{L_u C_f}}{s^2 + \frac{1}{L_u C_f}} \qquad \text{................ (1)}$$

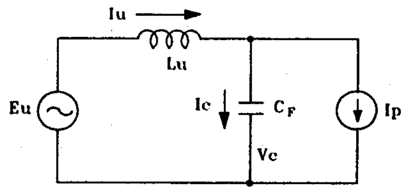

Fig.2 Equivalent Circuit of AC Filter

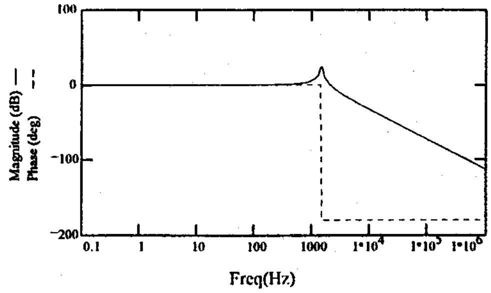

Fig.3 Transfer characteristic of filter showing LuCf resonance

Thus, we know that the filter circuit is a very oscillatory system from equation(1). So, it is necessary to suppress the oscillation caused by the resonance between AC filter capacitor and source inductance of power system. Generally, the AC filter which is composed of capacitor(Cf) and resister(Rf) is used, and Rf is inserted to suppress the line current and voltage resonance. The transfer function is given as.

$$\frac{I_u(s)}{I_p(s)} = \frac{\frac{R_f}{L_u}s + \frac{1}{L_uC_f}}{s^2 + \frac{R_f}{L_u}s + \frac{1}{L_uC_f}} \qquad \text{.......... (2)}$$

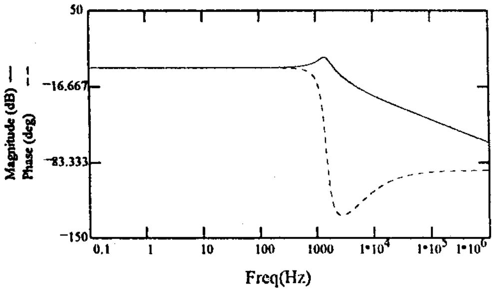

Fig.4 Transfer characteristic of filter with damping register Rf

Damping resister Rf is the smaller, the smaller AC voltage distortion is. Also current or voltage resonance at the AC terminal of PWM AC/DC converter will occur. In the other hand, the larger capacitor Cf is, the smaller AC voltage distortion is. The larger Cf may results in more current leading, and more power dissipated in Rf. Consequently, the appropriate Rf and Cf values are determined by solving above-mentioned inner-conflicting problem.

In this paper, the oscillation of AC filter circuit between Cf and Lu can be suppressed by inverting feedback control of AC capacitor current in the inner current control loop as shown in Fig.5, instead of inserting the damping resister Rf. Leading current can be easily compensated if arg $H(s)|_{f=60Hz} = 0$ is assumed as shown in fig.6.

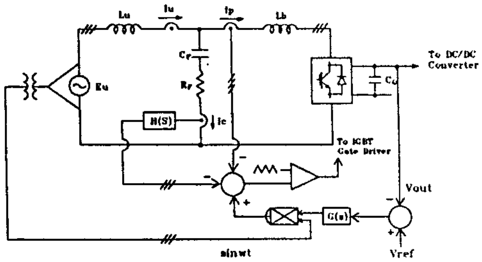

Fig.5 Control System of PWM AC/DC Converter

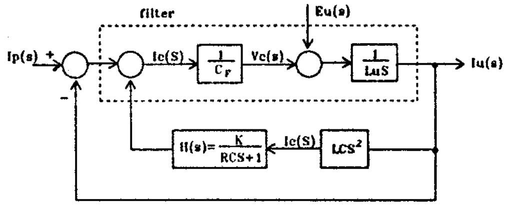

Fig.6 Block Diagram of Filter and Minor Loop Control Circuit

The transfer function of the proposed PWM control scheme becomes as follows.

$$\frac{I_u(s)}{I_p(s)} = \frac{\omega s+1}{\frac{\omega}{\omega_0^2}s^3 + \frac{1}{\omega_0^2}(1+k)s^2 + \omega s + 1} \qquad \text{... (3)}$$

where $\omega_0 = \frac{1}{\sqrt{L_uC_f}}$, $\omega = RC$

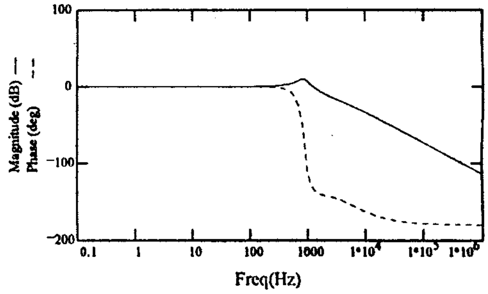

Fig.7 Closed-loop transfer function Iu(s)/Ip(s) with leading current compensation

Experimental Results

A 6KW prototype PWM AC/DC converter with miner loop control circuit for leading current compensation is build to verify experimentally.

The operation conditions are as follows.

AC line to line voltage = 220 Vac
DC output voltage Vout = 450 Vdc
IGBT switching frequency fs = 20 KHz
Source inductance Lu = 50 - 70 uH
AC filter capacitor Cf = 40 uF
Damping resister Rf = 0
Boost inductor Lb = 300 uH

The experimental waveforms for the input phase voltage and current at various load conditions (at no load and 60% load) are shown in fig.8, fig.9 and fig.10. The experimental results show that the three phase sinusoidal input line current with unity power factor by compensating AC filter capacitor current can be obtained.

Reference

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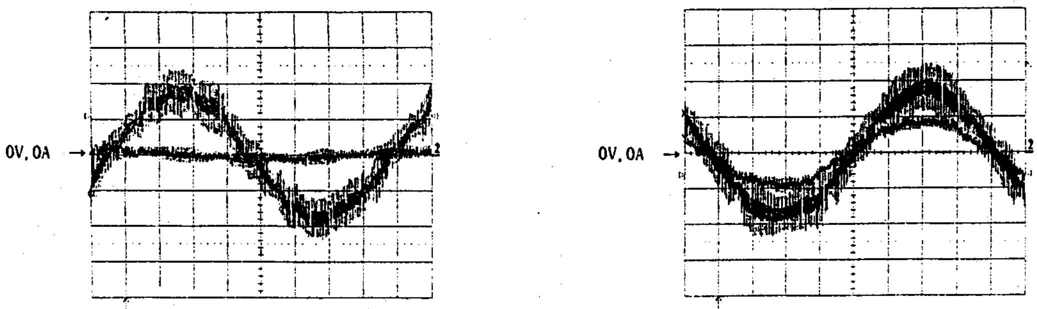
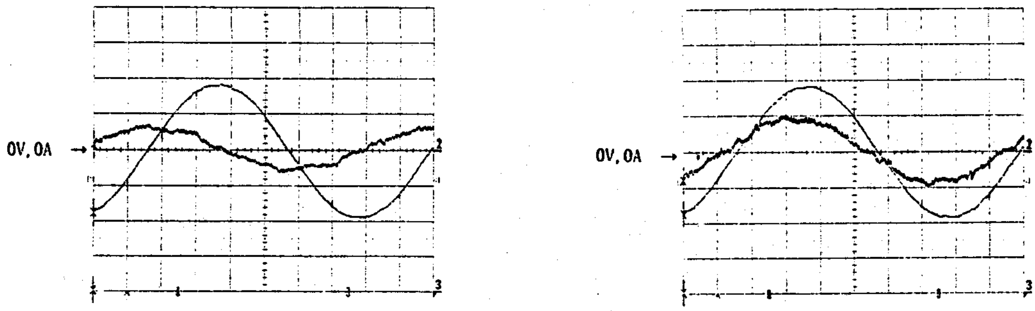


(a) at no load
(100V/div, 5A/div, 2ms/div)

(b) at 60% load
(100V/div, 10A/div, 2ms/div)

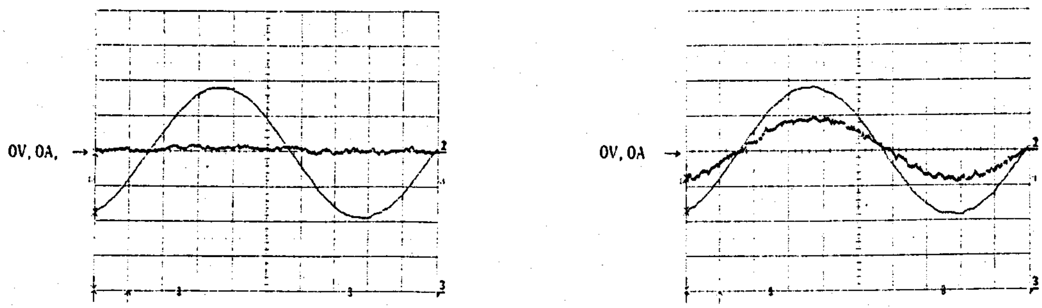
Fig.8 Phase vltage(Eu) and line current(Iu) in case of no AC filter



(a) at no load
(100V/div, 5A/div, 2ms/div)

(b) at 60% load
(100V/div, 10A/div, 2ms/div)

Fig.9 Phase voltage(Eu) and line current (Iu) in case of AC filter



(a) at no load
(100V/div, 5A/div, 2ms/div)

(b) at 60% load
(100V/div, 10A/div, 2ms/div)

Fig. 10 Phase voltage(Eu) and line current(Iu) in case of leading current compensation