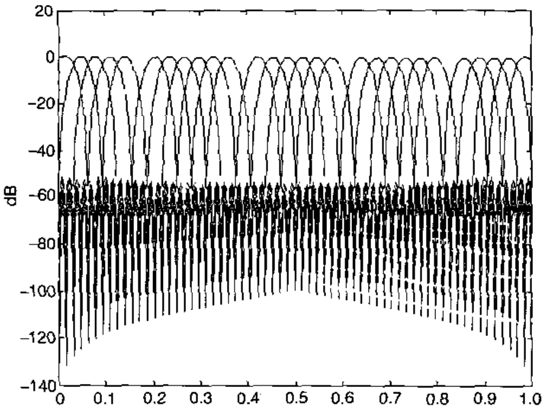

Fig. 1 *Frequency response magnitude of synthesis filter bank*

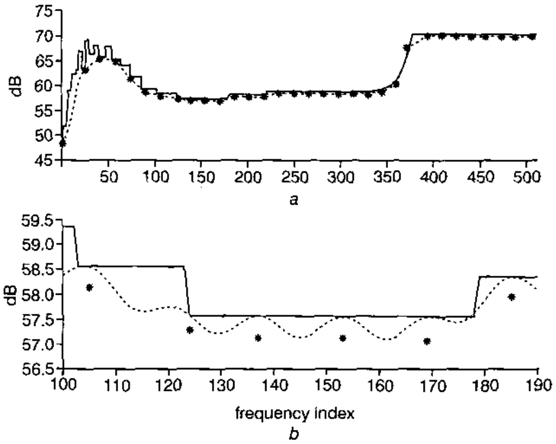

Fig. 2 *Masking threshold estimated for given audio frame, computed σ_i^2 values, and overall distortion*

a Masking threshold, σ_i^2, overall distortion
b Detail plot
—— masking threshold
* σ_i^2
------ overall distortion

© IEE 2002
19 March 2002
Electronics Letters Online No: 20020573
DOI: 10.1049/el:20020573

D. Martínez and N. Ruiz (*Departamento de Electrónica, Universidad de Jaén, Escuela Universitaria Politécnica, 23700 Linares, Jaén, Spain*)

E-mail: damian@ujaen.es

M. Rosa, F. Cruz and F. López (*Departamento de Teoría de la Señal y Comunicaciones, Universidad de Alcalá, Escuela Politécnica, 28871 Alcalá de Henares, Madrid, Spain*)

References

1 ZWICKER, E., and FASTL, H.: 'Psychoacoustics: facts and models' (Springer-Verlag, 1990)
2 ROSA, M., LÓPEZ, F., JARABO, M.P., MALDONADO, S., and RUIZ, N.: 'A new algorithm for translating psycho-acoustic information to the wavelet domain', *Signal Process.*, 2001, **81**, pp. 519–531
3 CAINI, C., and VANELLI-CORALLI, A.: 'Optimum bit allocation in band coding with nonideal reconstruction filters', *IEEE Signal Process. Lett.*, 2001, **8**, pp. 157–159
4 VAIDYANATHAN, P.P.: 'Multirate systems and filter banks' (Prentice-Hall, NJ, USA, 1993)
5 CRUZ, F., AMO, P., MARTÍN, P., and LÓPEZ, F.: 'Alternating analysis and synthesis filters: a new pseudo-QMF bank', *Digit. Signal Process.*, 2001, **11**, (4), pp. 329–345

Implementation of bi-directional AC-DC matrix converter

J.B. Ejea, E. Sanchis-Kilders, J.A. Carrasco, J.M. Espí and A. Ferreres

Experimental results are presented for an implemented bi-directional AC-DC matrix converter. With this structure it is possible to obtain a sinusoidal average input current in phase with the main input voltage and to regulate the output voltage in a wide range of variation.

Introduction: A three-phase AC-DC bi-directional matrix converter basically consists of six bi-directional switches arranged in a matrix as can be seen in Fig. 1.

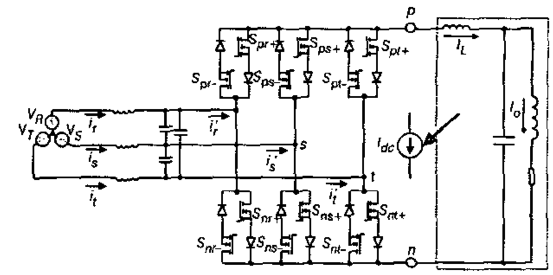

Fig. 1 *Bi-directional AC-DC matrix converter*

The space vector modulation technique can be employed to control this AC-DC matrix converter as proposed by Holmes [1] and during a switching period, ΔT, only two non-null converter states are generated with duration t_α and t_β.

To avoid open- and short-circuit hazards, a switch sequencer as proposed by Burany [2] can be used. The sequencer inputs are the requested converter state, the current-sign CS and the current-sign validity CD.

To test the converter, the dynamic transfer function of the power stage with inductive load has been obtained:

$$\frac{\bar{i}_L}{\bar{d}} = (\pm)\frac{\frac{3}{2}V_{pk}\left[\left(\frac{s}{\omega_{0p}}\right)^2+\frac{1}{Q_p}\frac{s}{\omega_{0p}}+1\right]}{L_m\omega_0(\beta+1)\left[\left(\frac{s}{\omega_0}\right)^3+\frac{1}{Q}\left(\frac{s}{\omega_0}\right)^2+\left(\frac{s}{\omega_0}\right)+\frac{1}{(\beta+1)Q}\right]} \quad (1)$$

where $\beta = L/L_m$ and

$$\omega_0 = \frac{1}{\sqrt{\left(\frac{L_m \cdot L}{L_m + L}\right)\cdot C}} \quad \omega_{0p} = \frac{1}{\sqrt{L_m C}} \quad (2)$$

are the resonance frequencies, with quality factors:

$$Q = \frac{L_m\omega_0}{R_m} \quad Q_p = \frac{L_m\omega_{0p}}{R_m} \quad (3)$$

V_{pk} is the peak amplitude of the sinusoidal input voltage, R_m and L_m are the resistive and inductive part of the load (18 Ω and 500 mH), respectively, and L and C are the inductance and capacitance of the output filter (1.2 mH and 400 μF).

Practical implementation: A 1.2 kW/8A AC-DC matrix converter with a switching frequency of 26 kHz has been built and tested. Average current control or 'conductance control' [3] has been used. The analogue feedback block is the same for positive and negative output voltage because the power stage transfer function for these two cases differs only in the sign (positive or negative). This is because the DSP processes separate the absolute value and sign of the output voltage of the current amplifier (Fig. 2). This prototype has been studied as applied to the power supply of magnets in accelerators. For this reason, an external loop to control the output current with the required precision has been used.

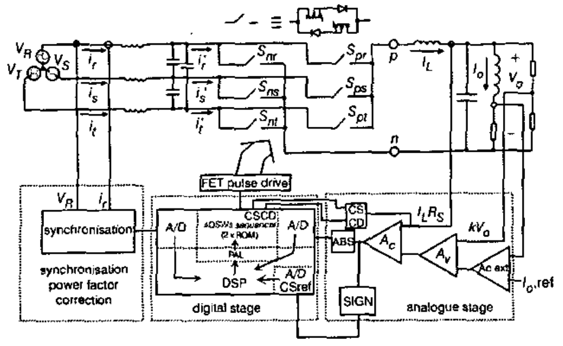

Fig. 2 *Schematic diagram of whole circuit*

A circuit has been utilised that acts as a PLL and provides the DSP with the appropriate synchronisation signal to correct the displacement factor degradation generated by the input filter [4].

Experimental results: Fig. 3 shows the input voltage and input current at full output power. The input current has a sinusoidal form as predicted by space vector modulation and the phase angle between voltage and current is almost zero.

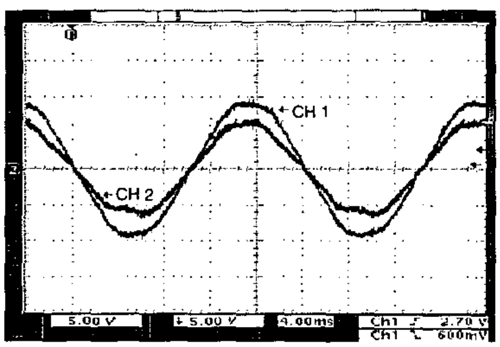

Fig. 3 *Input voltage and current for full output power*

The rectified output voltage V_{pn} and output filter inductor current are shown in Fig. 4 at medium output power. From this waveform it is possible to see the two non-null converter states, with duration t_α and t_β in a switching period, ΔT.

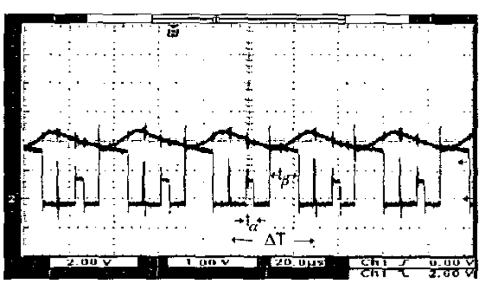

Fig. 4 *Measurement of V_{pn} and I_L*

Conditions: $V_{in} = 113\ V_{peak}$, $V_o = 75$ V, $I_o = 4$ A, CH1:I_L(2 A/div), CH2:0.1V_{pn}(1 V/div)

Fig. 5 compares the theoretical and measured frequency response. The phase margin is $\sim 60°$ with a crossover frequency of 100 Hz. The measured transfer function is in good agreement with that predicted by the model.

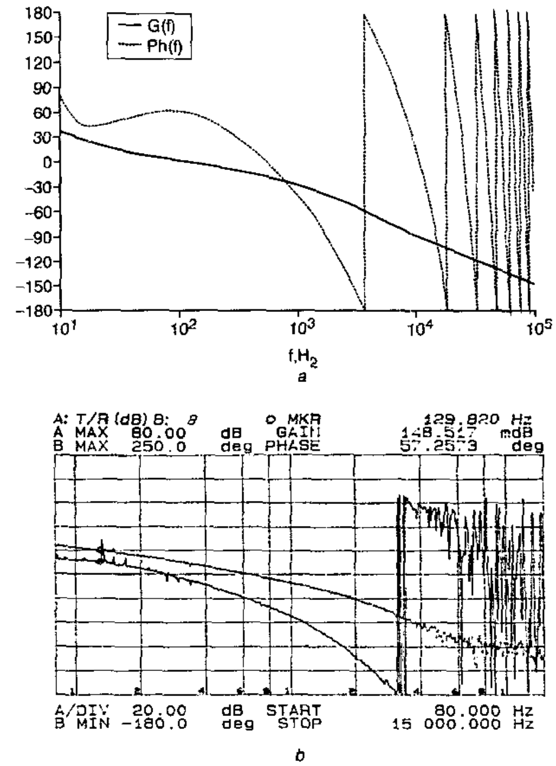

Fig. 5 *Theoretical and experimental open loop frequency response of the voltage loop*

a Theory *b* Experiment

Conclusions: Experimental results for the bi-directional AC-DC matrix converter with inductive load show good agreement with theoretical predictions. The converter provides automatic correction of the displacement factor, current control (with all the advantages that this means) and a wide range of variation of the output voltage. A very accurate averaged model of the power stage has been obtained and an algorithm of design for applying conductance control to the AC-DC matrix converter with inductive load has been implemented.

© IEE 2002

26 March 2002

Electronics Letters Online No: 20020633

DOI: 10.1049/el:20020633

J.B. Ejea, E. Sanchis-Kilders, J.M. Espí and A. Ferreres (*L.E.I.I., Dpto. de Ingeniería Electrónica, Universidad de Valencia, Spain*)

E-mail: an-ping.zhao@nokia.com

J.A. Carrasco (*Div. Electrónica, EPSE, Universidad de Miguel Hernández, Spain*)

References

1 HOLMES, D.G.: 'The general relationship between regular-sampled pulse-width-modulation for hard switched converters'. Conf. Rec. IEEE Applications Society Annual Industry Meeting, 1992, pp. 1002–1009

2 HUBER, L., BOROJEVIC, D., and BURANY, N.: 'Analysis, design and implementation of the space-vector modulator for forced commutated cycloconvertors', *IEE Proc. B*, 1992, **139**, (2), pp. 103–113

3 O'SULLIVAN, D., SPRUIJT, H., and CRAUSAZ, A.: 'Pulse-width-modulation conductance control', *ESA J.*, 1989, **13**, pp. 33–46

4 SANCHIS-KILDERS, E., : 'Conception and implementation of a three-phase rectifier with space vector control and soft-switching for a dynamic power factor correction' June 1997, Ph.D., University of Valencia, Spain