Annexure II-A: Filter Design Calculation For Electronics Ballast:

Source ind Zs in henery	Q of Zs	Source res. Rs	Reso. React. X_{Lr}	Reso. Ind. L_r	Reso. res	Q reso.	Reso. Cap X_{Cr}	Xcr	Tuned factor (N)	%THD	Fundamental	ballast current	Remarks
1.00	8.0	39.270	520.11	1.656	43.3	12.0	0.00000068	4681.0	3.0	104.2	0.1837	0.265	SELECT Resonance . Cap

Table 1 - Numerical results of impedances, voltages and currents at characteristeric harmonic orders of a series resonant circuit in a network with distorted supply voltage

h	X_s	R_s	X_{Cr}	X_{Lr}	R_r	X_L+(-X_C)	Impedance Z_f	Impedance Zs	I_h		I_f	I_s	I_s	U_B	U_B(%)	U-X_{lr}	U-X_{cr}
	Ohms	ohm	Ohms	Ohms		Ohms	Ohms	Ohms	amp	%	A	A	%	V	%	V	V
1	314.2	39.3	4681.0	520.1	43.3	-4160.9	4161.1	316.6	0.2	100.0	0.0	0.2	100.0	55.0	143.7	6.9	61.9
3	942.5	39.3	1560.3	1560.3	43.3	0.0	43.3	943.3	0.1	73.8	0.1	0.0	3.5	5.7	14.9	205.9	205.9
4	1256.6	39.3	1170.3	2080.5	43.3	910.2	911.2	1257.3	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
5	1570.8	39.3	936.2	2600.6	43.3	1664.4	1664.9	1571.3	0.1	46.0	0.0	0.0	25.5	69.5	181.6	108.6	39.1
6	1885.0	39.3	780.2	3120.7	43.3	2340.5	2340.9	1885.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	2199.1	39.3	668.7	3640.8	43.3	2972.1	2972.4	2199.5	0.1	35.8	0.0	0.0	22.2	84.7	221.3	103.7	19.1
9	2827.4	39.3	520.1	4681.0	43.3	4160.9	4161.1	2827.7	0.1	27.3	0.0	0.0	17.5	85.9	224.3	96.6	10.7
11	3455.8	39.3	425.5	5721.3	43.3	5295.7	5295.9	3456.0	0.0	27.3	0.0	0.0	7.0	41.8	109.3	45.2	3.4
13	4084.1	39.3	360.1	6761.5	43.3	6401.4	6401.6	4084.3	0.0	10.7	0.0	0.0	1.8	12.5	32.6	13.2	0.7
15	4712.4	39.3	312.1	7801.7	43.3	7489.6	7489.8	4712.6	0.0	8.0	0.0	0.0	5.3	43.4	113.3	45.2	1.8
17	5340.7	39.3	275.4	8841.9	43.3	8566.6	8566.7	5340.9	0.0	14.4	0.0	0.0	9.6	88.8	232.0	91.7	2.9
19	5969.0	39.3	246.4	9882.2	43.3	9635.8	9635.9	5969.2	0.0	11.8	0.0	0.0	7.8	81.1	211.8	83.2	2.1
										DF(A) %=	104.2		DF(B) %=	41.1	201.7	507.0	

Annexure II-B

P-Q THEORY WITH ZERO SEQUENCE CURRENT

It is possible to extend the instantaneous reactive power theory developed for three phase circuit including zero phase sequence components. The instantaneous space vectors ea, eb, and ec are transformed to 0-α-β co-ordinates as follows:

$$\begin{bmatrix} eo \\ e\alpha \\ e\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} ea \\ eb \\ ec \end{bmatrix} \qquad \text{(AIIB-1)}$$

like wise, the instantaneous space vectors i_o, i_α, and i_β on the 0-α-β co-ordinates are given as follows:

$$\begin{bmatrix} io \\ i\alpha \\ i\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} ia \\ ib \\ ic \end{bmatrix} \qquad \text{(AIIB-2)}$$

another instantaneous power p_o which is defined as the product of instantaneous space vectors, e_o and i_o on the zero axis:

$$p0 = e0 * i0 \qquad \text{(AIIB-3)}$$

$$\begin{bmatrix} p0 \\ p \\ q \end{bmatrix} = \begin{bmatrix} eo & 0 & 0 \\ 0 & e\alpha & e\beta \\ 0 & -e\beta & e\alpha \end{bmatrix} \begin{bmatrix} i0 \\ i\alpha \\ i\beta \end{bmatrix} \qquad \text{(AIIB-4)}$$

$$\begin{bmatrix} i0 \\ i\alpha \\ i\beta \end{bmatrix} = \begin{bmatrix} eo & 0 & 0 \\ 0 & e\alpha & e\beta \\ 0 & -e\beta & e\alpha \end{bmatrix}^{-1} \begin{bmatrix} p0 \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} eo & 0 & 0 \\ 0 & e\alpha & e\beta \\ 0 & -e\beta & e\alpha \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ p \\ 0 \end{bmatrix} +$$

$$\begin{bmatrix} eo & 0 & 0 \\ 0 & e\alpha & e\beta \\ 0 & -e\beta & e\alpha \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 0 \\ q \end{bmatrix}$$

$$\begin{bmatrix} i0 \\ i\alpha \\ i\beta \end{bmatrix} = \begin{bmatrix} i0 \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ i\alpha p \\ i\beta p \end{bmatrix} + \begin{bmatrix} 0 \\ i\alpha q \\ i\beta q \end{bmatrix} \qquad \text{(AIIB-5)}$$

from equation (e) the instantaneous currents on the a-b-c coordinates are divided in the following three components, respectively:

$$\begin{bmatrix} ia \\ ib \\ ic \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i0 \\ 0 \\ 0 \end{bmatrix}$$

$$+ \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} 0 \\ i\alpha p \\ i\beta p \end{bmatrix}$$

$$+ \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} 0 \\ i\alpha q \\ i\beta q \end{bmatrix} \qquad \text{((AIIB-6))}$$

$$= \begin{bmatrix} ia0 \\ ib0 \\ ic0 \end{bmatrix} + \begin{bmatrix} iap \\ ibp \\ icp \end{bmatrix} + \begin{bmatrix} iaq \\ ibq \\ icq \end{bmatrix}$$

where

$$ia0 = ib0 = ic0 = {i0}/{\sqrt{3}}$$

let the a, b, c phase instantaneous powers be p_a, p_b, and p_c respectively. by applying the equation (f), following is obtained:

$$\begin{bmatrix} pa \\ pb \\ pc \end{bmatrix} = \begin{bmatrix} ea * ia0 \\ eb * ib0 \\ ec * ic0 \end{bmatrix} + \begin{bmatrix} ea * iap \\ eb * ibp \\ ec * icp \end{bmatrix} + \begin{bmatrix} ea * iaq \\ eb * ibq \\ ec * icq \end{bmatrix}$$

$$\begin{bmatrix} pa \\ pb \\ pc \end{bmatrix} = \begin{bmatrix} pa0 \\ pb0 \\ pc0 \end{bmatrix} + \begin{bmatrix} pap \\ pbp \\ pcp \end{bmatrix} + \begin{bmatrix} paq \\ pbq \\ pcq \end{bmatrix}$$

the instantaneous reactive power in each phase P_{aq}, p_{bq} and p_{cq} make no contribution to the instantaneous power flow in the three phase circuit which is represented by p_o and p, because the sum of the instantaneous power is always zero.

Annexure II-C
Results of Shunt Active Power Filter

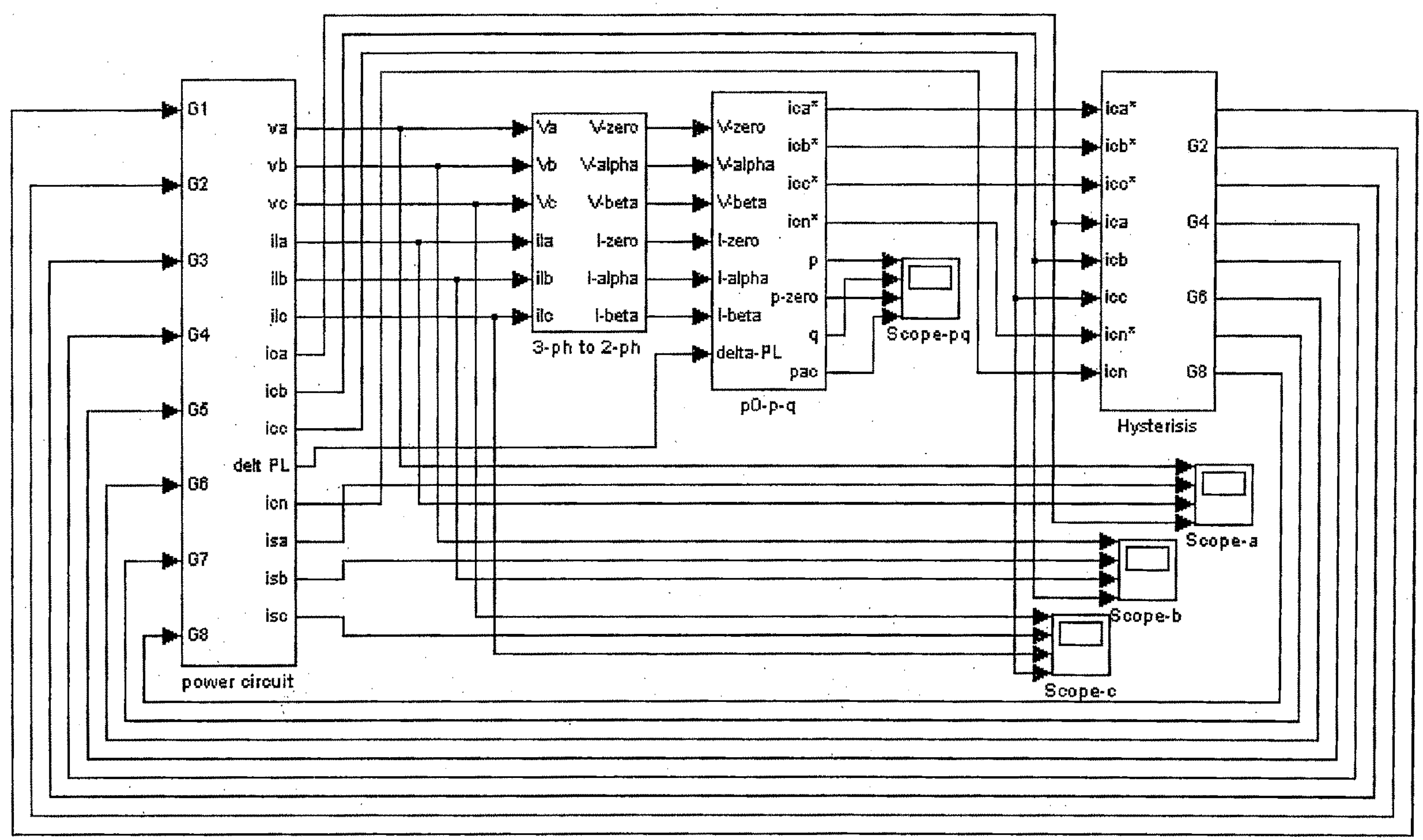
RESULT

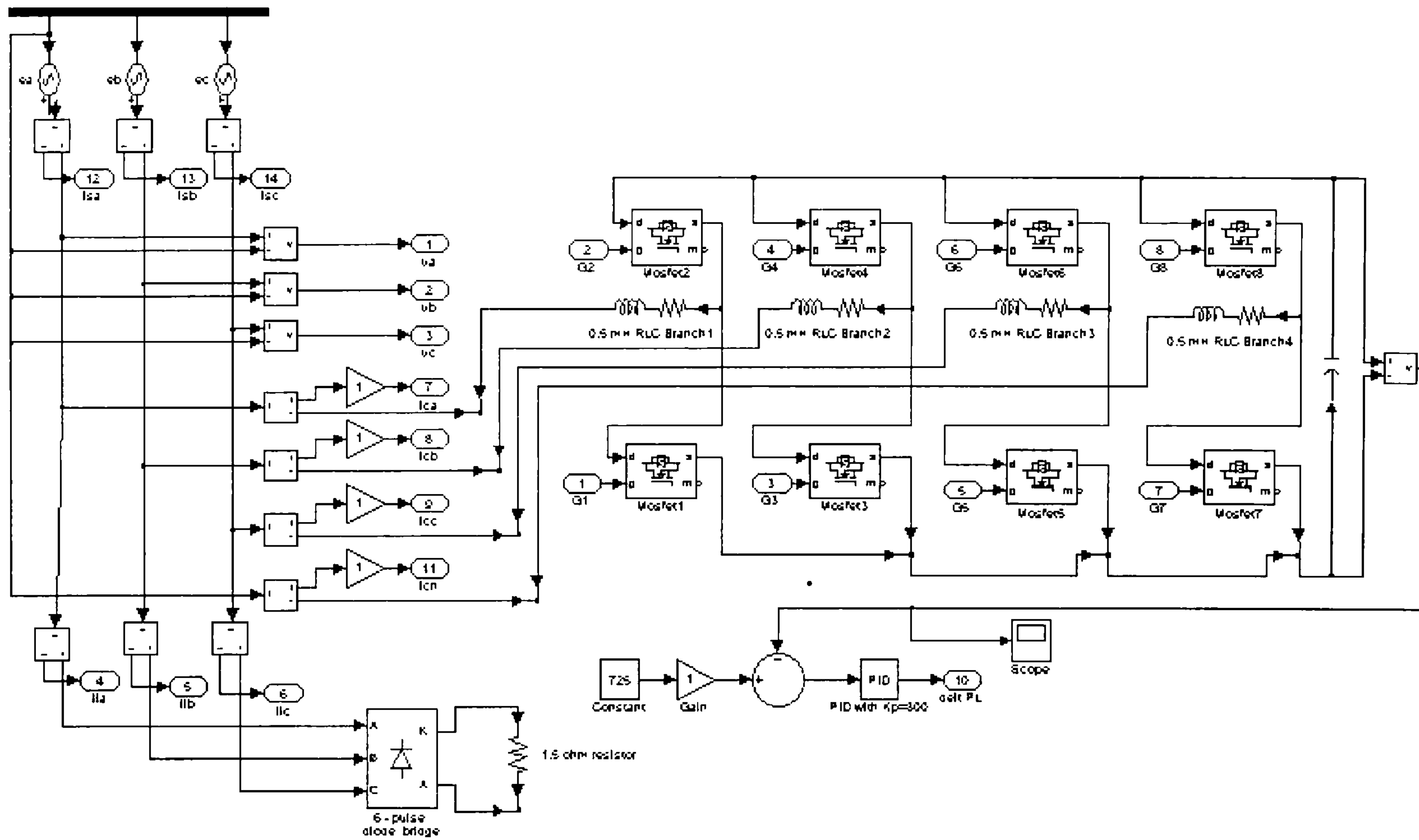
The simulations as well as experimental results are given here.

Simulation results

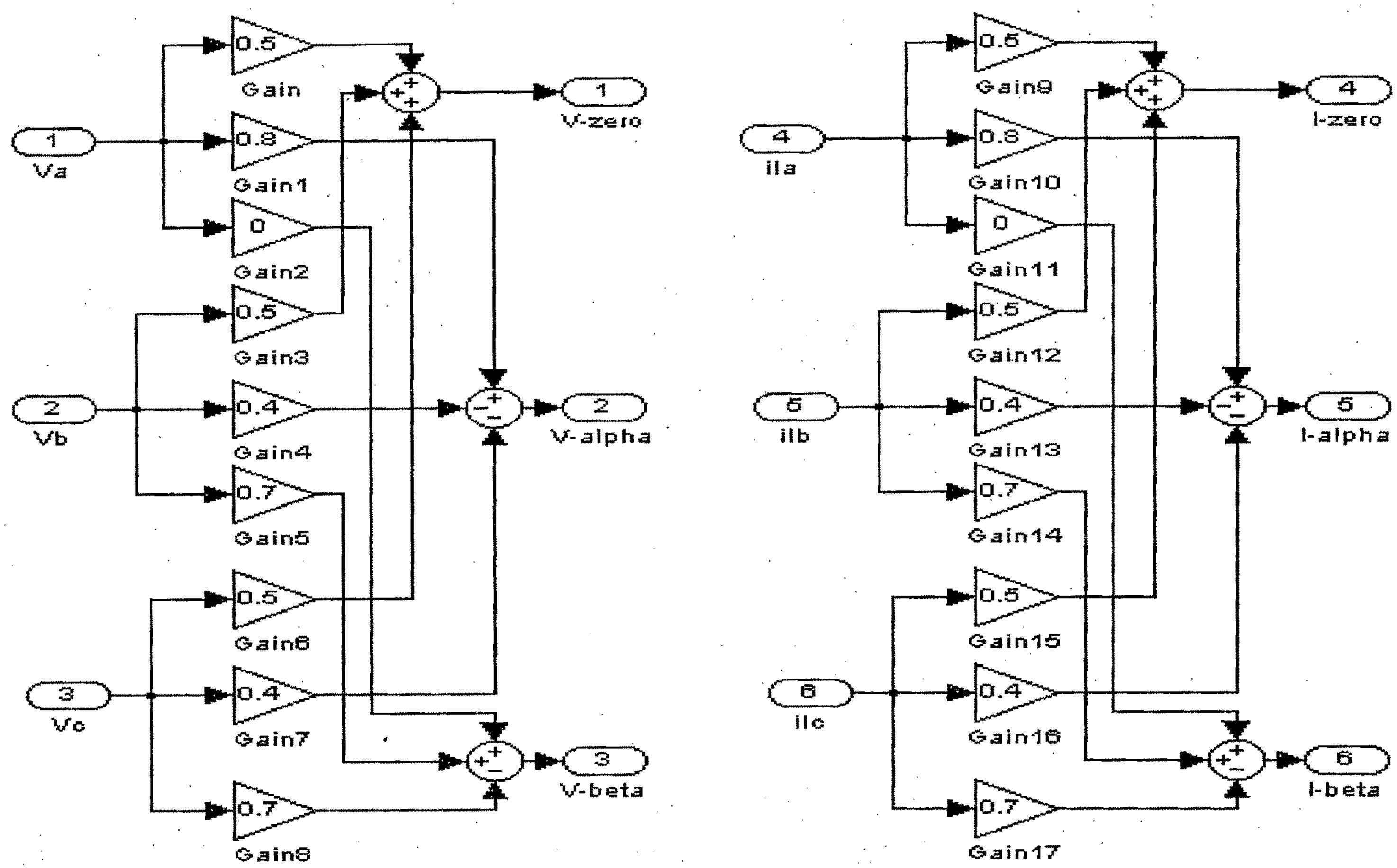
A complete model of the shunt active filter for 5 amps, 800V DC with input voltage of 440V and 5-amp load was implemented MATLAB (SIMULINK) and the most important results will be presented to compare actual and simulated results. The fundamental frequency of the system is 50 Hz. The wave-form of source voltage, source current, load current and compensating current is observed for a-phase, b-phase, & c-phase using scope available in the simulation tools. These results show that total harmonic current required by the load is supplied by the shunt active filter and absent from the source. Result are shown at the end of this chapter

ACTIVE FILTER SIMULATION BLOCK DIAGRAM

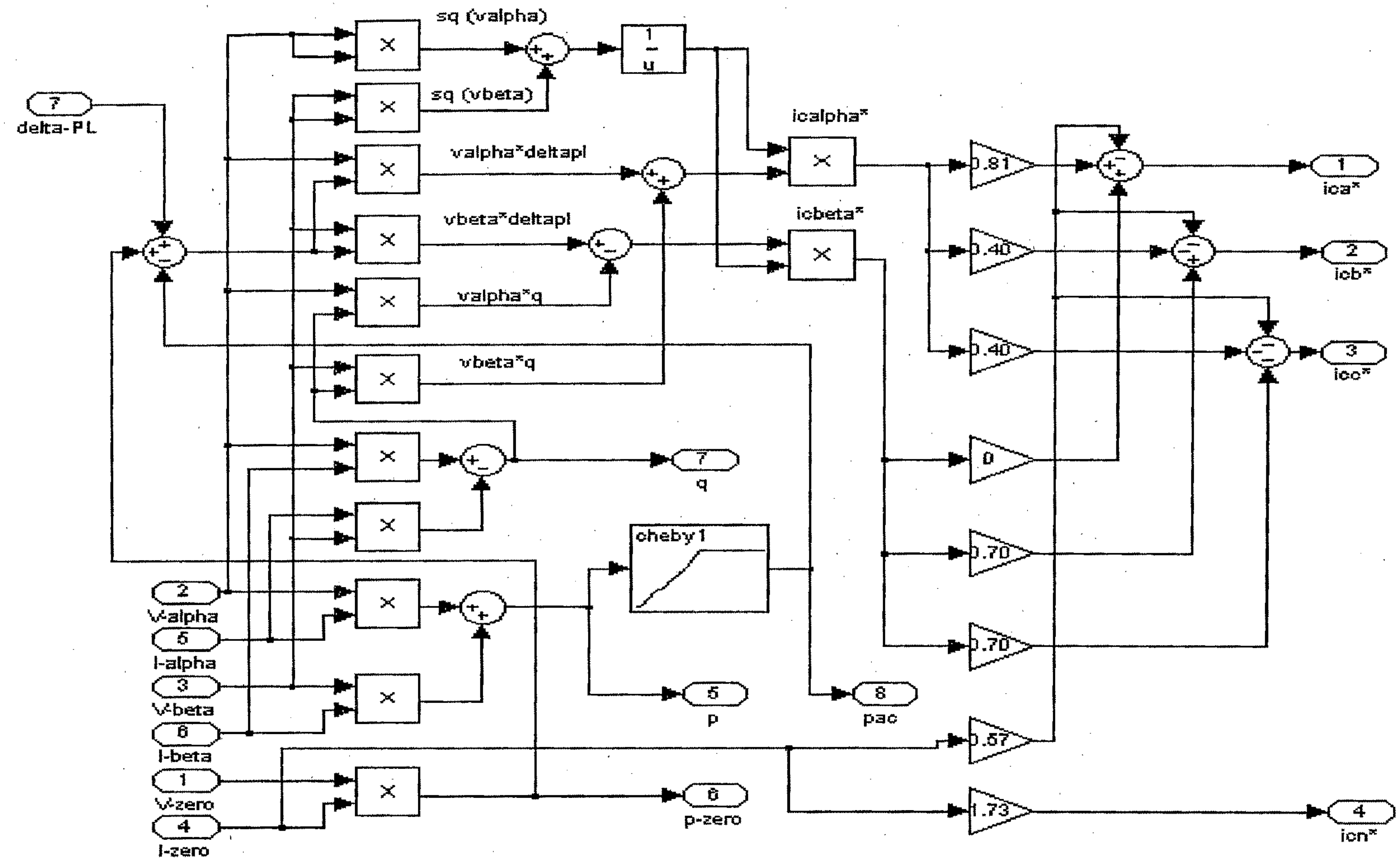




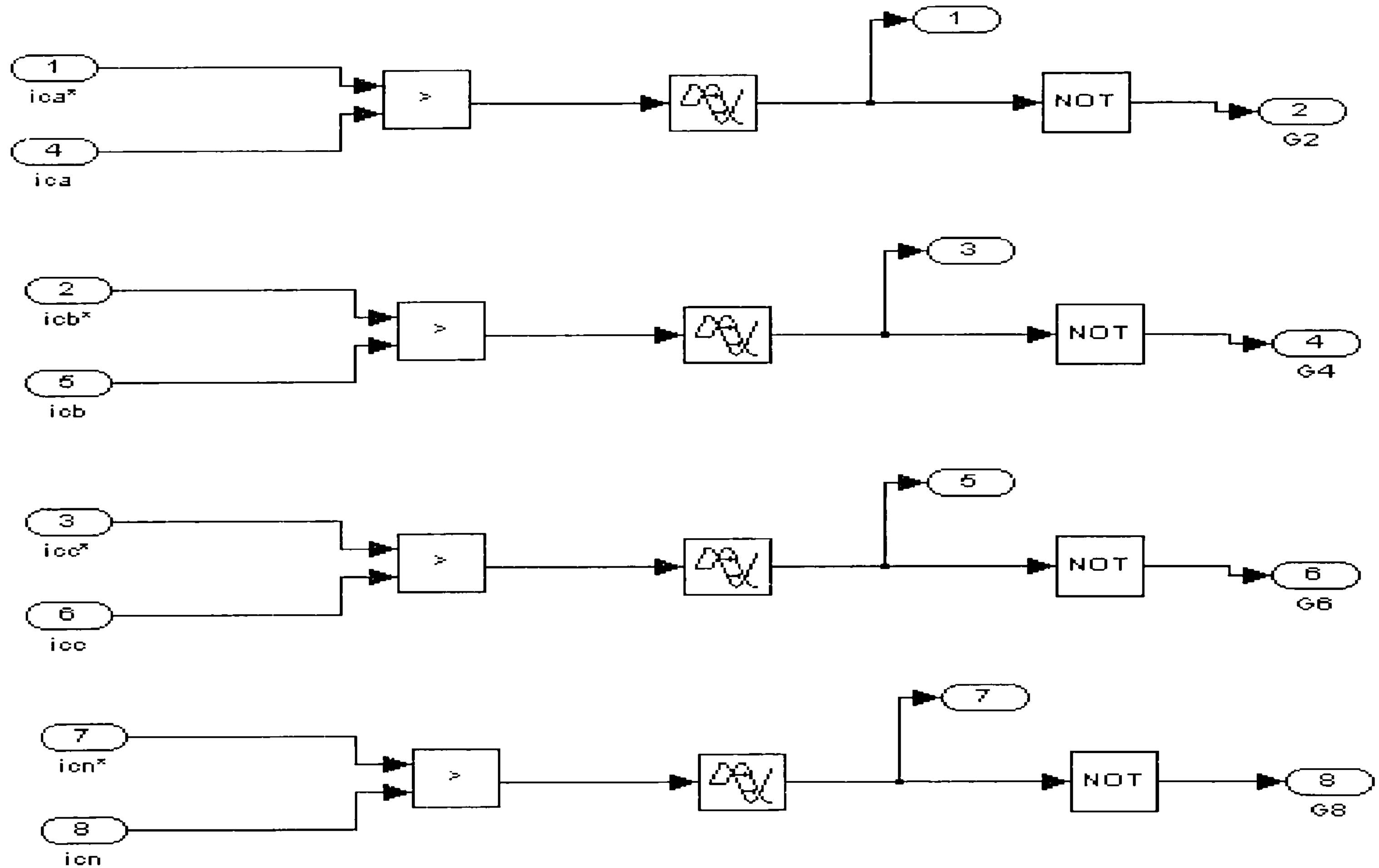
ACTIVE FILTER POWER CIRCUIT DIAGRAM FOR SIMULATION



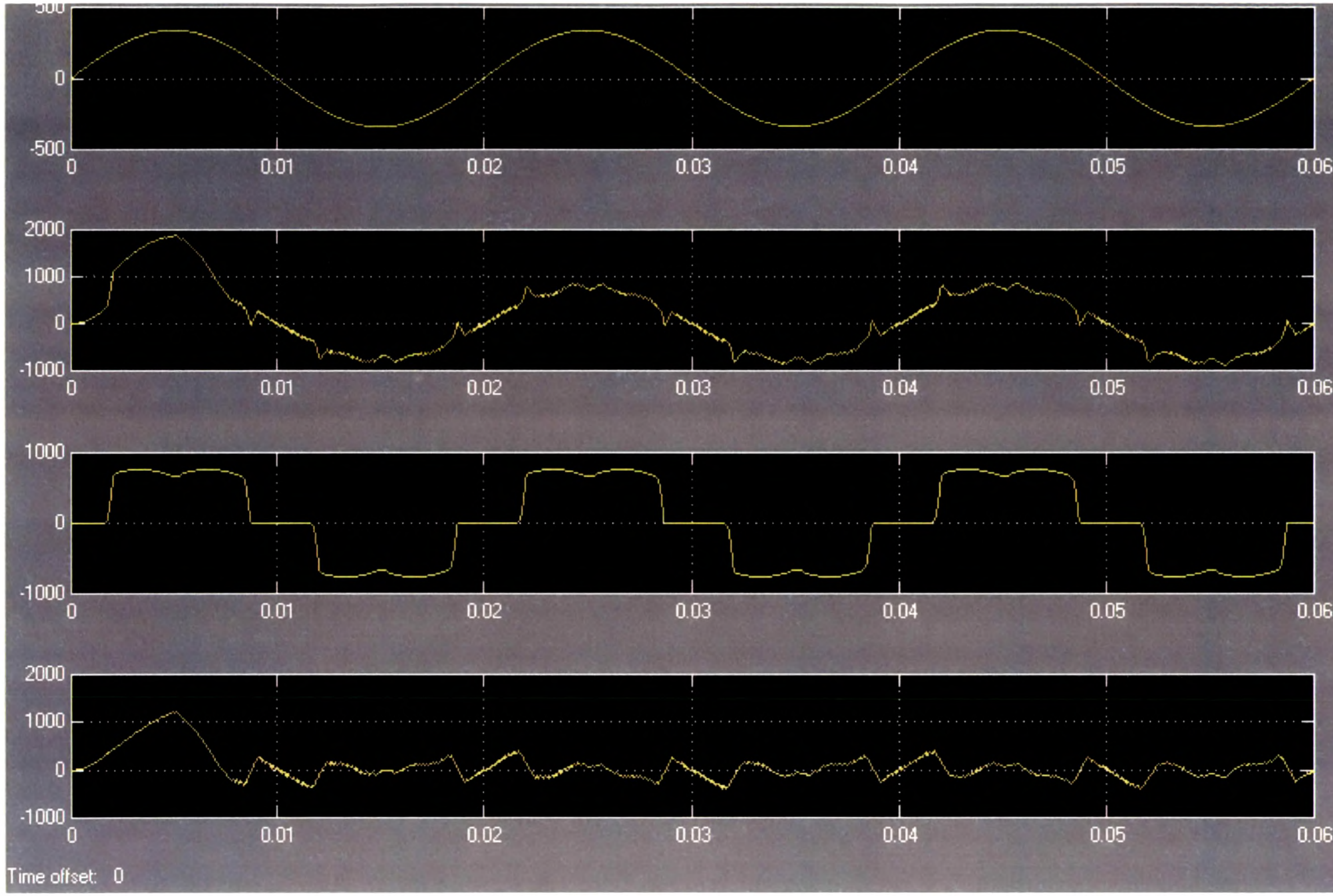
THREE PHASE TO ALPHA-BETA TRANSFORMATION



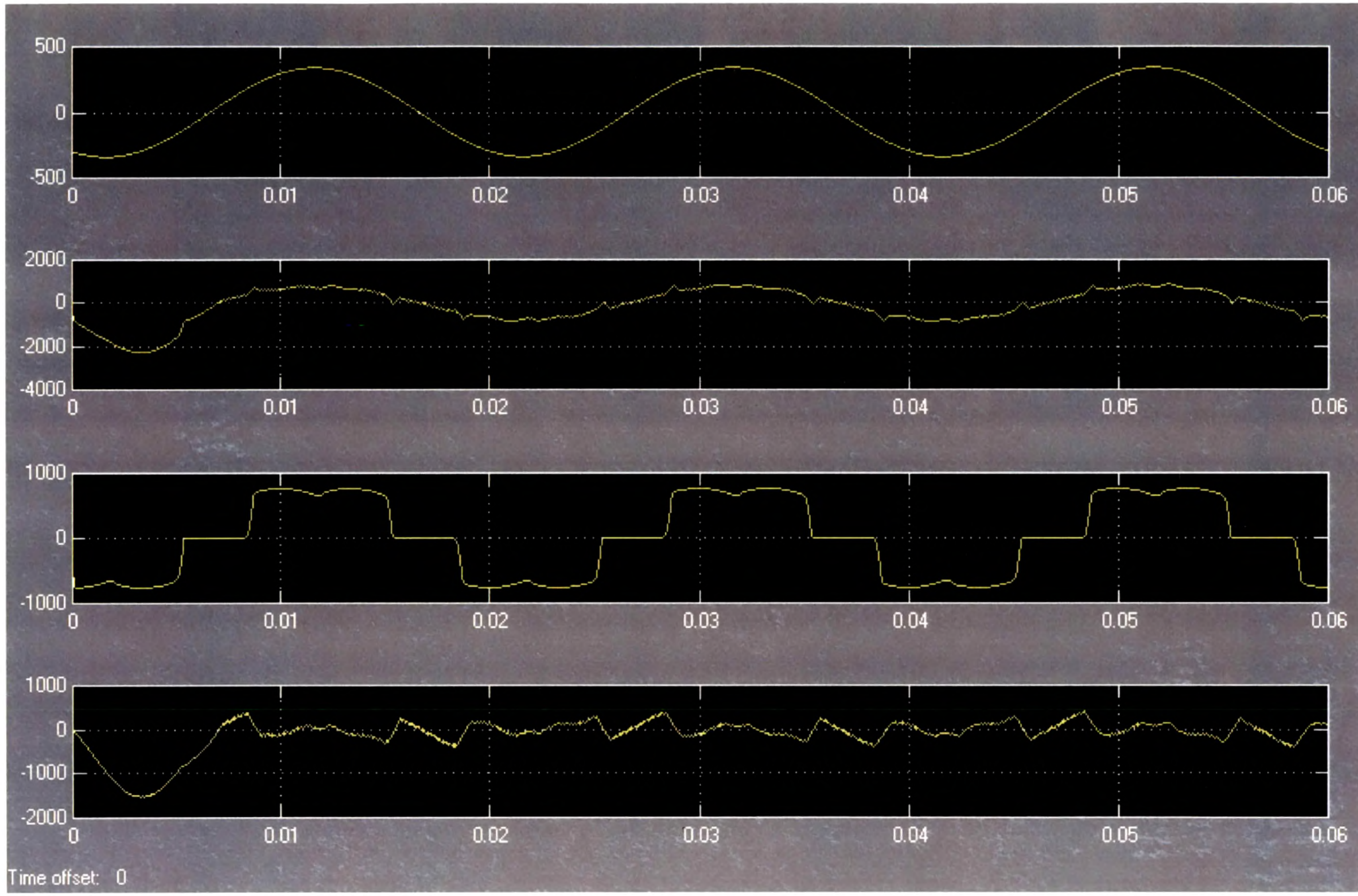
POWER CALCULATION AND COMPENSATING REFERANCE CURRENT GENERATION



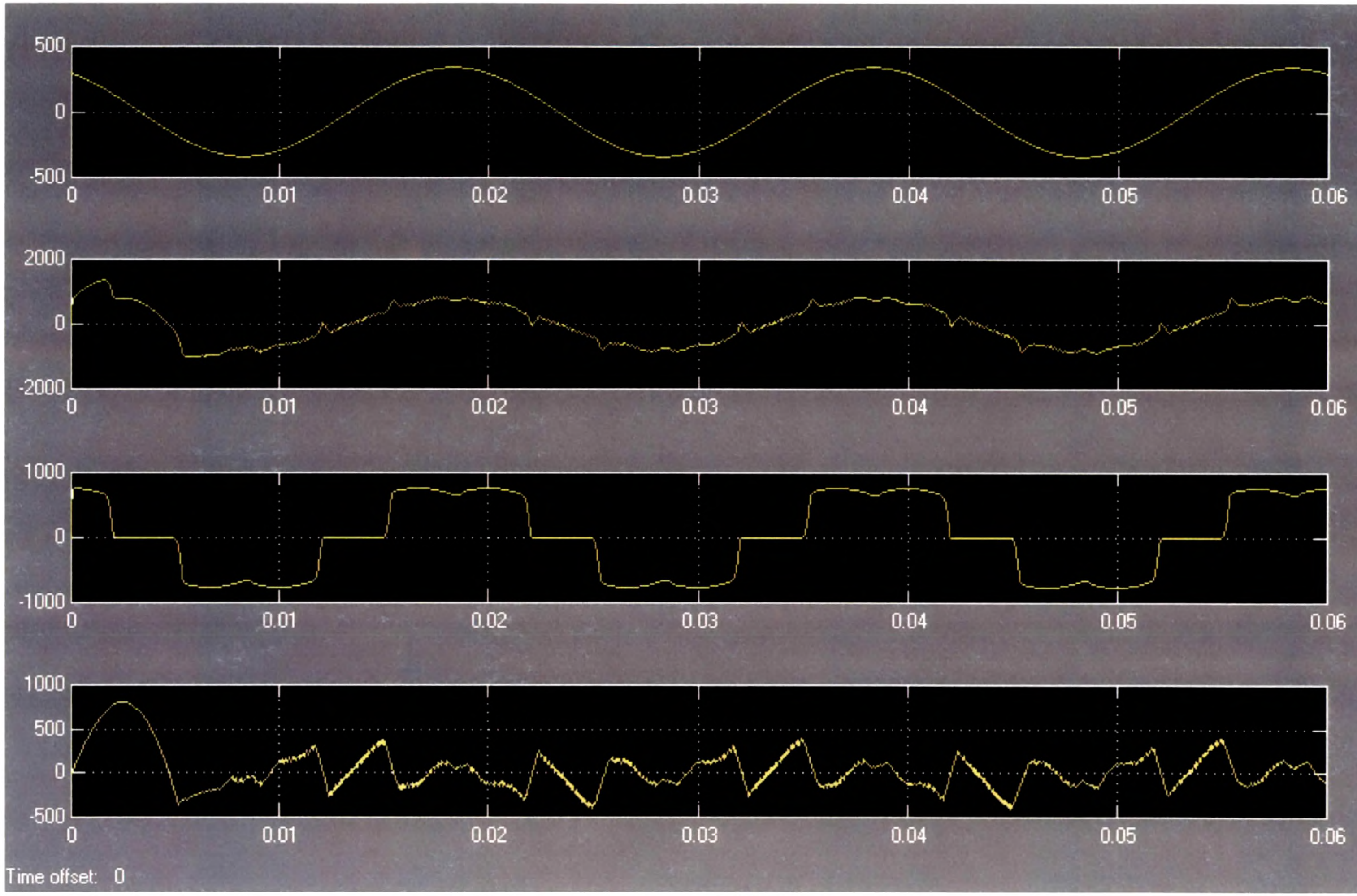
HYSTERISIS CURRENT CONTROLLER



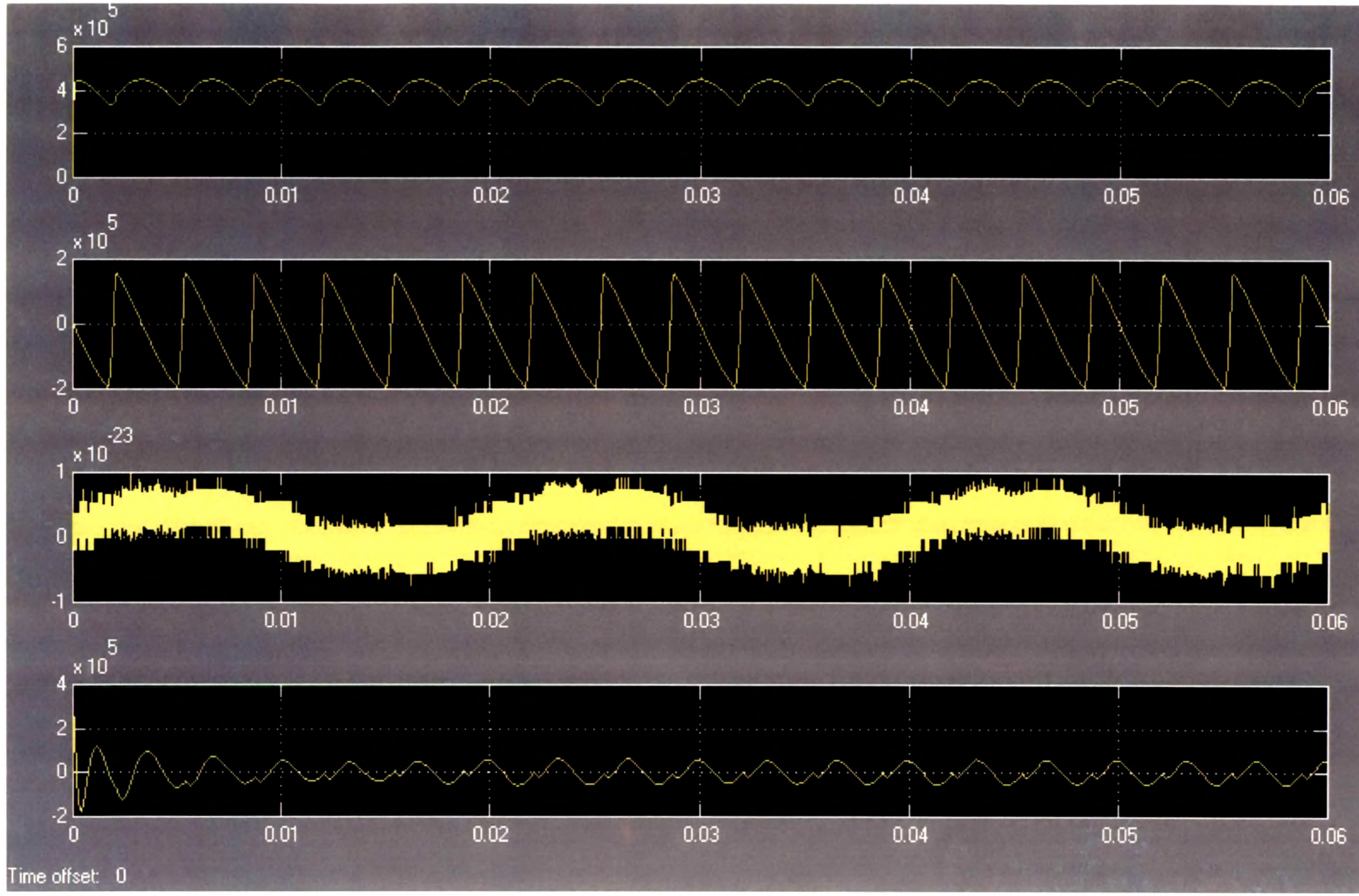
SOURCE -VOLTAGE, SOURCE –CURRENT, LOAD-CURRENT AND COMPENSATING-CURRENT FOR A-PHASE



SOURCE -VOLTAGE, SOURCE –CURRENT, LOAD-CURRENT AND COMPENSATING-CURRENT FOR B-PHASE

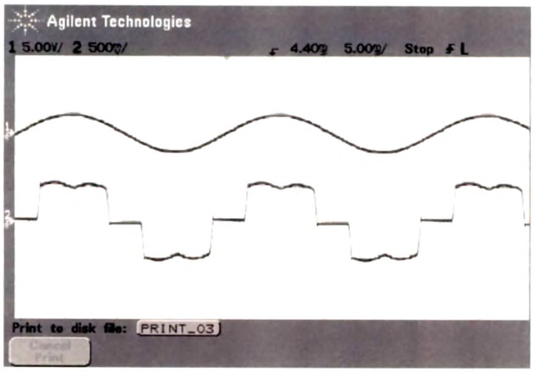


SOURCE -VOLTAGE, SOURCE –CURRENT, LOAD-CURRENT AND COMPENSATING-CURRENT FOR C-PHASE

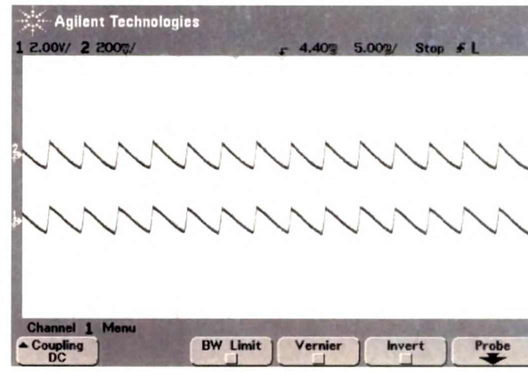


p-ACTIVE POWER, q-REACTIVE POWER, p_0 AND P_{dc} FOR ACTIVE POWER FILTER

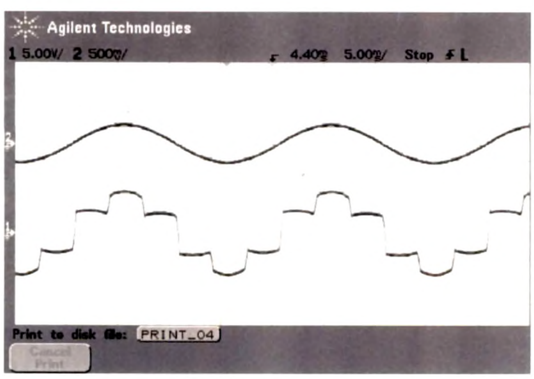
EXPERIMENTAL RESULTS:



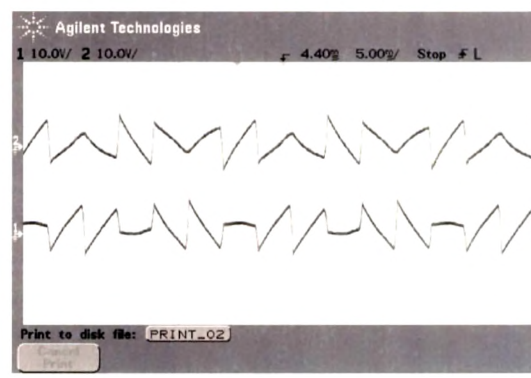
CONTROL WAVEFORM FOR v-ALPHA AND i-ALPHA



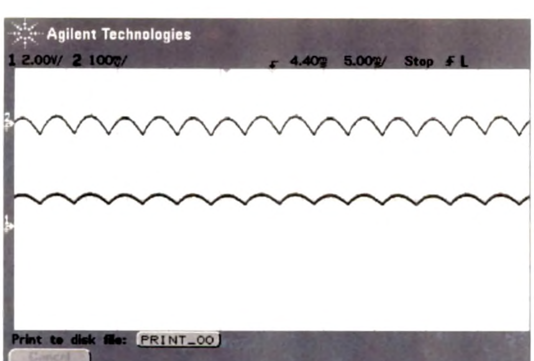
CONTROL WAVEFORM FOR qac AND q (REACTIVE POWER)



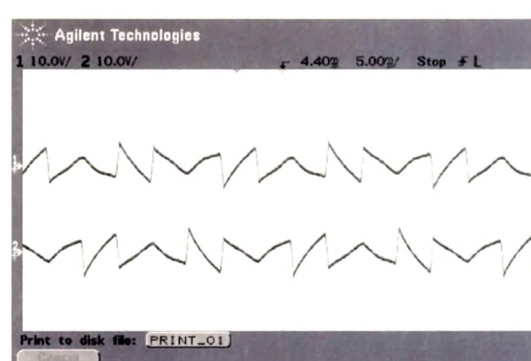
CONTROL WAVEFORM FOR v-BETA AND i-BETA



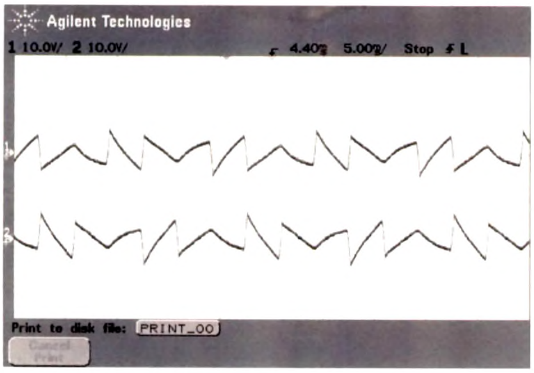
CONTROL WAVEFORM FOR ic-ALPHA & ic-BETA



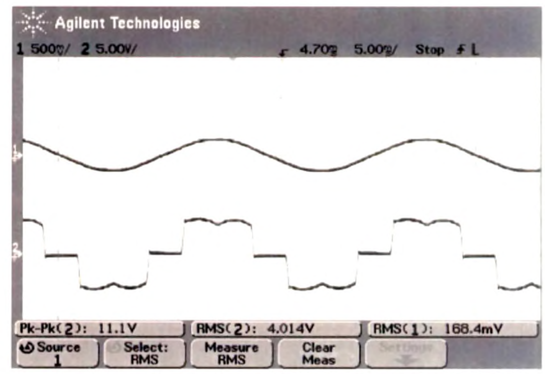
CONTROL WAVEFORM FOR pac AND p (POWER)



CONTROL WAVEFORM FOR ica, & icb

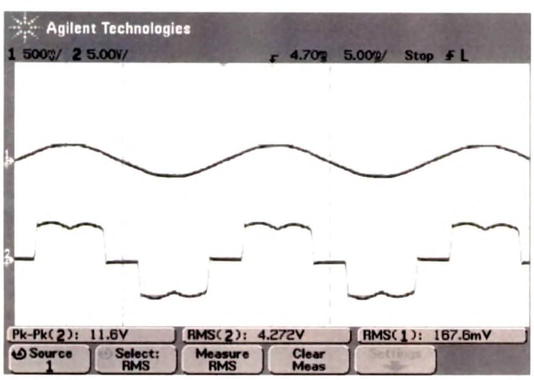


CONTROL WAVEFORM FOR ica, AND icc



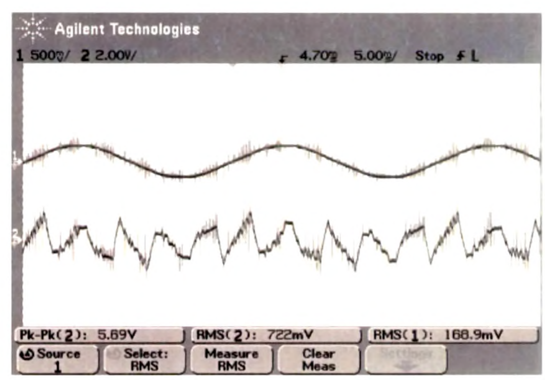
ACTUAL WAVEFORM FOR SOURCE VOLTAGE

AND LOAD CURRENT FOR C-PHASE



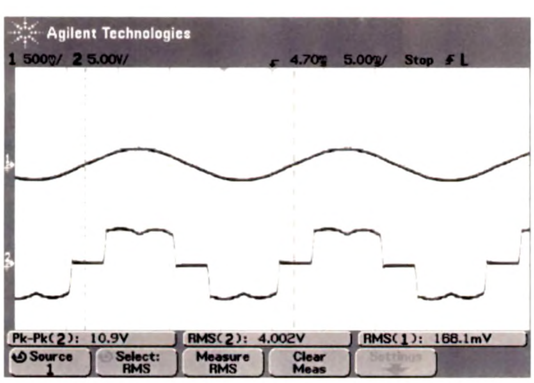
ACTUAL WAVEFORM FOR SOURCE VOLTAGE

AND LOAD CURRENT FOR A-PHASE



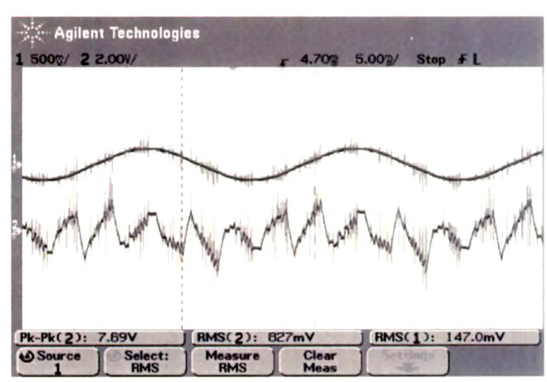
ACTUAL WAVEFORM FOR SOURCE VOLTAGE

AND COMPENSATING CURRENT FOR A-PHASE



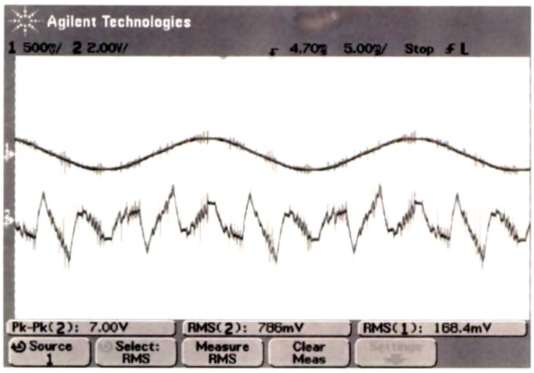
ACTUAL WAVEFORM FOR SOURCE VOLTAGE

AND LOAD CURRENT FOR B-PHASE

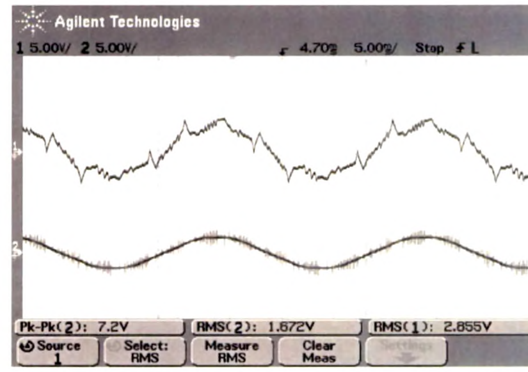


ACTUAL WAVEFORM FOR SOURCE VOLTAGE

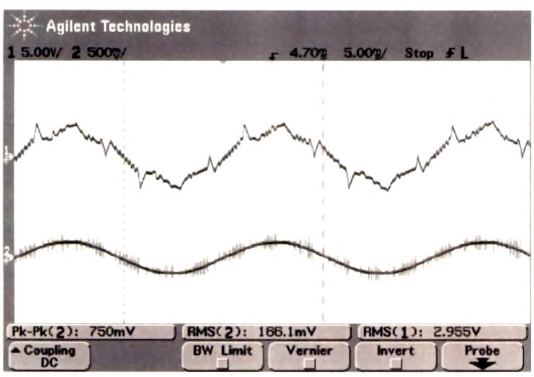
AND COMPENSATING CURRENT FOR B-PHASE



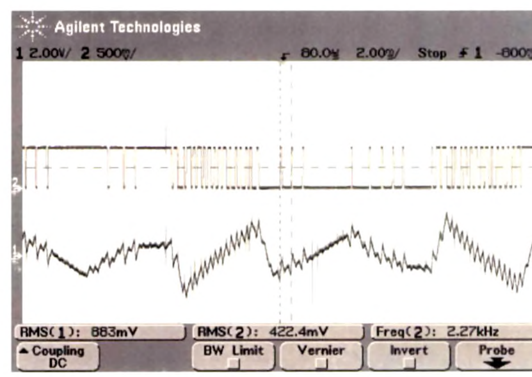
ACTUAL WAVEFORM FOR SOURCE VOLTAGE AND COMPENSATING CURRENT FOR C-PHASE



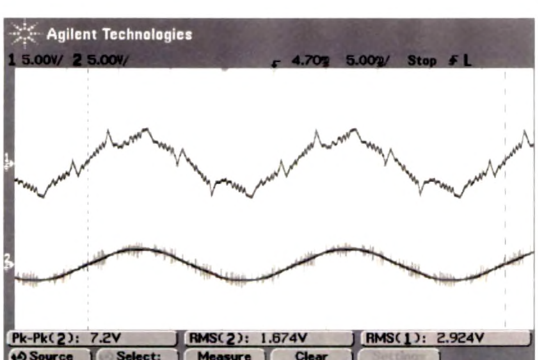
ACTUAL WAVEFORM FOR SOURCE CURRENT AND SOURCE VOLTAGE FOR PHASE- C



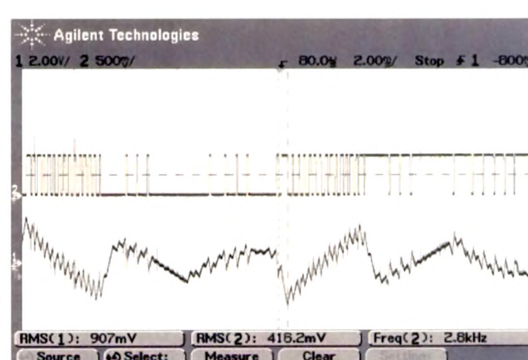
ACTUAL WAVEFORM FOR SOURCE CURRENT AND SOURCE VOLTAGE FOR PHASE-A



ACTUAL WAVEFORM FOR Vce AND COMPENSATING CURRENT FOR A-PHASE UPPER IGBT



ACTUAL WAVEFORM FOR SOURCE CURRENT AND SOURCE VOLTAGE FOR PHASE-B

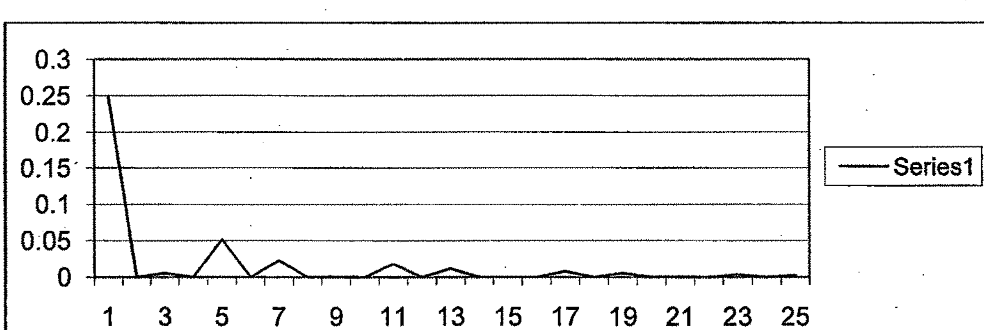


ACTUAL WAVEFORM FOR Vce AND COMPENSATING CURRENT FOR A-PHASE LOWER IGBT

FFT ANALYSIS OF SOURCE CURRENT WITHOUT COMPENSATING

(CT PROBE RATIO 10)

Fundamental	50Hz	
Harm no.	Voltage magnitude Volts	Voltage %
1	0.2478	100.00
2	0.0001	0.04
3	0.0054	2.18
4	0.0002	0.08
5	0.0517	20.86
6	0.0001	0.04
7	0.0228	9.20
8	0.0001	0.04
9	0.0008	0.32
10	0	0.00
11	0.018	7.26
12	0	0.00
13	0.0115	4.64
14	0	0.00
15	0.0003	0.12
16	0.0001	0.04
17	0.0079	3.19
18	0	0.00
19	0.0056	2.26
20	0	0.00
21	0.0002	0.08
22	0.0001	0.04
23	0.0035	1.41
24	0	0.00
25	0.0026	1.05
	THD%=	24.85



FFT ANALYSIS OF SOURCE CURRENT WITH COMPENSATION.

(CT PROBE RATIO 10)

Fundamental Frequency= 50 Hz		
Harm no.	Voltage magnitude Volts	Voltage %
1	0.2554	100.00
2	0.0035	1.37
3	0.0046	1.80
4	0.0014	0.55
5	0.0136	5.32
6	0.0019	0.74
7	0.0058	2.27
8	0.0025	0.98
9	0.0004	0.16
10	0.0015	0.59
11	0.0051	2.00
12	0.0006	0.23
13	0.0014	0.55
14	0.0008	0.31
15	0.0024	0.94
16	0.0011	0.43
17	0.0027	1.06
18	0.0005	0.20
19	0.0008	0.31
20	0.0007	0.27
21	0.0013	0.51
22	0.0003	0.12
23	0.0028	1.10
24	0.0005	0.20
25	0.0006	0.23
	THD%=	7.02