ECE 4643

POWER ELECTRONICS

LABORATORY : 3

AC-AC Controllers

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1 Objective

The objective of this lab experiment is to investigate and analyse the performance of a $3\,\phi$ AC-AC power electronic controlled AC converters while supplying a $3\,\phi$ induction motor. The harmonic contents of the input and output voltages and currents of the converter will be investigated as well as the PF_{out}, V_{out}, Q and η

2 Procedure

2.1 Introduction

The introductory step of this lab is to step the circuit as shown in the lab manual. Once the circuit is set as shown in the Figure 1 below the supply voltage is increased to 200 V. Using the DAM the corresponding values for I_{Ain}, P_{in}, Q_{in}, V_{out}, I_{Aout}, P_{out}, Q_{out}, PF_{out}, η are recorded. For further justification we also calculated the η using the data P_{out} and P_{in} in matlab. We didnt see a significant change in the graph for low firing angles once the firing angle crosses about 100 degrees changes are noticed in the data. Once the firing angle reaches 60 degrees input and output waveforms are recorded with harmonic spectrum of the input and output voltage and current.

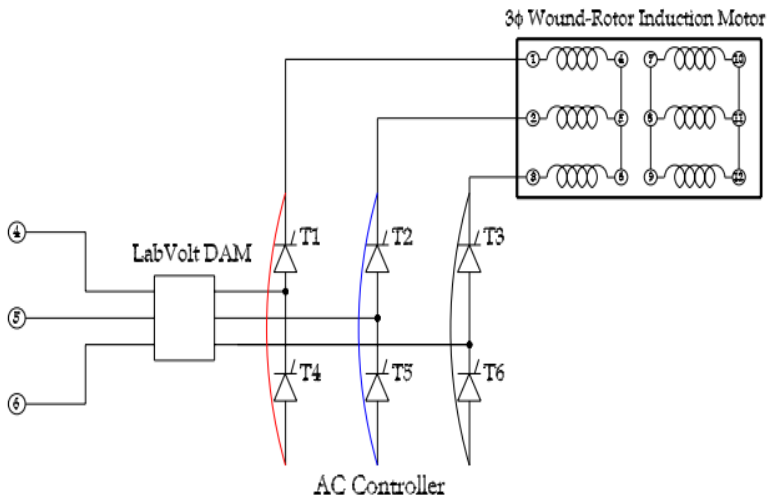

Figure 1: 3ϕ thyristor AC controller

2.2 Voltage and Current waveforms

Figure 2 and Figure 3 represents the signals in time domain

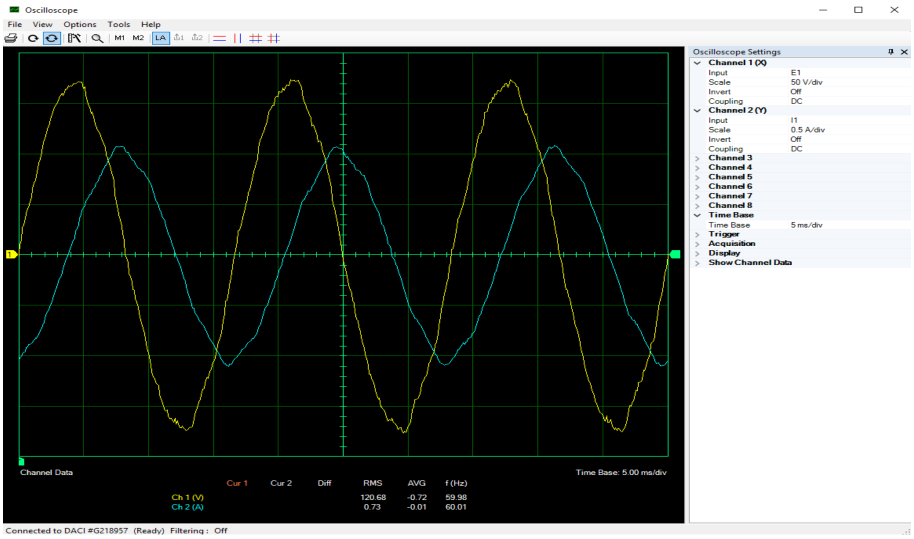

Figure 2: V_{in} versus I_{Ain}

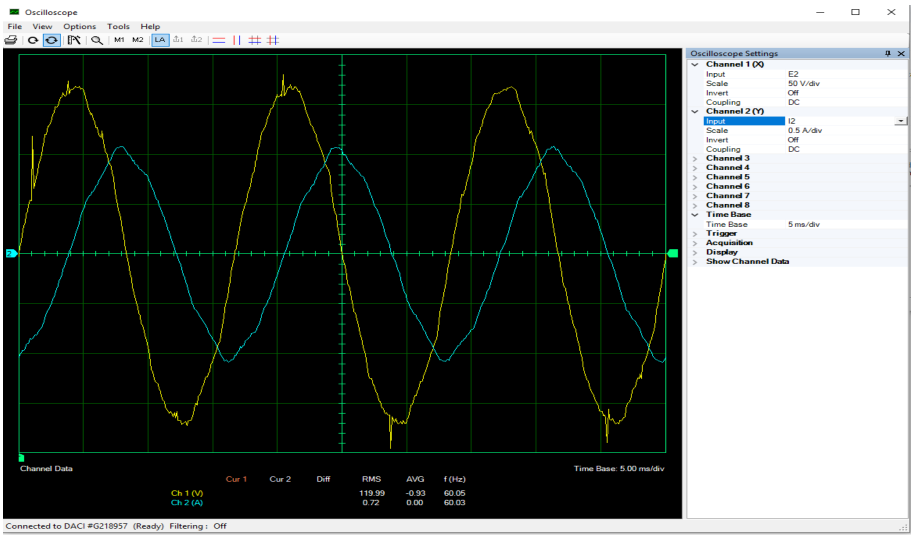

Figure 3: V_{out} versus I_{Aout}

2.3 Harmonic Analysis of the waveforms

2.3.1 Input Signal

Figure 4 represents harmonic analysis of the input voltage signal V_{in}

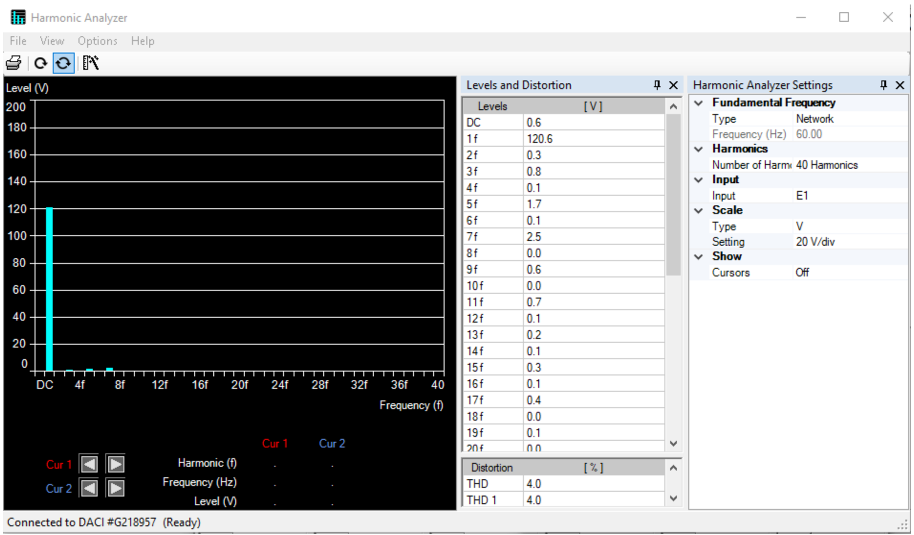

Figure 4: V_{in} harmonic components

Figure 5 represents harmonic analysis of the input current signal I_{Ain}

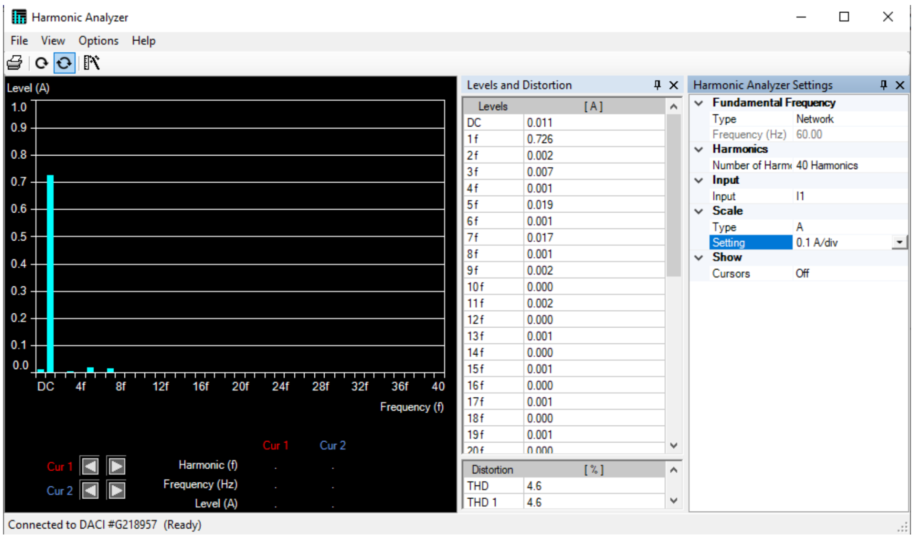

Figure 5: I_{Ain} harmonic components

2.3.2 Output Signal

Figure 6 represents harmonic analysis of the input voltage signal V_{out}

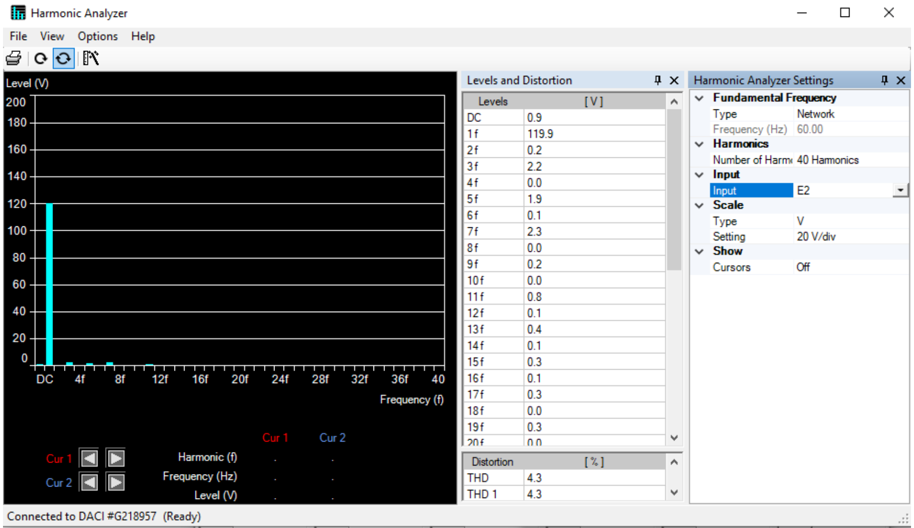

Figure 6: V_{out} harmonic components

Figure 7 represents harmonic analysis of the input current signal I_{Aout} From the Figure 2

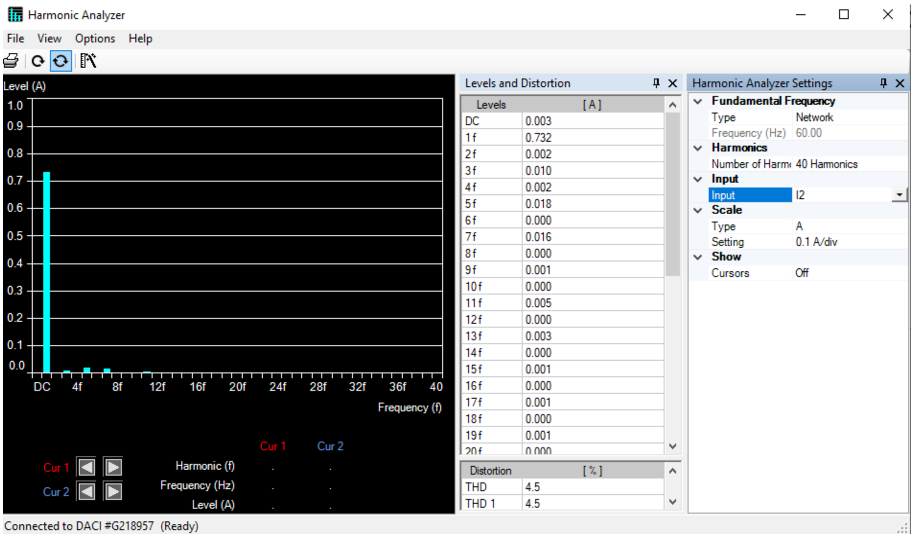

Figure 7: I_{Aout} harmonic components

and Figure 3 we can see that I_{Ain} and I_{Aout} are the same as expected. However the V_{in} and V_{out} are bit different due to the distortion present in the V_{out}. The waveforms for the current are very similar to the AC-DC converter since each diode is conducting twice per cycle.

2.4 Data Table

α	I_{Ain}	P_{in}	Q_{in}	V_{out}	I_{Aout}	P_{out}	Q_{out}	PF_{out}	η	η_{calc}
0	0.713	13.08	85.97	119.3	0.716	12.03	85.23	0.141	92.95	0.928
20	0.721	13.19	85.95	119.6	0.723	12.45	86.12	0.143	92.60	0.953
40	0.725	13.20	85.03	119.8	0.723	12.23	86.57	0.143	92.05	0.971
60	0.722	13.20	86.27	120	0.74	12.22	86.17	0.143	92.71	0.971
80	0.716	13.90	85.05	119.7	0.716	12.96	84.80	0.151	92.70	0.969
100	0.576	11.21	65.78	101.2	0.573	10.48	55.41	0.181	93.45	0.959
110	0.307	5.66	31.40	54.76	0.305	5.536	14.9	0.327	97.77	0.959
120	0.24	3.23	27.15	24.37	0.3	2.67	0.937	0.360	82.53	0.959

Table 1: 3ϕ thyristor AC controller Data

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3 Calculations and Questions

- From the data in the Table 1, create the graphs for α vs V_{out}, α vs PF_{out}, α vs Q_{out} and α vs η

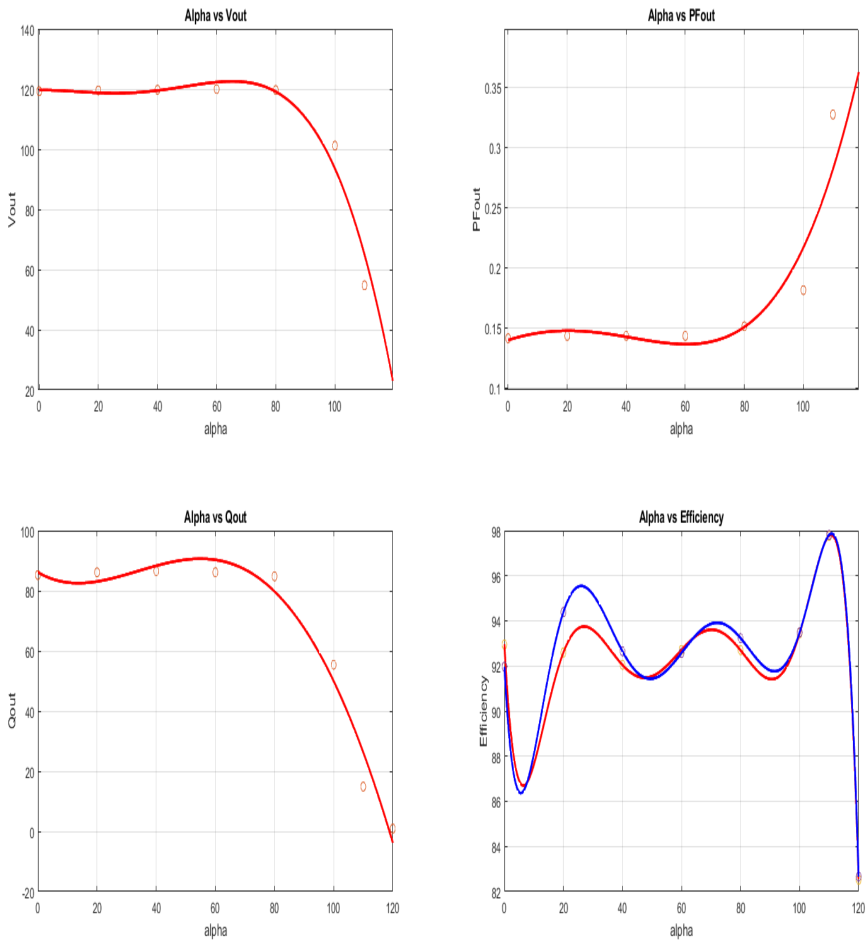

Figure 8: Output plots for α

- Comments on the graphs for Figure 8.
  When α reached well over 80°, the wound rotor induction motor's speed slowed rapidly and eventually stalled when the α was set to 100°. From the figure 8 we can see that V_{out} was fairly constant till 80° then the exponential decrease is observed due to the decrease in the conduction of the thyristors. From the Q_{out} diagram it is seen that the exponential relation exists the output and the α. However from the PF_{out} plot, the output was fairly constant till the value of 50°. Once the α crosses the 50°, exponential rise can be observed. The most significant observation is noticed in the relationship between η vs α, which behaved like a seventh order polynomial. It can be seen that the maximum value of η is recorded when α has a value of 110°. Each of the graphs plotted using polyfit function in matlab to get the best fit among points.

- Formula Used.

$$S_{in} = \sqrt{P_{in}^2 + Q_{in}^2}$$

$$PF_{in} = \frac{P_{in}}{S_{in}}$$

$$S_{out} = \sqrt{P_{out}^2 + Q_{out}^2}$$

$$PF_{out} = \frac{P_{out}}{S_{out}}$$

$$\eta = \frac{P_{out}}{P_{in}} * 100\%$$

4 Discussions and Conclusion

The main purpose of this lab is to investigate the performance of a 3ϕ AC-AC power electronic converter supplying a 3ϕ induction motor. The harmonic componenets of the input and output currents and voltages are observed with PF_{out}, V_{out}, Q_{out}, Q_{in} and η. For the α having the value of 60 degrees the waveforms of the input and output voltage and current are recorded with their corresponding fourier transform for their harmonic analysis. From the time domain spectrum of the input and output signals some distortion can be observed due to the switching of the thyristors. The effects of increasing the α can be observed form the Table 1. It can be seen from the values of PF_{out}, Q_{out}, Q_{in} and η. From the figure 8, it was noticed significant changes occurred when α was way over $80°$ mark. No linear relation can be observed the figure 8. The plot for the η vs α is a fourth order polynomial, with maximum efficiency of 98%. Two graphs are plotted, the red plot is the one for the datas taken from the DAM. The blue plot is the data taken from the efficiency calculation.

```
clc
clear all
alpha=[0 20 40 60 80 100 110 120];
Vout=[119.3 119.6 119.8 120 119.7 101.2 54.76 24.37];
PFout=[0.141 0.143 0.143 0.143 0.151 0.181 0.327 0.360];
Qout=[85.23 86.12 86.57 86.17 84.80 55.41 14.9 0.937];
n=[92.95 92.60 92.05 92.71 92.70 93.45 97.77 82.53];
Pin=[13.08 13.19 13.20 13.20 13.90 11.21 5.66 3.23];
Pout=[12.03 12.45 12.23 12.22 12.96 10.48 5.536 2.67];
n_mea=(Pout./Pin)*100;
coef1=polyfit(alpha,Vout,0);

subplot(221)
plot(alpha,Vout,'o')
x=alpha;
y=Vout
coefficients = polyfit(x, y, 4);
xFit = linspace(min(x), max(x), 100000);
yFit = polyval(coefficients , xFit);
hold on;
plot(xFit, yFit, 'r-', 'LineWidth', 2);
grid on;

coefficients =0

subplot(222)
plot(alpha,PFout,'o')
x1=alpha;
y1=PFout
coefficients = polyfit(x1, y1, 4);
xFit1 = linspace(min(x1), max(x1), 100000);
yFit1 = polyval(coefficients , xFit1);
hold on;
plot(xFit1, yFit1, 'r-', 'LineWidth', 2);
grid on;

coefficients =0

subplot(223)
plot(alpha,Qout,'o')
x2=alpha;
y2=Qout
coefficients = polyfit(x2, y2, 4);
xFit2 = linspace(min(x2), max(x2), 100000);
yFit2 = polyval(coefficients , xFit2);
hold on;
plot(xFit2, yFit2, 'r-', 'LineWidth', 2);
grid on;

coefficients =0
```

```
subplot(224)
plot(alpha,n,'o')
x3=alpha;
y3=n
coefficients = polyfit(x3, y3, 7);
xFit3 = linspace(min(x3), max(x3), 100000);
yFit3 = polyval(coefficients , xFit3);
hold on;
plot(xFit3, yFit3, 'r-', 'LineWidth', 2);
grid on;

coefficients =0
hold on;
plot(alpha,n_mea,'o')
x4=alpha;
y4=n_mea;
coefficients = polyfit(x4, y4, 7);
xFit4 = linspace(min(x4), max(x4), 100000);
yFit4 = polyval(coefficients , xFit4);
hold on;
plot(xFit4, yFit4, 'b', 'LineWidth', 2);
grid on;
```