MIDDLE EAST TECHNICAL UNIVERSITY
ELECTRICAL AND ELECTRONICS ENGINEERING DEPARTMENT

EE463 STATIC POWER CONVERSION – 1

EXPERIMENT #2

THREE PHASE AC CHOPPER

EXPERIMENT DATE: 23.11.2018

FRIDAY MORNING

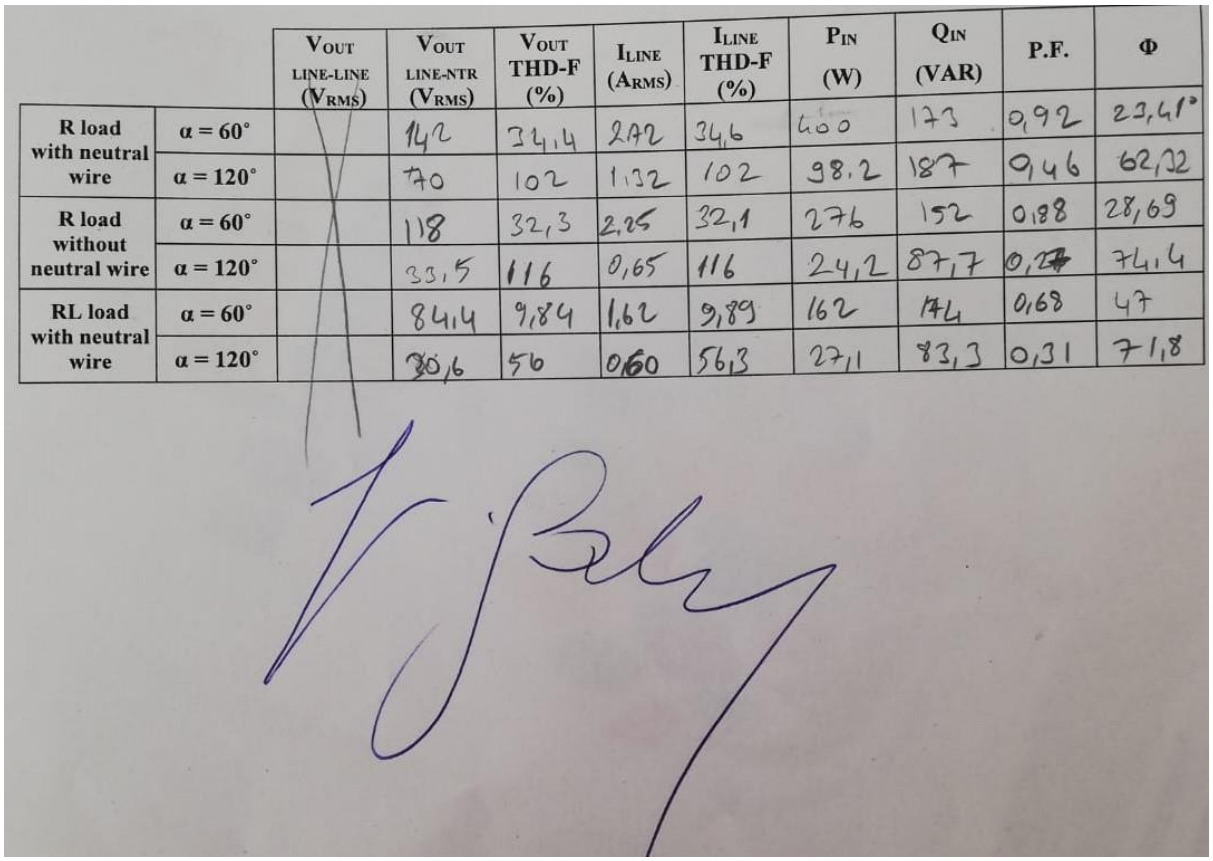
Ali AYDIN - 2093326

Nail TOSUN - 2094696

Table of Content

EQUIPMENT LIST

- HPS SystemTechnik Transformer Trainer
- Three phase resistive load bank
- Three phase capacitive load bank
- Three phase inductive load bank
- Two different wattmeters
- Resistive Load Bank 1 3ϕ, each resistor 192Ω, 250W
- Inductive Load Bank 1 3ϕ, each inductor 0.61H, 250VAR
- Autotransformer 1 3ϕ, 240 V, 8 A
- Oscilloscope 1 TPS2024 with four isolated channels
- Thyristor Based Converter Module 1 Semikron, SemiTeach Module; Thyristor: 1200V 55A, Diode: 1200V 47A.
- DC Power Supply 1 GW Instek, 40V 5A



		V_{OUT} LINE-LINE (V_{RMS})	V_{OUT} LINE-NTR (V_{RMS})	V_{OUT} THD-F (%)	I_{LINE} (A_{RMS})	I_{LINE} THD-F (%)	P_{IN} (W)	Q_{IN} (VAR)	P.F.	Φ
R load with neutral wire	α = 60°		142	34,4	2,72	34,6	400	173	0,92	23,41°
	α = 120°		70	102	1,32	102	98,2	187	0,46	62,32
R load without neutral wire	α = 60°		118	32,3	2,25	32,1	276	152	0,88	28,69
	α = 120°		33,5	116	0,65	116	24,2	87,7	0,27	74,4
RL load with neutral wire	α = 60°		84,4	9,84	1,62	9,89	162	174	0,68	47
	α = 120°		30,6	56	0,60	56,3	27,1	83,3	0,31	71,8

INTRODUCTION

In this experiment, we examined the three phase AC Chopper with different load type. Also, we examined with neutral wire connected and without it connected. In first and second part, we observed with and without neutral line. Also, in first and third part, we observed outputs with respect to different type of load.
We established the simulink setup in the figure 1.

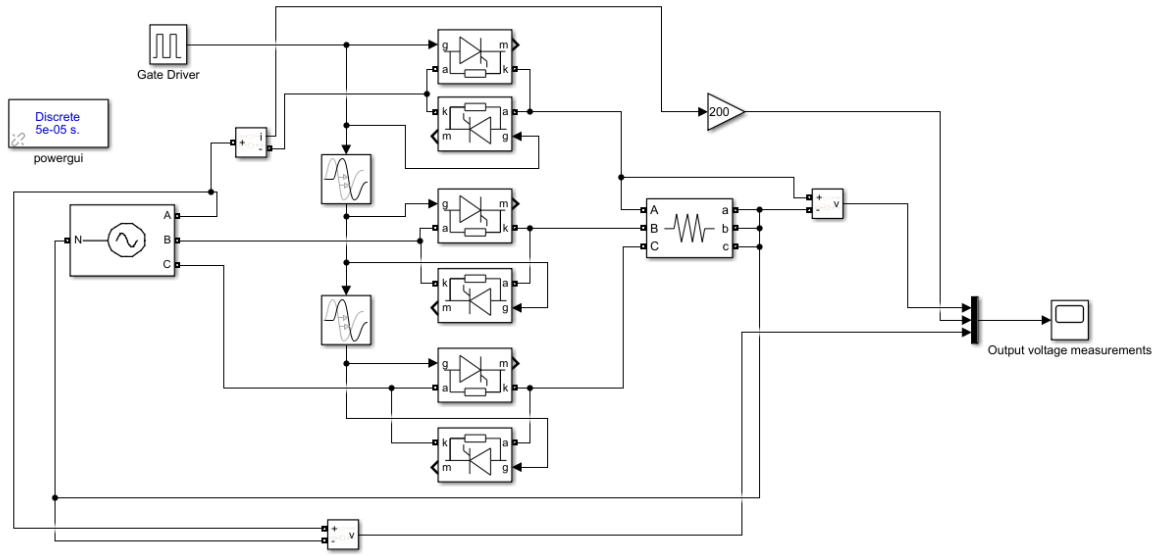


Figure 1: Simulink model to simulate AC Chopper

RESISTIVE LOAD WITH NEUTRAL WIRE

Laboratory Data and Graph

Table 1: Experimental results for Resistive load with neutral line

		Vout Line-Ntr (Vrms)	Vout THD-F (%)	Iline (Arms)	Iline THD-F (%)	Pin (W)	Qin (VAR)	P.F.	Φ
R Load with neutral wire	α = 60˚	142	34.4	2.72	34.6	400	173	0.92	23.41
	α = 120˚	70	102	1.32	102	98.2	187	0.46	62.32

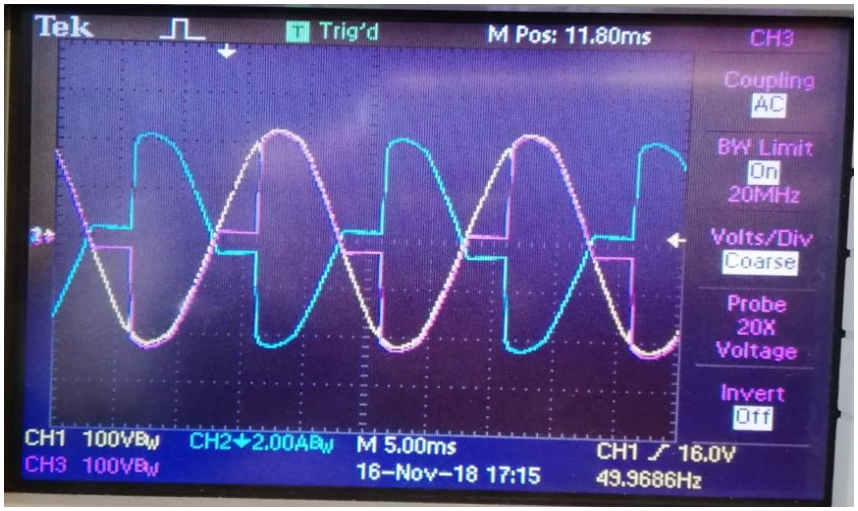


Figure 2: Waveforms of input voltage(yellow), input current(blue) and output voltage(red) with firing angle 60 degree

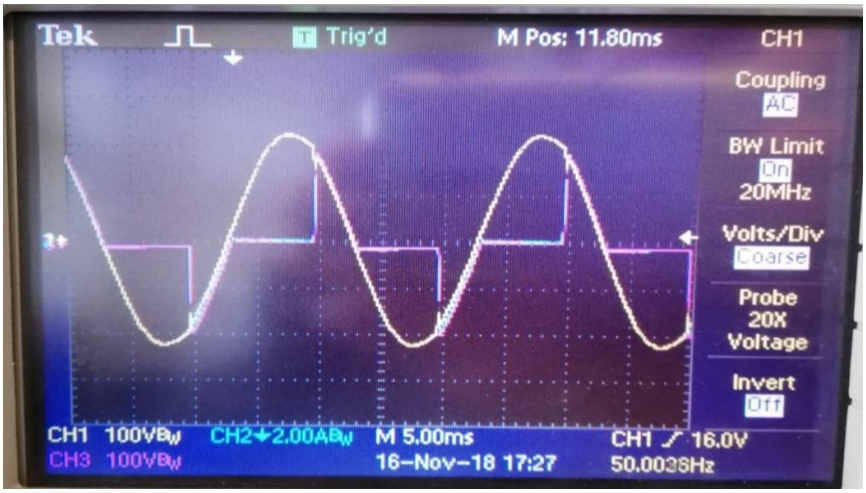


Figure 3: Waveforms of input voltage(yellow), input current(blue) and output voltage(red) with firing angle 120 degree

Simulation Graphs

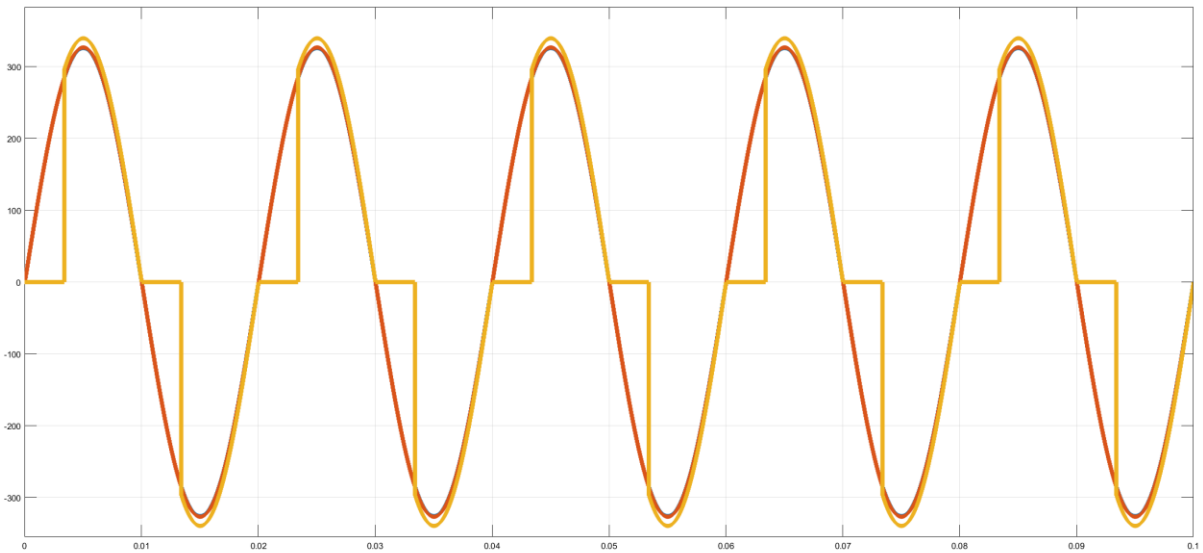


Figure 4: Simulation result for resistive load with neutral line and firing angle 60 degree

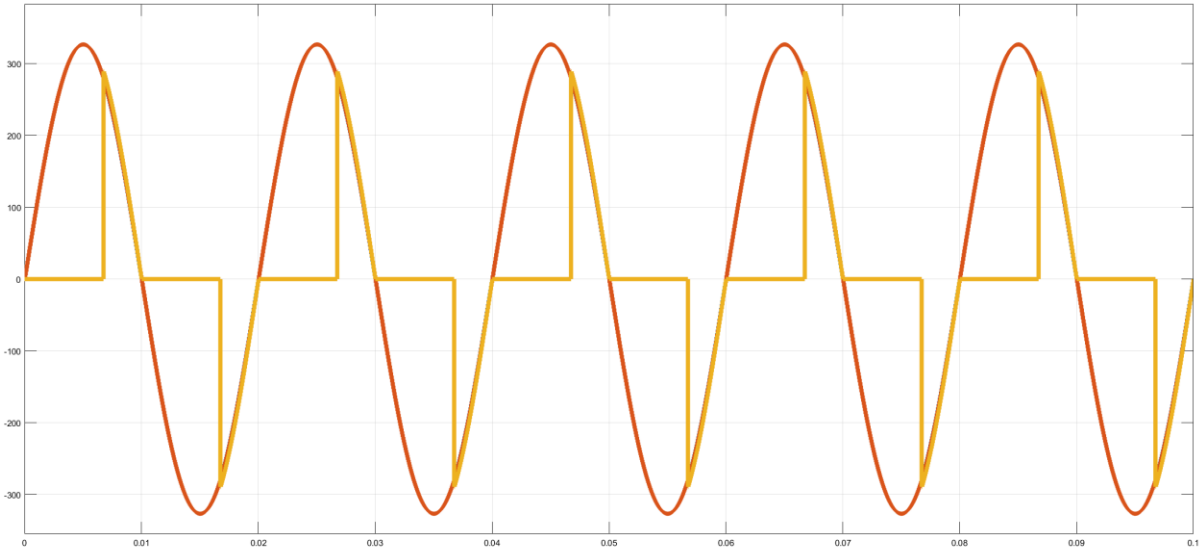


Figure 5: Simulation result for resistive load with neutral line and firing angle 120 degree

Current is so small value with respect to voltages and we multiply the current with 200 to obtain the same scale.

Theoretical Approach

We made experiment with two different firing angle and with neutral wire. When we connect the neutral wire, chopper behaves like single phase controlled rectifier. When this rectifier consists of thyristor, it works with two quadrant which are rectifier and inverter. We observed both of them in the experiment since we applied two firing angle which are 60 and 120 degree. When we fired the thyristor at 60 degree, chopper behaved like rectifier and power flow from source to load. When we fired at 120 degree, chopper behaved like inverter but power flow from source to load since we do not have any active power supply in load side.

When input voltage is

$$V_s = \sqrt{2} * V_{rms} * sin(wt)$$

we can calculate the output average voltage as

$$V_{out} = 0.9 * V_s * cos(\alpha) - \frac{2 * w * L_s * I_d}{\Pi}$$

We can understand above formula that power quality is related to firing angle since firing angle affects the average voltage.

Moreover, output current waveform is like output voltage waveform since load is resistive and current is

$$I_{out} = \frac{V_{out}}{R}$$

THD and harmonic currents because of caused delay in firing thyristors is increased with increasing of firing angle.

When average voltage decreased with increasing firing angle, real power taken from source decreases. Also, power factor decreases since power factor formula is

$$PF = 0.9 * cos(\alpha)$$

RESISTIVE LOAD WITHOUT NEUTRAL WIRE

Laboratory Data and Oscilloscope Graph

Table 2: Experimental results for Resistive load without neutral line

		Vout Line-Ntr (Vrms)	Vout THD-F (%)	Iline (Arms)	Iline THD-F (%)	Pin (W)	Qin (VAR)	P.F.	Φ
R Load without neutral wire	α=60˚	118	32.3	2.25	32.1	276	152	0.88	28.69
	α=120˚	33.5	116	0.65	116	24.2	87.7	0.27	74.4

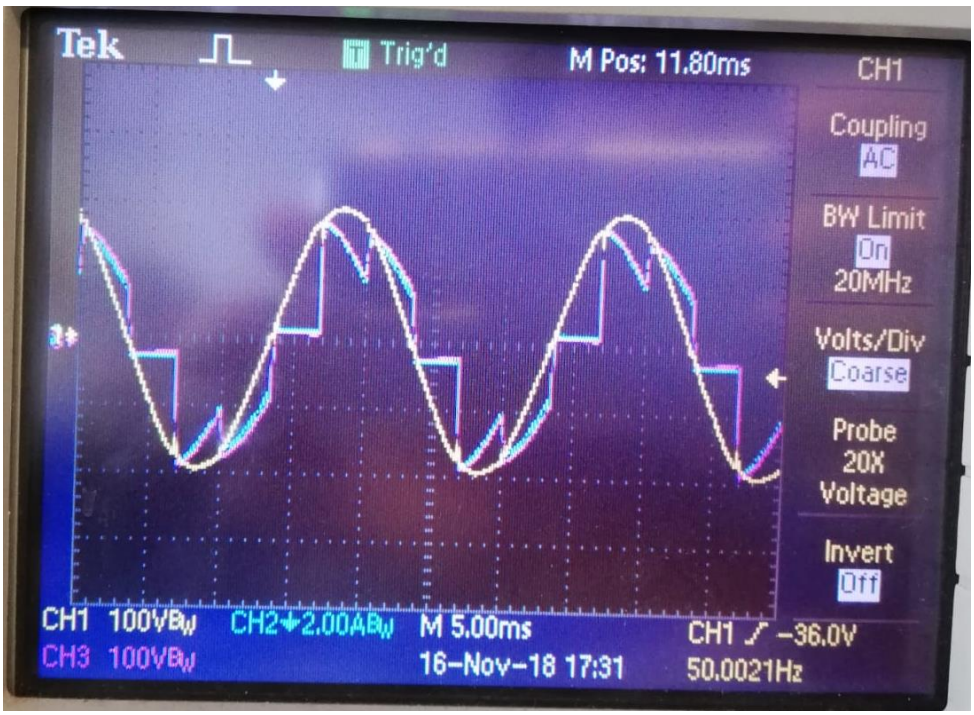


Figure 6: Waveforms of input voltage(yellow), input current(blue) and output voltage(red) with firing angle 60 degree

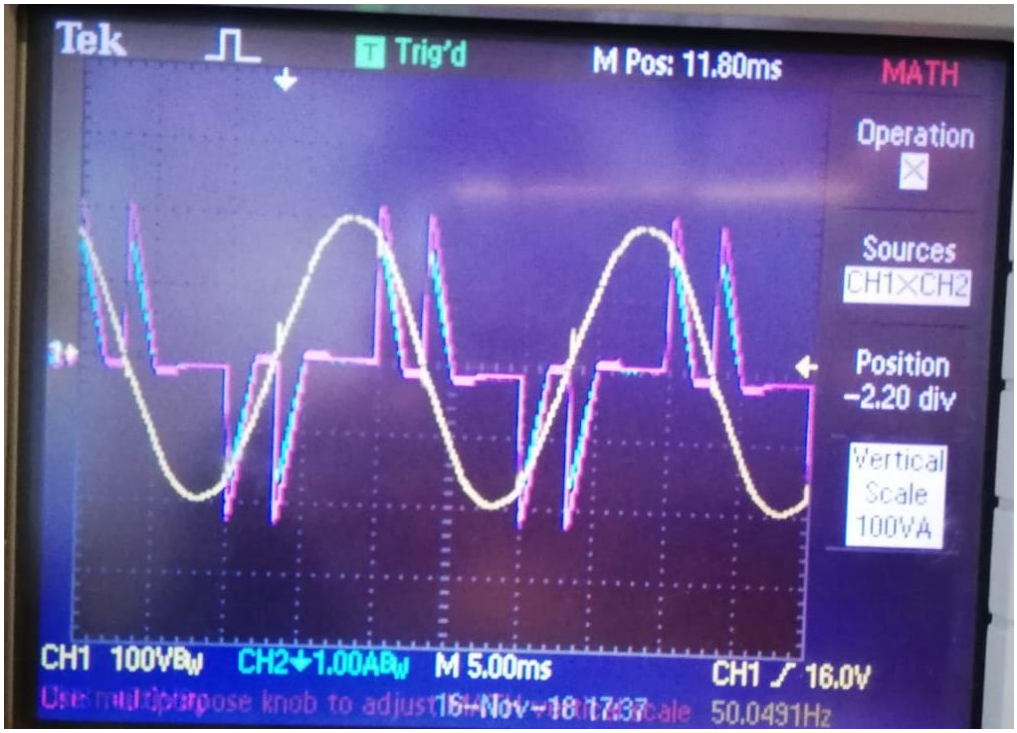


Figure 7: Waveforms of input voltage(yellow), input current(blue) and output voltage(red) with firing angle 120 degree

Simulation Graph

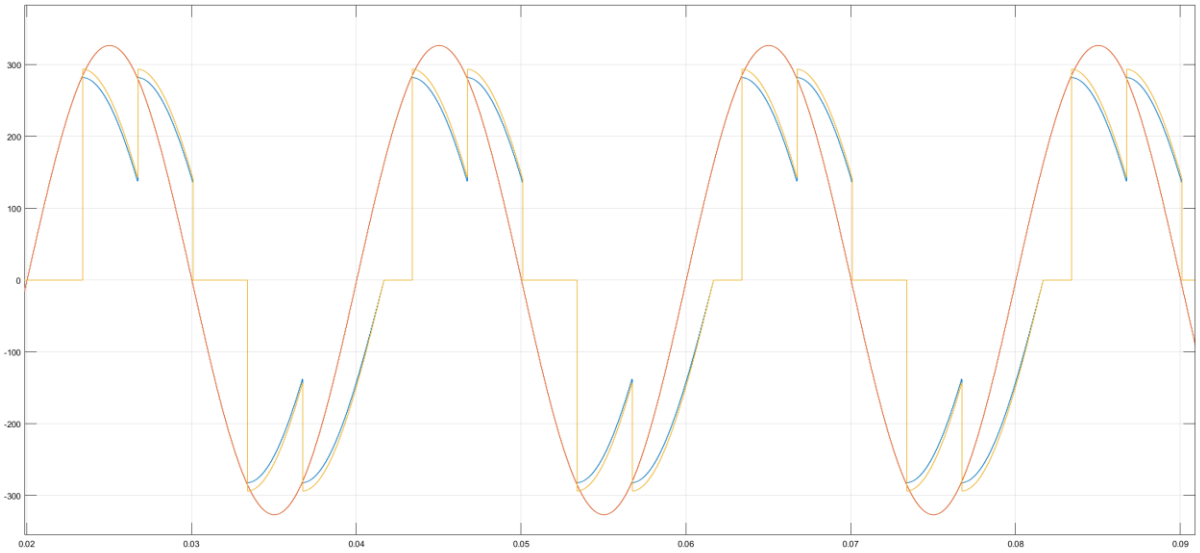


Figure 8: Simulation result for resistive load without neutral line and with firing angle 60 degree

Theoretical Approach

In this part, we do not connect the neutral line and converter does not behave like single rectifier. To complete the path, current should go to other phase and there is some loss since they cut off each other. Due to that, third harmonic lost.

Average voltage decreased with respect to first part. Because of that, input power decreased. Moreover, current affected the same like voltage.

RESISTIVE AND INDUCTIVE LOAD WITH NEUTRAL WIRE

Laboratory Data and Oscilloscope Graph

Table 3: Experimental results for Resistive and Inductive load with neutral line

		Vout Line-Ntr (Vrms)	Vout THD-F (%)	Iline (Arms)	Iline THD-F (%)	Pin (W)	Qin (VAR)	P.F.	Φ
RL Load without neutral wire	α=60˚	84.4	9.84	1.62	9.89	162	174	0.68	47
	α=120˚	30.6	56	0.60	56.3	27.1	83.3	0.31	71.8

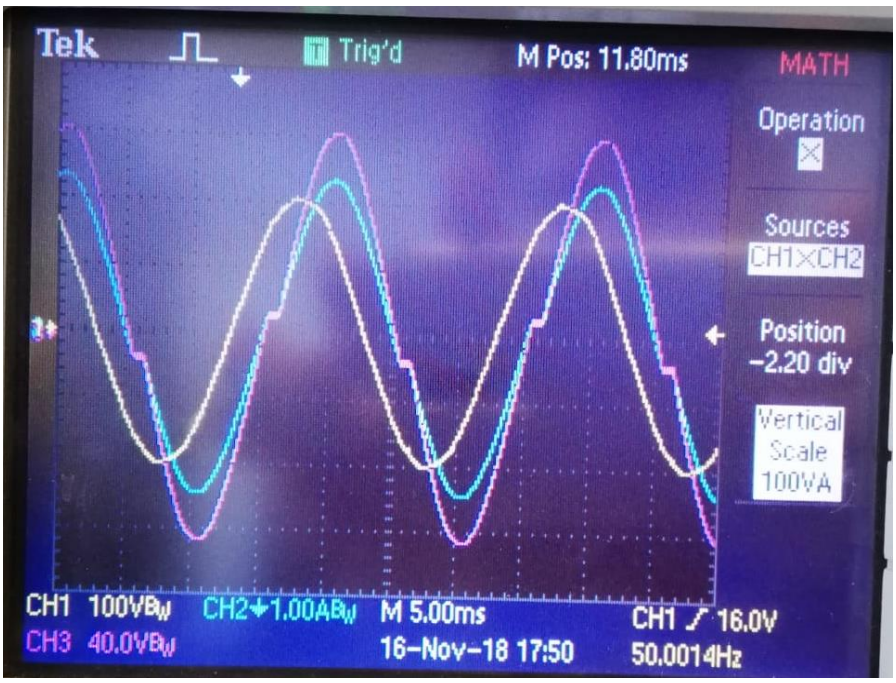


Figure 9: Waveforms of input voltage(yellow), input current(blue) and output voltage(red) with firing angle 60 degree

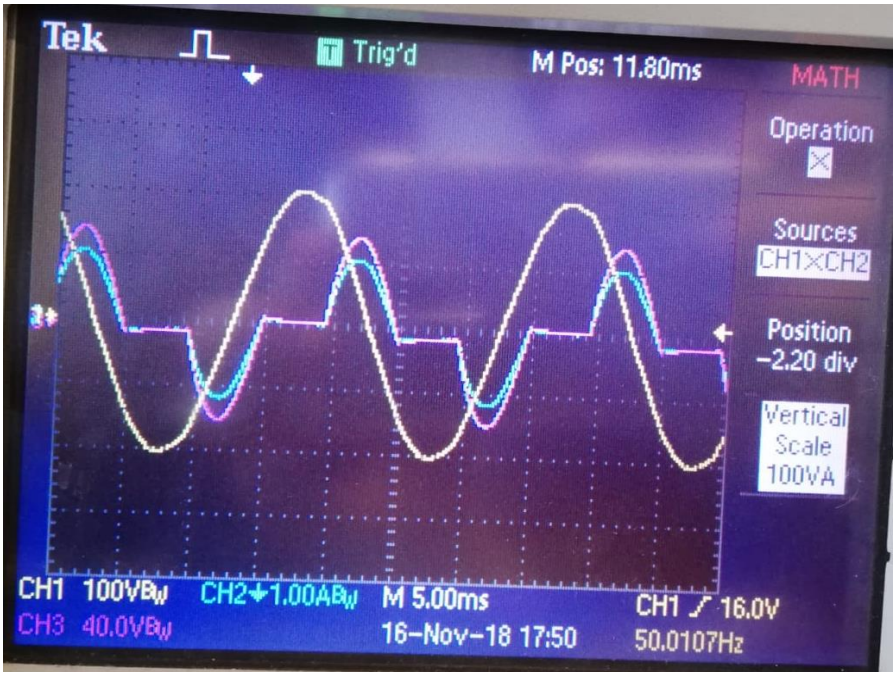


Figure 10: Waveforms of input voltage(yellow), input current(blue) and output voltage(red) with firing angle 120 degree

Simulation Graph

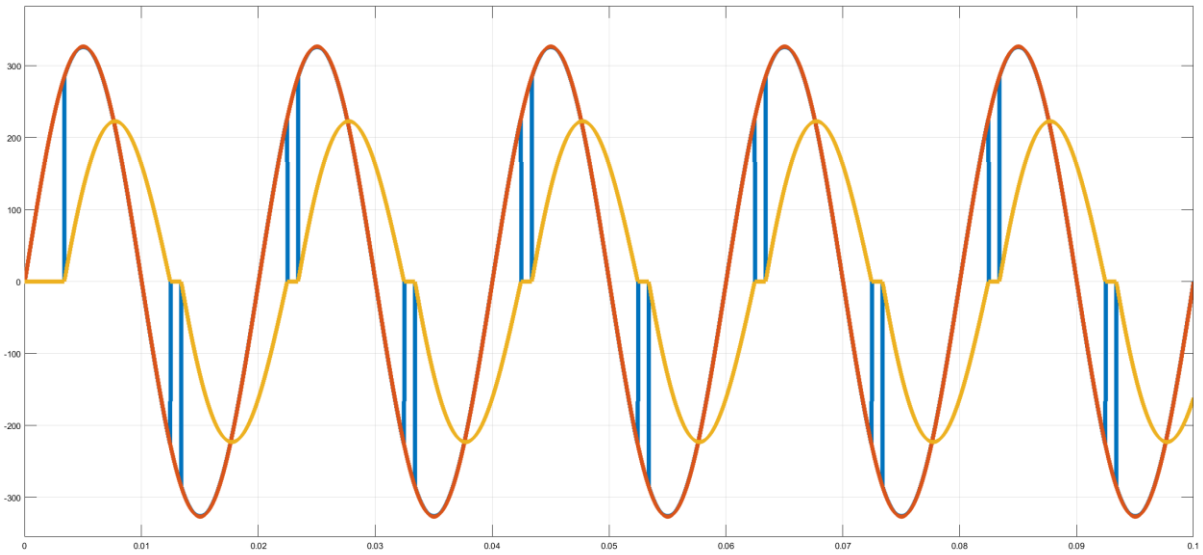


Figure 11: Simulation result for resistive and inductive load with neutral line and firing angle 60 degree

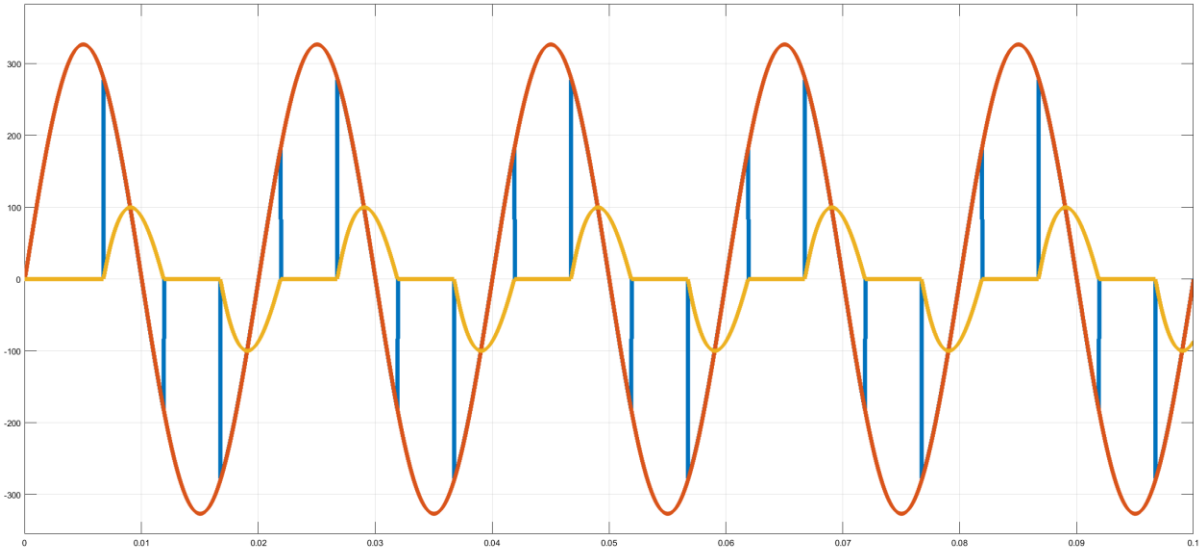


Figure 12: Simulation result for resistive and inductive load with neutral line and firing angle 120 degree

Theoretical Approach

In this step, we work with series RL load. We observed effect of inductive load in the figures. When thyristor is fired, inductor current starts to fill. Normally, at 180 degree, voltage should have been 0 but it did not since load is inductive and current fell directly to zero immediately. Due to this, to make current is zero, voltage went to below zero. Shortly, the thyristor will continue to conduct the load current until all the inductive energy stored in the load inductor L is completely utilized and the load current through thyristor falls to zero at ωt = β, where β is referred to as the Extinction angle, at which the load current falls to zero.

In this configuration, output average voltage is

$$V_{av} = \frac{2 * V_{rms}}{\pi} * cos(\alpha)$$

We can interpret that average voltage decreases with increasing firing angle and with respect to other part average voltage decreased since due to current, voltage fell below zero to fall the current zero. Due to that, input power decreases. Also, power factor decreases since power factor formula is the same with R load.

THD decreased with respect to other part since thanks to inductive load, it provides smooth increasing and falling to current.

CONCLUSION

In this experiment, we worked with AC Chopper converter and used it with different load and connection configuration.

In first part, we connected it to resistive load and we observed output waveforms with two different firing angles. Also, we calculated its THD, power factor etc. by using oscilloscope.

In second part, we connected the same load but we disconnected the neutral line. After this configuration, output voltage and current waveforms are distorted by lack of third harmonic.

In final part, we examined it with series resistive and inductive load.