

Experiment # 4

Three-Phase Converters (Controlled Rectifiers)

Objectives

- Setting up various topologies of Three-Phase Controlled Rectifiers and understanding their operation with various types of load
- Measuring and interpreting various parameters of the Three-Phase Controlled Rectifiers
- Understanding the operation of various types of Three-Phase Controlled Rectifiers and deriving their Control Characteristics

Components and Accessories

1	735 09	Load, Power Electronics
1	735 012	Phase Commutated Converter
1	735 122	Converter Controller Unit
1	735 190	Phase Control Noise Filter 3X4.5A
1	726 80	Transformer 45/90, 3 N
1	524 013S	Sensor-CASSY 2 – Starter
1	735 012 – 03 M3C	Mask (Bridge Topology)
1	735 012 – 08 B6C	Mask (Bridge topology)
1	735 012 – 09 B6HA, B6HK	Mask (Bridge topology)
1	500 59	Set of 10 safety bridging plugs, black
1	500 591	Set of 10 safety bridging plugs with tap, black
2	500 640	Safety Connection Lead 100 cm yellow/green
4	500 641	Safety Connection Lead 100 cm, red

Theory

The Three-Phase Controlled-Rectifiers convert the three-phase AC voltage into a DC voltage with controllable average value via the firing angle of the SCRs. The output of these converters is composed of a DC value plus Harmonics; undesirable components. Three-Phase converters are of various types:

A) Three-Phase Half-Wave Controlled Rectifier

- For a resistive load, the average output voltage of a Three-Phase Half-Wave Converter is:

$$V_{dc} = \frac{3}{2\pi} \int_{\frac{\pi}{6}+\alpha}^{\pi} V_m \sin \omega t \, d\omega t$$

...

$$V_{dc} = \frac{3V_m}{2\pi} \left(1 + \cos \left(\frac{\pi}{6} + \alpha \right) \right); \quad \frac{\pi}{6} < \alpha < \frac{5\pi}{6}$$

- For a resistive load, the **root-mean-square** of a Three-Phase Half-Wave Converter is:

$$V_{rms} = \sqrt{\frac{3}{2\pi} \int_{\frac{\pi}{6}+\alpha}^{\pi} (V_m \sin \omega t)^2 \, d\omega t}$$

...

$$V_{rms} = \sqrt{3}V_m \sqrt{\left(\frac{5}{24} - \frac{\alpha}{4\pi} + \frac{1}{8\pi} \sin \left(\frac{\pi}{3} + 2\alpha \right) \right)}; \quad \frac{\pi}{6} < \alpha < \frac{5\pi}{6}$$

- For a highly inductive load, the average output voltage of a Three-Phase Half-Wave Converter is:

$$V_{dc} = \frac{3\sqrt{3}V_m}{2\pi} \cos(\alpha); \quad 0 < \alpha < \pi$$

- For a highly inductive load, the rms value of the output voltage of a Three-Phase Half-Wave Converter is:

$$V_{rms} = \sqrt{\frac{3}{2\pi} \int_{\frac{\pi}{6}+\alpha}^{\frac{5\pi}{6}+\alpha} (V_m \sin \omega t)^2 \, d\omega t}$$

...

$$V_{rms} = \sqrt{3}V_m \sqrt{\left(\frac{1}{6} + \frac{\sqrt{3}}{8\pi} \cos(2\alpha) \right)}; \quad 0 < \alpha < \pi$$

- **If the load was purely resistive, but $\alpha < \frac{\pi}{6}$,** then the output voltage is continuous and has the same average value as that with a highly inductive Load. The same argument is valid also for the RMS value of the output voltage!

B) Three-Phase Semi-Converter

- The average output voltage is:

$$V_{dc} = \frac{3}{2\pi} \int_{\frac{\pi}{6}+\alpha}^{\frac{7\pi}{6}} v_{ac} d\omega t$$

...

$$V_{dc} = \frac{3\sqrt{3}V_m}{2\pi} (1 + \cos \alpha); \quad 0 \leq \alpha \leq \pi$$

- For $\alpha > \frac{\pi}{3}$ and discontinuous output voltage, the root-mean-square of the output voltage is:

$$V_{rms} = \sqrt{\frac{3}{2\pi} \int_{\frac{\pi}{6}+\alpha}^{\frac{7\pi}{6}} (v_{ac})^2 d\omega t}$$

...

$$V_{rms} = \sqrt{3}V_m \sqrt{\frac{3}{4\pi} \left(\pi - \alpha + \frac{\sin 2\alpha}{2} \right)}; \quad \frac{\pi}{3} \leq \alpha \leq \pi$$

- For $\alpha \leq \frac{\pi}{3}$, and continuous output voltage, the root-mean-square of the output voltage is:

$$V_{rms} = \sqrt{\frac{3}{2\pi} \left[\int_{\frac{\pi}{6}+\alpha}^{\frac{\pi}{2}} (v_{ab})^2 d\omega t + \int_{\frac{\pi}{2}}^{\frac{5\pi}{6}+\alpha} (v_{ac})^2 d\omega t \right]}$$

...

$$V_{rms} = \sqrt{3}V_m \sqrt{\frac{3}{4\pi} \left(\frac{2\pi}{3} + \sqrt{3}(\cos \alpha)^2 \right)}$$

C) Three-Phase Full-Converter

- For a highly inductive load, the average output voltage of a Three-Phase Full-Converter is:

$$V_{dc} = \frac{3\sqrt{3}V_m}{\pi} \cos \alpha; \quad 0 \leq \alpha \leq \pi$$

- For a highly inductive load, the rms value of the output voltage of a Three-Phase Full-Converter is:

$$V_{rms} = \sqrt{\frac{6}{2\pi} \int_{\frac{\pi}{6}+\alpha}^{\frac{\pi}{2}+\alpha} (v_{ab})^2 d\omega t}$$

...

$$V_{rms} = \sqrt{3}V_m \sqrt{\left(\frac{1}{2} + \frac{3\sqrt{3}}{4\pi} \cos 2\alpha\right)}$$

- For $\alpha < \frac{\pi}{3}$ the output voltage is continuous and does not have any negative instantaneous value regardless of the load type (resistive or highly inductive). Thus, for $\alpha < \frac{\pi}{3}$ and a resistive load the average output voltage is the same as the average output voltage of a highly inductive Load.

- For a highly inductive load and $\alpha > \frac{\pi}{3}$, the instantaneous output voltage has negative parts. Thus, with a resistive load (and with $\alpha > \frac{\pi}{3}$), the instantaneous output voltage cannot be negative (because the output current cannot be negative) and the average output voltage in the resistive load case is:

$$V_{dc} = \frac{6}{2\pi} \int_{\frac{\pi}{6} + \alpha}^{\frac{5\pi}{6}} v_{ab} d\omega t$$

...

$$V_{dc} = \frac{3\sqrt{3}V_m}{\pi} \left(1 + \cos\left(\alpha + \frac{\pi}{3}\right)\right); \quad \frac{\pi}{3} \leq \alpha \leq \frac{4\pi}{6}$$

- For further details, refer to EE3305 Power Electronics course lecture notes and to Appendix C.

Experimental Procedure

Basic Settings:

Converter Controller Unit (cat. no. 735 122) and Phase Commutated Converter (cat. no. 735 012):

- Connect the “Phase Commutated Converter” (cat. no.735 012), the “Converter Control Unit” (cat. no.735 122), the “Transformer” (cat. no.726 80), the “Load, Power Electronics” (cat. no.735 09), and the measurement instruments in the way you see in the figure in each corresponding paragraph.
- Lay the corresponding mask (for example “735 012-08 (B6C)”) on the commutated converter.
- Disconnect the “Converter Control Unit” from the 12V power supply. Now connect it again.
- The lower display of the “Converter Control Unit” indicates the delay angle. For the “B6C controlled” bridge for example, you can change the angle from 0° up to 150°.
- The “Converter Control Unit” automatically detects the mask of the controlled converter.
- The LED named “OK ” will flash.
- With the button “MODE” select the corresponding pulse form.

- Now the LEDs to the “pulse form” and to the “bridge topology” will light up.
- Now actuate the knob “OK” for the correct pulse form and the recognized bridge.
- If the correct LED does not light up, i.e. by wrong recognizing bridge, please check the following points:
 1. Does the correct mask lay on the “Phase Commutated Converter”?
 2. Is the mask well contacted with the “Network controlled converter”, so the four optical sensors can detect the pattern on the back side of the mask?
 3. Are the “Converter Control Unit” and the “Phase Commutated Converter” connected by the cable with the 25 pin D-sub?
 4. If the right LED does not shine, please change manually the settings using the knobs “MODE” and “COMMUTATION”.
- Press the button “OK” if the “LEDs for the bridge topology” of the “Converter Controller Unit” light up.

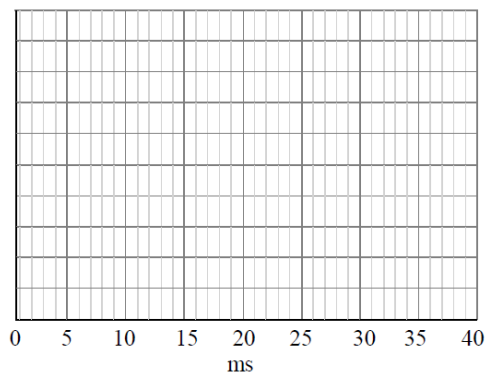
Do not press “OK” if the right LED does not light up!

- Turn the knob to the right or to the left to change the delay angle

4.1 Three-Phase Half-Wave Converter

Notes:

- Do not turn on any part of the equipment without a prior notice from the supervisor
- Connect one transformer secondary to produce a **phase-to-neutral voltage of 45V**
- Type of load used: Resistive/Inductive load: 33.3Ω (3 resistors in parallel, of 100Ω each)/ 50mH
- Mask (Bridge topology): “735 012 – 03 M3C”
- Pulse form: “Pulse”
- Use CASSY and its associate software (CASSY LAB) to measure/plot the currents and voltages in the AC Controller. To plot the time profiles appropriately, from the CASSY Lab open the file [M3C_R_0.labx](#), for an angle of 0° , and adjust the new plots’ settings to be similar to those in the file you have just opened; set the time span to 40ms.



- In all the circuits to be connected, ignore the measurement meters; instead of an Ammeter put a short circuit, and just open circuit the Voltmeter.
- Symbols Table:

u_{s01} : the input voltage
 i_s : the input current
 u_{V1} : the valve voltage
 u_d : the output voltage
 i_d : the output current

I) Three-Phase Half-Wave Converter with Resistive Load

Connect the components as shown in Figure 4.1. The load is purely resistive of 33.3Ω (3 resistors in parallel, of 100Ω each). Ensure that the Transformer's secondaries produce a **phase-to-neutral voltage of 45V**.

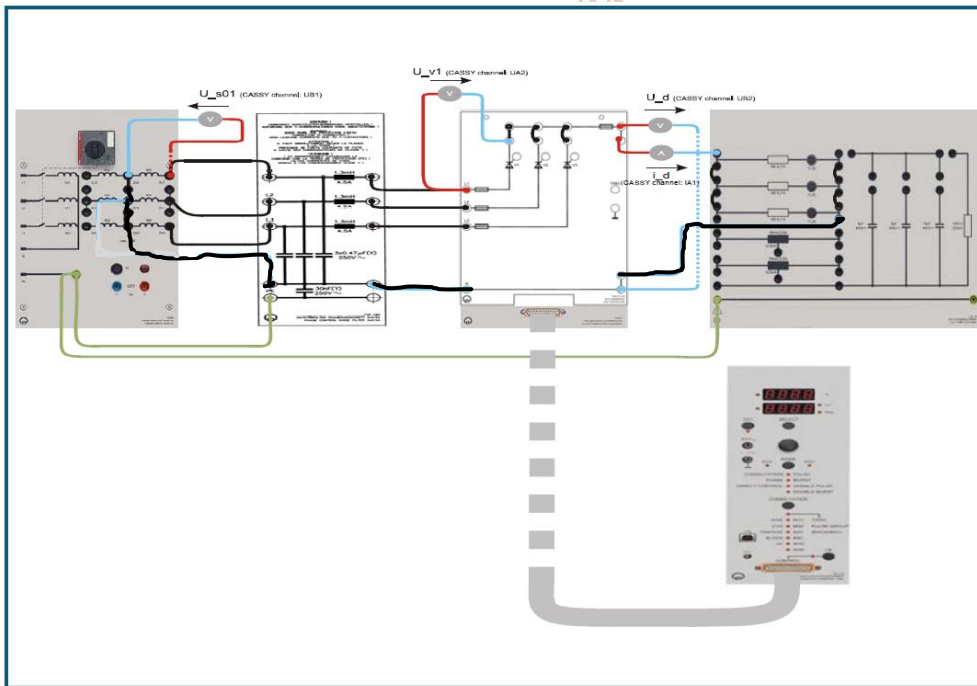


Figure 4.1 Configuration of a Three-Phase Half-Wave Converter supplying a purely resistive load of 33.3Ω

- 1) Initially, connect the CASSY probes to plot/measure the input voltage (u_{s01}) and the input current (i_s); using the CASSY LAB software
- 2) Adjust the Converter Control Unit (Cat. No. 735 122) to produce a delay angle of 45°

Ask

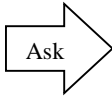
- 3) Turn on the Transformer Supply Voltage Cat. No. 726 80
- 4) Plot the traces of the input voltage (u_{s01}) and the input current (i_s); take screen shots of these plots!
- 5) Measure the rms value of the input voltage (u_{s01}), and the rms and average values of input current (i_s); using the CASSY LAB software
- 6) Turn off the Transformer Supply Voltage Cat. No. 726 80
- 7) Connect the voltage probe of CASSY to measure/plot the SCR (valve) voltage (u_v); leave the current probe unchanged

Ask

- 8) Turn on the Transformer Supply Voltage Cat. No. 726 80
- 9) Plot the SCR voltage (u_v) and the input current (i_s); take screen shots of these plots!
- 10) Comment on the voltage and current waveforms of the SCR!
- 11) Turn off the Transformer Supply Voltage Cat. No. 726 80
- 12) Connect the probes of CASSY to measure/plot the output voltage (u_d) and the output current (i_d)

Ask

- 13) Turn on the Transformer Supply Voltage Cat. No. 726 80
- 14) Plot the output voltage (u_d) and the output current (i_d); take screen shots of these plots!
- 15) Measure the peak-to-peak ripple at the output voltage
- 16) Measure the average and rms values of the output voltage (u_d) and the output current (i_d)
- 17) What is the frequency of the output voltage? Comment!
- 18) Turn off the Transformer Supply Voltage Cat. No. 726 80, and **keep the connections as they are!**
- 19) Calculate the Form Factor (FF) using the measured values
- 20) Calculate the Ripple Factor (RF) using the measured values
- 21) Calculate the Transformer Utilization Factor (TUF)
- 22) Calculate the theoretical average, and rms values of the output voltage, and then calculate FF, RF, and TUF! Compare with the measured values! Comment!
- 23) Adjust the Converter Control Unit (Cat. No. 735 122) to produce a delay angle of 90°
- 24) Repeat steps 13) to 22), comment on the plots obtained!
- 25) Compare the results obtained for the two delay angles in terms of FF, RF and TUF
- 26) Adjust the Converter Control Unit (Cat. No. 735 122) to produce a delay angle (α°) ranging from 0° to 150° in 30° step to fill in Table 4.1.



27) Turn on the Transformer Supply Voltage Cat. No. 726 80

Table 4.1: The effect of the delay angle on the average value of output voltage and current of a Three-Phase Half-Wave Converter

Delay angle (α°)	0°	30°	60°	90°	120°	150°
The measured average output voltage ($u_d(\alpha)$) [V]						
The measured average output current ($i_d(\alpha)$) [A]						
Normalized measured average output voltage, $u_d(\alpha) / u_d(\alpha=0^\circ)$						
Normalized measured average output current, $i_d(\alpha) / i_d(\alpha=0^\circ)$						
Calculated (theoretical) average output voltage [V]						
Normalized theoretical average output voltage, $u_d(\alpha) / u_d(\alpha=0^\circ)$						

28) Turn off the Transformer Supply Voltage Cat. No. 726 80; **keep the connections unchanged!**

29) Plot the control characteristic; the normalized measured and calculated output voltage versus α

30) Compare the experimental (practical) and theoretical values! Explain!

II) Three-Phase Half-Wave Converter with Resistive – Inductive (RL) Load

Modify the load connections to match those shown in Figure 4.2. The load is RL type of 33.3Ω (3 resistors in parallel, of 100Ω each) and 50mH (1 inductor in series). Ensure that the Transformer's secondaries produce a **phase-to-neutral voltage of 45V**.

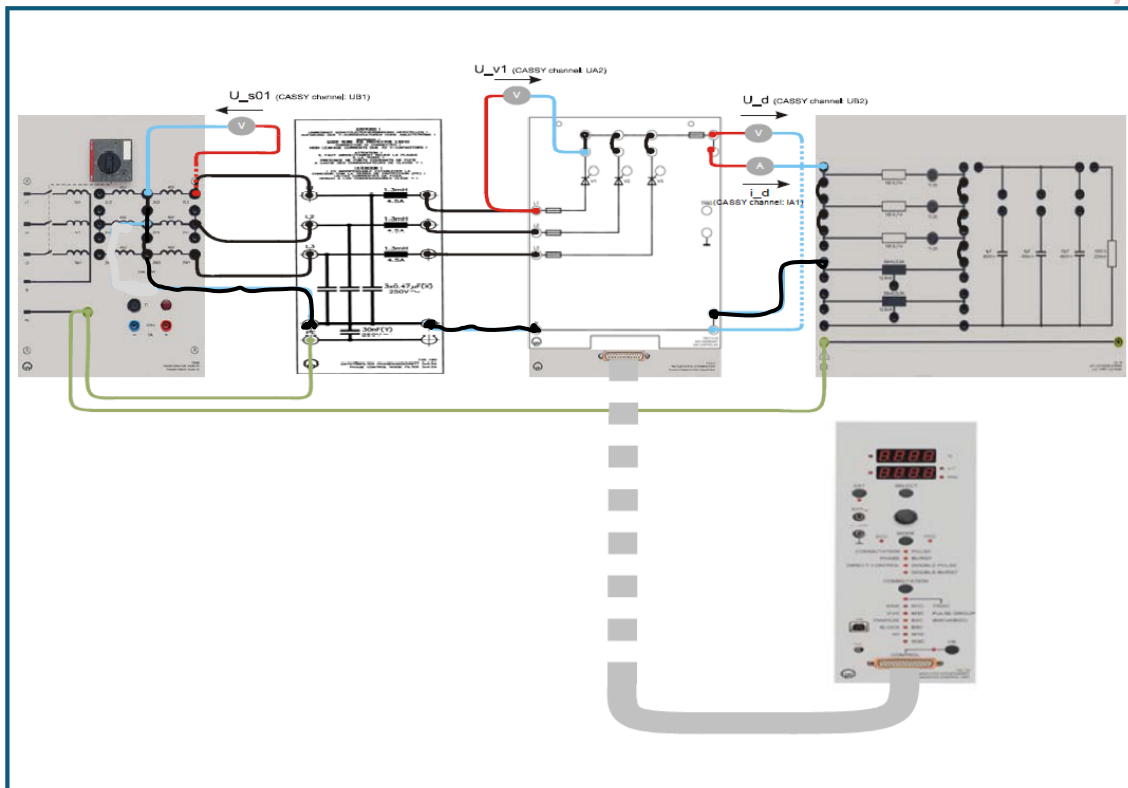
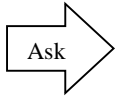
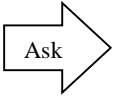


Figure 4.2 Configuration of Three-Phase Half-Wave Converter supplying a Resistive - Inductive load of 33.3Ω & 50mH

- 1) Initially, connect the CASSY probes to plot/measure the input voltage (u_{s01}) and the input current (i_s); using the CASSY LAB software
- 2) Adjust the Converter Control Unit (Cat. No. 735 122) to produce a delay angle of 45°
- 3) Turn on the Transformer Supply Voltage Cat. No. 726 80
- 4) Plot the traces of the input voltage (u_{s01}), and the input current (i_s); take screen shots of these plots!
- 5) Measure the rms value of the input voltage (u_{s01}), and the rms and average values of input current (i_s); using the CASSY LAB software
- 6) Turn off the Transformer Supply Voltage Cat. No. 726 80
- 7) Connect the voltage probe of CASSY to measure/plot the SCR (valve) voltage (u_v); leave the current probe unchanged



- 8) Turn on the Transformer Supply Voltage Cat. No. 726 80
- 9) Plot the SCR voltage (u_v) and the input current (i_s); take screen shots of these plots!
- 10) Comment on the voltage and (input) current waveforms of the SCR!
- 11) Turn off the Transformer Supply Voltage Cat. No. 726 80
- 12) Connect the probes of CASSY to measure/plot the output voltage (u_d) and the output current (i_d)



- 13) Turn on the Transformer Supply Voltage Cat. No. 726 80
- 14) Plot the output voltage (u_d) and the output current (i_d); take screen shots of these plots!
- 15) Measure the average and rms values of the output voltage (u_d) and the output current (i_d)
- 16) Turn off the Transformer Supply Voltage Cat. No. 726 80, and **keep the connections as they are!**
- 17) Calculate the Form Factor (FF) using the measured values
- 18) Calculate the Ripple Factor (RF) using the measured values
- 19) Calculate the Transformer Utilization Factor (TUF)
- 20) Adjust the Converter Control Unit (Cat. No. 735 122) to produce a delay angle of 90°
- 21) Repeat steps 13) to 19), comment on the plots obtained!
- 22) Compare the results obtained for the two delay angles in terms of FF, and RF
- 23) Compare the three types of loads (R, L, and RL) on the performance of the converter

4.2 Three-Phase Semi-Converter

Notes:

- Do not turn on any part of the equipment without a prior notice from the supervisor
- Connect the transformers secondaries as Y and to produce a **phase-to-neutral voltage of 45V**
- Type of load used: resistive load: 300Ω (3 resistors in series, of 100Ω each)
- Mask (Bridge topology): “735 012 – 09 B6HA, B6HK”
- Pulse form: “Pulse”

Symbols Table:

u_{s01}	: the input voltage
i_s	: the input current
u_{V1}	: the valve (SCR1) voltage
i_{T1}	: the valve (SCR1) current
u_d	: the output voltage
i_d	: the output current

I) Three-Phase Semi-Converter with a Resistive Load

Connect the components as shown in Figure 4.3. The load is purely resistive of 300Ω (3 resistors in series, of 100Ω each). Ensure that the Transformer's secondary produces a **phase-to-neutral voltage of 45V**.

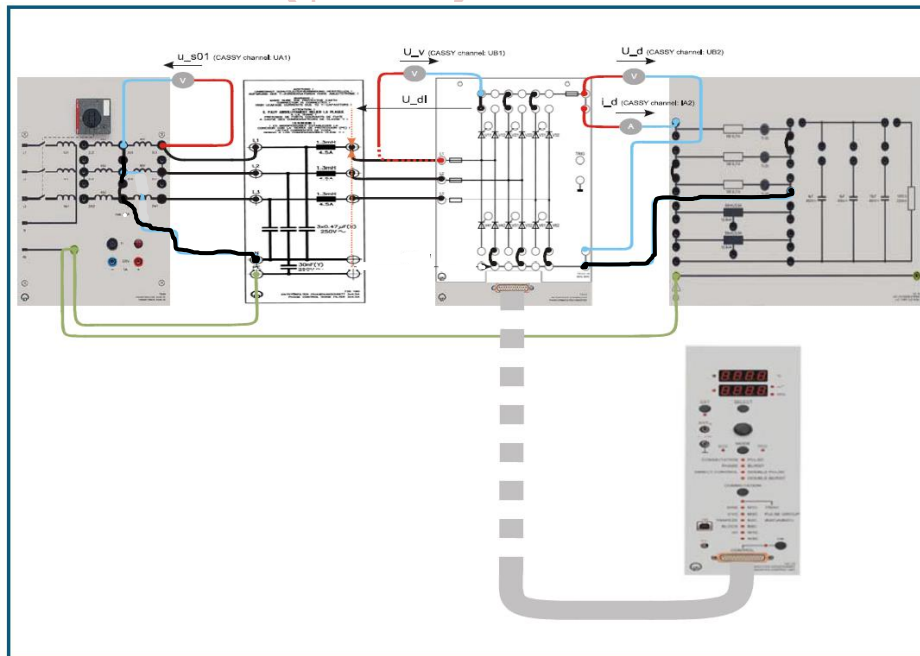


Figure 4.3 Configuration of Three-Phase Semi-Converter supplying a purely resistive load of 300Ω

1) Initially, connect the CASSY probes to plot/measure the input voltage (u_{s01}), and the input current (i_s); using the CASSY LAB software

2) Adjust the Converter Control Unit (Cat. No. 735 122) to produce a delay angle of 45°

Ask

3) Turn on the Transformer Supply Voltage Cat. No. 726 80

4) Plot the traces of the input voltage (u_{s01}) and the input current (i_s); take screen shots of these plots!

5) Measure the rms value of the input voltage (u_{s01}) and the input current (i_s); using the CASSY LAB software

6) Turn off the Transformer Supply Voltage Cat. No. 726 80

7) Connect the probes of CASSY to measure/plot SCR1 (valve) voltage (u_{v1}) and SCR1 (valve) current (i_{T1})

Ask

8) Turn on the Transformer Supply Voltage Cat. No. 726 80

9) Plot SCR1 voltage (u_{v1}) and current (i_{T1}); take screen shots of these plots!

10) Comment on the voltage and current waveforms of the SCR!

11) Turn off the Transformer Supply Voltage Cat. No. 726 80

12) Connect the probes of CASSY to measure/plot the output voltage (u_d) and the output current (i_d)

Ask

13) Turn on the Transformer Supply Voltage Cat. No. 726 80

14) Plot the output voltage (u_d) and the output current (i_d); take screen shots of these plots!

15) Measure the peak-to-peak ripple at the output voltage

16) Measure the average and rms values of the output voltage (u_d) and the output current (i_d)

17) What is the frequency of the output voltage? Comment!

18) Turn off the Transformer Supply Voltage Cat. No. 726 80. **Keep the connections as they are!**

19) Calculate the Form Factor (FF) using the measured values

20) Calculate the Ripple Factor (RF) using the measured values

21) Calculate the Transformer Utilization Factor (TUF)

22) Calculate the theoretical average, and rms values of the output voltage, and then calculate FF, RF, and TUF! Compare with the measured values! Comment!

23) Adjust the Converter Control Unit (Cat. No. 735 122) to produce a delay angle of 90°

24) Repeat steps 13) to 22), comment on the plots obtained!

25) Compare the results obtained for the two delay angles in terms of FF, RF, and TUF

26) Adjust the Converter Control Unit (Cat. No. 735 122) to produce a delay angle (α°) ranging from 0° to 150° in 30° step to fill in Table 4.2.

Ask

27) Turn on the Transformer Supply Voltage Cat. No. 726 80

Table 4.2: The effect of the delay angle on the average value of output voltage and current of a Three-Phase Semi-Converter

Delay angle (α°)	0°	30°	60°	90°	120°	150°
The measured average output voltage ($u_d(\alpha)$) [V]						
The measured average output current ($i_d(\alpha)$) [A]						
Normalized measured average output voltage, $u_d(\alpha) / u_d(\alpha=0^\circ)$						
Normalized measured average output current $i_d(\alpha) / i_d(\alpha=0^\circ)$						
Calculated (theoretical) average output voltage [V]						
Normalized theoretical average output voltage, $u_d(\alpha) / u_d(\alpha=0^\circ)$						

28) Turn off the Transformer Supply Voltage Cat. No. 726 80; **keep the connections unchanged**

29) Plot the control characteristic; the normalized measured and calculated output voltage versus α

30) Compare the experimental (practical) and theoretical values! Explain!

II) Three-Phase Semi-Converter with Resistive-Inductive Load

Connect the components as shown in Figure 4.4. The load resistance is 300Ω (3 resistors in series, of 100Ω each) and its inductance is 50mH (1 inductance in series). Ensure that the Transformer's secondaries produce a **phase-to-neutral voltage of 45V**.

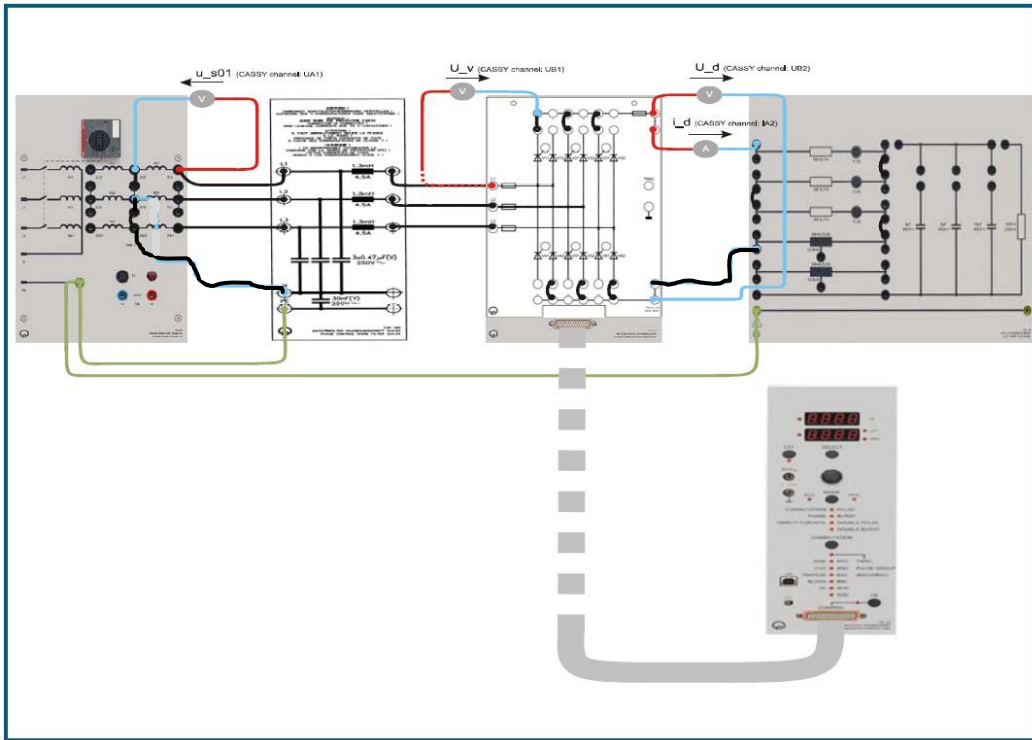


Figure 4.4 Configuration of Three-Phase Semi-Converter supplying an RL load of 300Ω and 50mH

- 1) Initially, connect the CASSY probes to plot/measure the input voltage (u_{s01}) and the input current (i_s); using the CASSY LAB software
- 2) Adjust the Converter Control Unit (Cat. No. 735 122) to produce a delay angle of 45°
- 3) Turn on the Transformer Supply Voltage Cat. No. 726 80
- 4) Plot the traces of the input voltage (u_{s01}) and the input current (i_s); take screen shots of these plots!
- 5) Measure the rms value of the input voltage (u_{s01}) and the input current (i_s); using the CASSY LAB software
- 6) Turn off the Transformer Supply Voltage Cat. No. 726 80
- 7) Connect the probes of CASSY to measure/plot SCR1 (valve) voltage (u_{v1}) and SCR1 (valve) current (i_{T1})
- 8) Turn on the Transformer Supply Voltage Cat. No. 726 80
- 9) Plot SCR1 voltage (u_{v1}) and current (i_{T1}); take screen shots of these plots!

- 10) Comment on the voltage and current waveforms of the SCR!
- 11) Turn off the Transformer Supply Voltage Cat. No. 726 80
- 12) Connect the probes of CASSY to measure/plot the output voltage (u_d) and the output current (i_d)
- 13) Turn on the Transformer Supply Voltage Cat. No. 726 80
- 14) Plot the output voltage (u_d) and the output current (i_d); take screen shots of these plots!
- 15) Measure the average and rms values of the output voltage (u_d) and the output current (i_d)
- 16) Turn off the Transformer Supply Voltage Cat. No. 726 80, and **keep the connections as they are!**
- 17) Calculate the theoretical average, rms values of the output voltage, and then compare with the measured values! Comment!
- 18) Adjust the Converter Control Unit (Cat. No. 735 122) to produce a delay angle of 90°
- 19) Repeat steps 13) to 17), comment on the plots obtained!
- 20) Compare the results obtained with the purely resistive load, with those obtained for the RL load for the two delay angles in terms of waveforms of the output voltage, its average and rms values.

4.3 Three-Phase Full-Converter

Notes:

- Do not turn on any part of the equipment without a prior notice from the supervisor
- Connect one transformer secondary to produce a **phase-to-neutral voltage of 45V**
- Type of load used: Resistive/Inductive load: 300Ω (3 resistors in series, of 100Ω each) in series with an inductor of 50mH
- Mask (Bridge topology): "735 012 – 08 B6C"
- Pulse form: "Pulse"

Symbols Table:

u_{s01}	: the input voltage
i_s	: the input current
u_d	: the output voltage
i_d	: the output current
u_{V1}	: the SCR1 voltage
u_{V4}	: the SCR4 voltage
i_{T1}	: the SCR1 current
i_{T4}	: the SCR4 current

I) Three-Phase Full-Converter with a Resistive Load

Connect the components as shown in Figure 4.5. The load is purely resistive of 300Ω (3 resistors in series, of 100Ω each). Ensure that the Transformer's secondary produces a **phase-to-neutral voltage of 45V**.

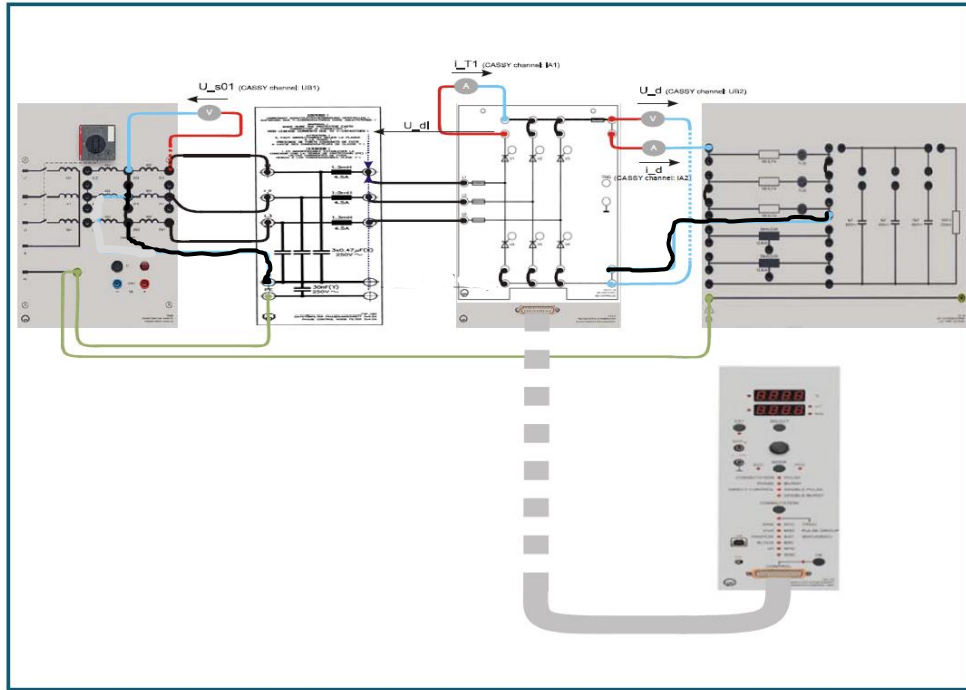
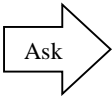


Figure 4.5 Configuration of Three-Phase Full-Converter supplying a purely resistive load of 300Ω

- 1) Initially, connect the CASSY probes to plot SCR1 voltage (u_{v1}) and SCR1 current (i_{T1})
- 2) Adjust the Converter Control Unit (Cat. No. 735 122) to produce a delay angle of 45°
- 3) Turn on the Transformer Supply Voltage Cat. No. 726 80
- 4) Plot the SCR voltage (u_{v1}) and current (i_{T1}); take screen shots of these plots!
- 5) Comment on the voltage and current waveforms of the SCR!
- 6) Turn off the Transformer Supply Voltage Cat. No. 726 80, and **keep the connections as they are!**
- 7) Connect the CASSY probes to plot/measure the output voltage (u_d), and the output current (i_d); using the CASSY LAB software
- 8) Turn on the Transformer Supply Voltage Cat. No. 726 80
- 9) Plot the traces of the output voltage (u_d) and the output current (i_d); take screen shots of these plots!
- 10) Measure the rms and average values of the output voltage (u_d) and the output current (i_d); using the CASSY LAB software

- 11) Measure the peak-to-peak ripple at the output voltage
- 12) What is the frequency of the output voltage? Comment!
- 13) Turn off the Transformer Supply Voltage Cat. No. 726 80
- 14) Calculate the Form Factor (FF) using the measured values
- 15) Calculate the Ripple Factor (RF) using the measured values
- 16) Calculate the theoretical average and rms values of the output voltage, and then calculate FF, RF and TUF! Compare with the measured values! Comment!
- 17) Adjust the Converter Control Unit (Cat. No. 735 122) to produce a delay angle of 90°
- 18) Repeat steps 8) to 16), comment on the plots obtained!
- 19) Compare the results obtained for the two delay angles in terms of FF, RF and TUF
- 20) Adjust the Converter Control Unit (Cat. No. 735 122) to produce a delay angle (α°) ranging from 0° to 150° in 30° step to fill in Table 4.3.



- 21) Turn on the Transformer Supply Voltage Cat. No. 726 80

Table 4.3: Effect of delay angle on average output voltage and current of Three-Phase Full Converter

Delay angle (α°)	0°	30°	60°	90°	120°	150°
The measured average output voltage ($u_d(\alpha)$) [V]						
The measured average output current ($i_d(\alpha)$) [A]						
Normalized measured average output voltage, $u_d(\alpha) / u_d(\alpha=0^\circ)$						
Normalized measured average output current, $i_d(\alpha) / i_d(\alpha=0^\circ)$						
Calculated (theoretical) average output voltage [V]						
Normalized theoretical average output voltage $u_d(\alpha) / u_d(\alpha=0^\circ)$						

- 22) Turn off the Transformer Supply Voltage Cat. No. 726 80; **keep the connections unchanged**
- 23) Plot the control characteristic; the normalized measured and calculated output voltage versus the delay angle (α)
- 24) Compare the experimental (practical) and theoretical values! Explain!

I) Three-Phase Full-Converter with Resistive-Inductive Load

Reconnect the RL load components as shown in Figure 4.6. The load resistance is 300Ω (3 resistors in series, of 100Ω each) and its series inductance is **50mH**. Ensure that the Transformer's secondary produces a **phase-to-neutral voltage of 45V**.

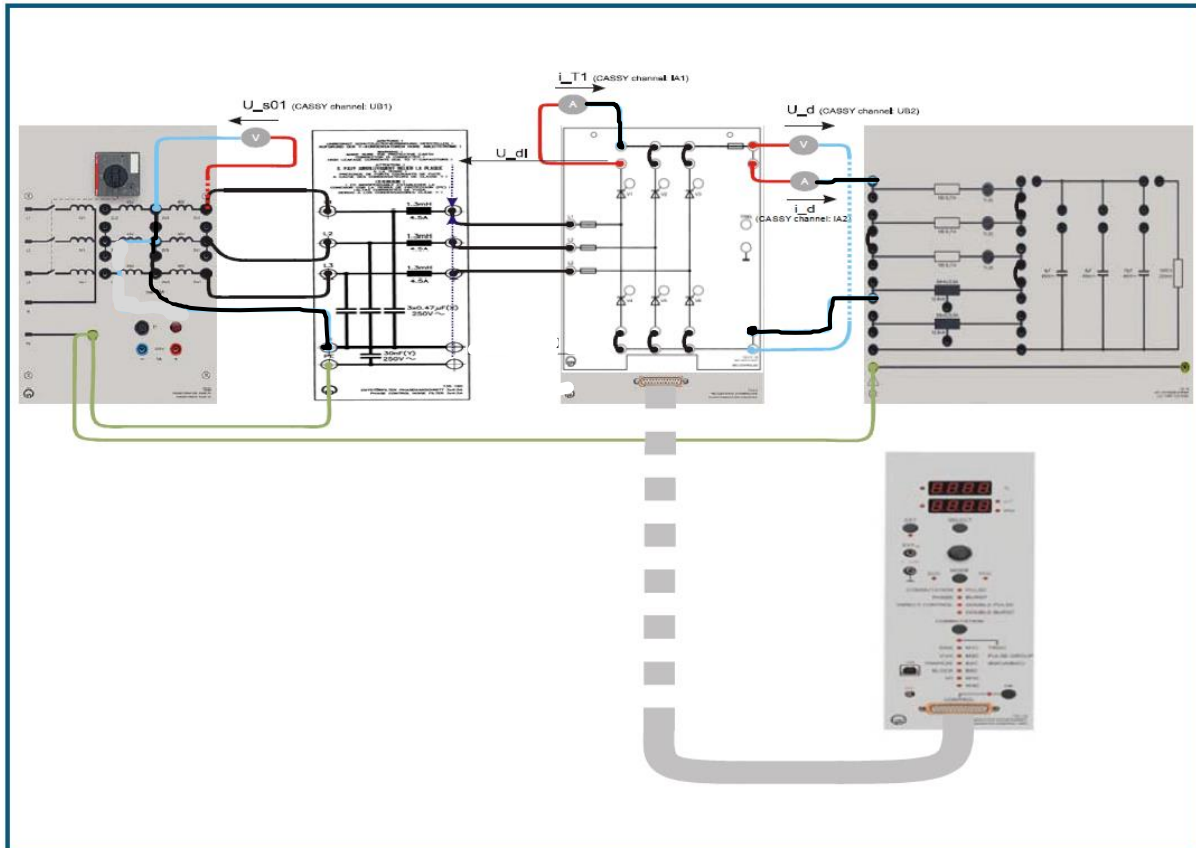


Figure 4.6 Configuration of Three-Phase Full-Converter supplying an RL load of 300Ω and 50mH

- 1) Initially, connect the CASSY probes to plot/measure the input voltage (u_{s01}) and the input current (i_s); using the CASSY LAB software
- 2) Adjust the Converter Control Unit (Cat. No. 735 122) to produce a delay angle of 45°
- 3) Turn on the Transformer Supply Voltage Cat. No. 726 80
- 4) Plot the traces of the input voltage (u_{s01}), and the input current (i_s); take screen shots of these plots!
- 5) Measure the rms value of the input voltage (u_{s01}) and the rms value of input current (i_s); using the CASSY LAB software
- 6) Turn off the Transformer Supply Voltage Cat. No. 726 80
- 7) Connect the probes of CASSY to measure/plot SCR1 (valve) voltage (u_{v1}) and SCR1 (valve) current (i_{T1})

Ask

8) Turn on the Transformer Supply Voltage Cat. No. 726 80

9) Plot SCR1 voltage (u_{v1}) and current (i_{T1}); take screen shots of these plots!

10) Turn off the Transformer Supply Voltage Cat. No. 726 80

11) Comment on the voltage and current waveforms of the SCR!

12) Connect the probes of CASSY to measure/plot the output voltage (u_d) and output current (i_d)

Ask

13) Turn on the Transformer Supply Voltage Cat. No. 726 80

14) Plot the output voltage (u_d) and the output current (i_d); take screen shots of these plots!

15) Measure the average and rms values of the output voltage (u_d) and the output current (i_d)

16) Comment on the output voltage and current waveforms!

17) Turn off the Transformer Supply Voltage Cat. No. 726 80, and **keep the connections as they are!**

18) Adjust the Converter Control Unit (Cat. No. 735 122) to produce a delay angle of 90°

19) Repeat steps 13) to 17), comment on the plots obtained!

20) Compare the results obtained for the purely resistive load, with those obtained for the RL load for the two delay angles in terms of waveforms of the output voltage and current, their average and rms values.