EE463 POWER ELECTRONICS –I

EXPERIMENT 3

THREE-PHASE FULL-BRIDGE CONTROLLED RECTIFIER

WARNING!

- **Always remember that you are working with voltages and currents which may be hazardous to human life. Do not touch live contacts! If you need to connect, disconnect equipment/wires, shut off the system, and complete the work, and then re-start. While checking connections, use one hand only.**
- **Before moving on to the next experimental step, make sure that main supplies are switched off and the autotransformers are set to 0% output.**
- **Pay attention to team-work and coordination. Do not energize your circuits unless you are sure that no one is touching/checking the connections.**
- **For the experiments involving energy storage devices such as capacitors, make sure that you discharge the energy storage element before leaving laboratory.**
- **If you feel uncomfortable or you are unsure of the circuit you constructed, ask your assistant for help.**

1.1OBJECTIVE

The objective of the experiment is to investigate the operation of the three-phase full-bridge controlled rectifier under various firing angle conditions for resistive and resistive-inductive loads. Important rectifier variations such as presence of line inductance, insertion of a three-phase ac line reactor between the rectifier and the line, effect of adding a free-wheeling diode are also considered.

1.2EQUIPMENT LIST

Basically the following components are required in carrying out the experiment:

Component /Instrument	Qty.	Specifications
Resistive Load Bank	1	3ϕ, each resistor R1=192Ω, 250W
Inductive Load Bank	1	3ϕ, each inductor L1=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 Rating: 1200V 55A, Diode Rating: 1200V 47A.
DC Power Supply	1	GW Instek, 40V 5A
Three-phase ac line reactor	1	3ϕ, 5 mH, 7A

Figure 1. Resistive load bank

Figure 2. Inductive load bank

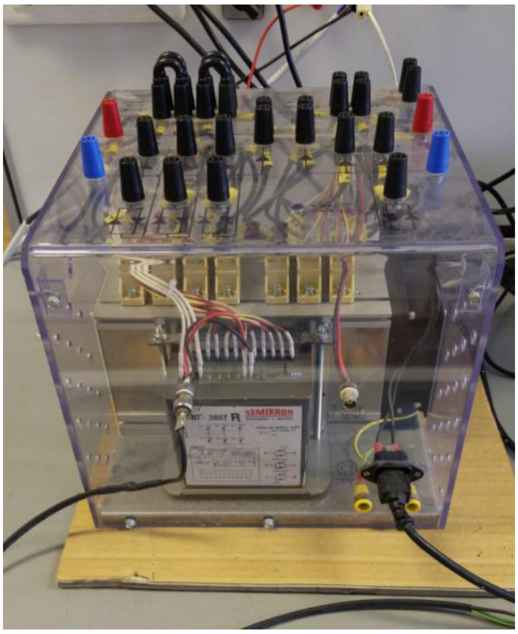


Figure 3. Semiteach module

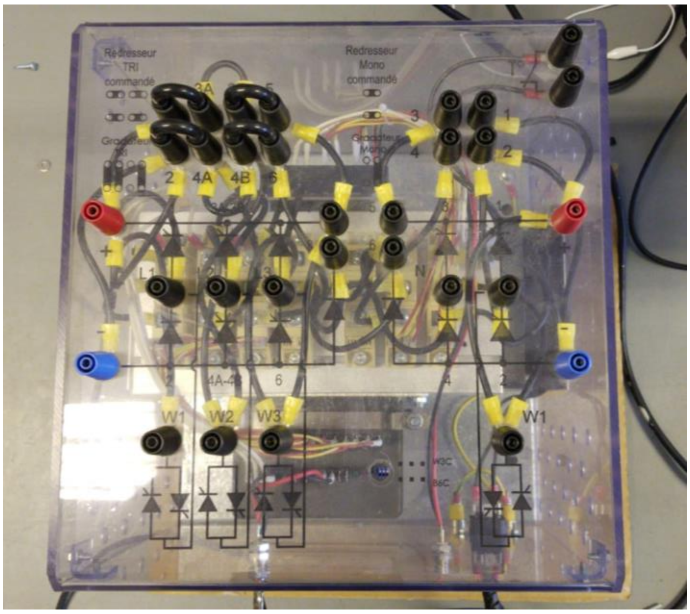


Figure 4. Module's terminal connections

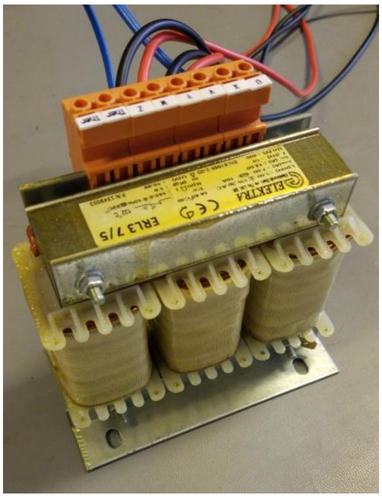


Figure 5. Three phase inductance

1.3 PROCEDURE

Before continuing with the experiment, make sure that you read and understood the important notes listed below.

Notes on the Semiteach Thyristor Teaching Module:

In this experiment, a thyristor teaching unit will be used which enables us to create delays while triggering thyristors. This operation is done via a control voltage applied to the control input (named RT 380T) of the system. By applying various voltages between 0-5V to the control input from the DC power supply, different firing angles can be created. **A voltage greater than 5V, will permanently damage the device.** Therefore, while you are changing the control voltage, be very careful. Remember that rotating knob that is used to adjust the voltage output of the power supply is not very sensitive: **first make sure that you disabled the power output of the supply and then adjust the voltage**. Finally, enable the output.

Also, note that the thyristor module that will be used in the experiment **does not respond to voltages which have a peak value less than 160 V**. Therefore, if you enable a gate control voltage and raise the autotransformer output from zero, it is normal to observe a zero output at the load until the incoming AC voltage reaches 160 V peak value.

Notes on the Utilization of Load Banks:

- Inductor load banks shall always be at the ground level (do not carry or put them on other units).
- Inductor load banks shall not be directly exposed to dc voltage. If there is a risk of dc component on the exciting source or saturation risk, you must accompany the inductor banks with a series connected resistive load bank.
- Resistive load banks shall not be covered with any material. Nothing shall be placed on or around them. Resistive load banks may be put on the floor level or on top of inductive load banks. If there is noticeable heat around the resistive load banks, reduce the voltage, check the connections make sure that the resistors do not get any voltage higher than their rated voltage and do not carry any higher current than their rated current (230V and 1A each individual component).
- All the load bank components are designed to carry 1 A current (dc/ac for the resistors, ac for inductors and capacitors). Do not create the risk of higher current in these components by carefully adjusting the source voltage and connection configuration and source types.
- **Do not disconnect the resistive or inductive load bank cables while they are live!!!**
- **Do not off switch inductors and do not switch on capacitors when the system is live!!!**

1.3.1 Common Procedure

Throughout all steps in this experiment, following common procedure will apply.

- **Set the DC supply voltage limit to 5V**. Do not give voltage higher than 5V to control signal.
- Make sure that the switch connections of the thyristor teaching module are configured according to Fig.1.1. Note that the jumpers (between [1,3A] and [3B, 5]) and (between [2,4A] and [4B, 6]) are shorted to form up a three-phase full-bridge rectifier.
- Connection diagram of resistive and inductive load banks for the experiment is given in Fig. 1.2 and Fig. 1.3.
- As three phase input to the thyristor module, apply **phase to neutral voltage with peak value of 200 V** using autotransformer.
- Take the critical waveforms on the oscilloscope for the report.
- Always take notes on important observations and use them in the report.
- After each part is completed, call the assistant.

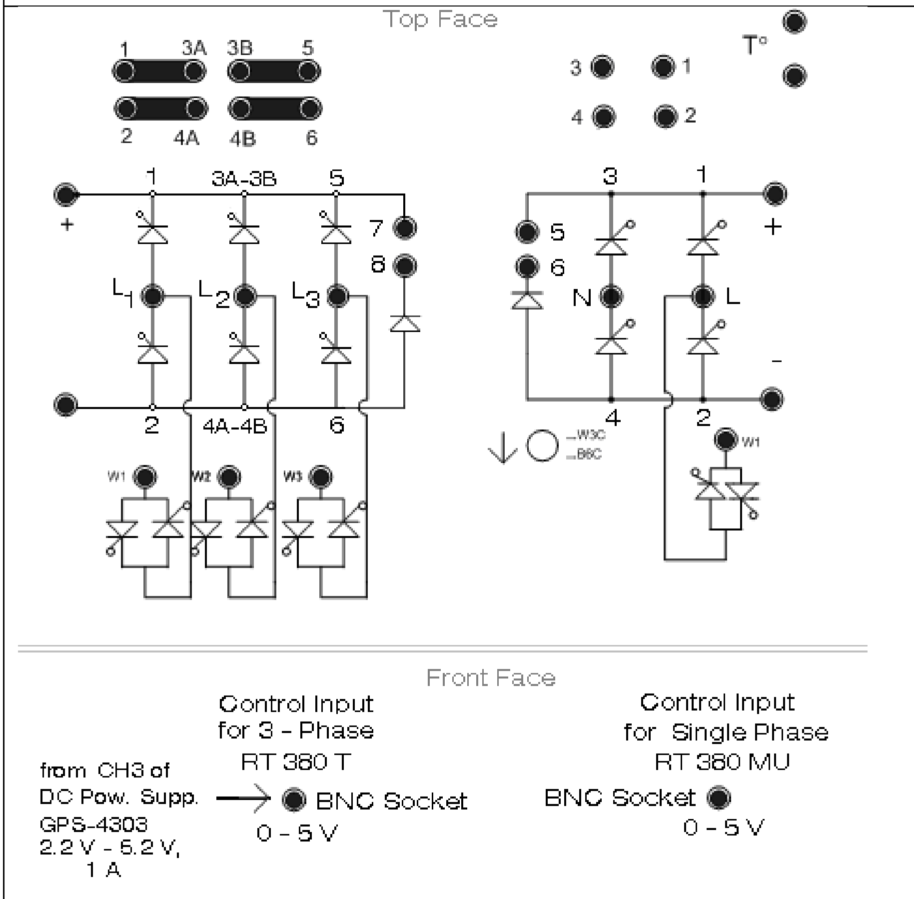
Fully controllable 3-ø bridge rectifier (B6C)	Checklist
 	Input L1, L2, L3 Output + of 3 ø bridge Control Input 0-5 of RT 380T Jumpers 1-3A 2-4A 3B-5 4B-6 Minidip Position OFF

Fig. 1.1. *Connection diagram for thyristor converter module*

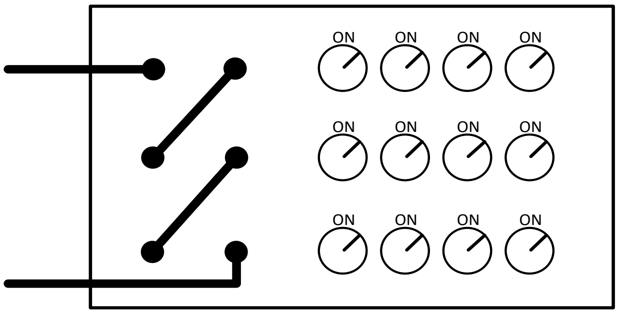


Fig.1.2. *Connection diagram for inductive load banks (L=3xL1/4). Note that all phases are connected in series.*

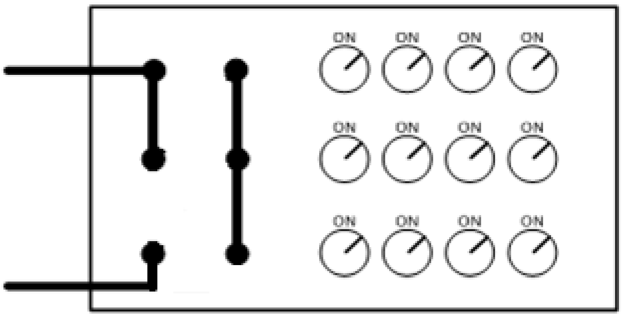


Fig.1.3. *Connection diagram for resistive load banks (R=R1/4+(R1/4)/2=3R1/8). Note that two phases are connected in parallel, and connected in series to third phase.*

1.3.2 Three-Phase Full-Bridge Controlled Rectifier Feeding a Resistive Load

Connect only resistive load bank in this step.

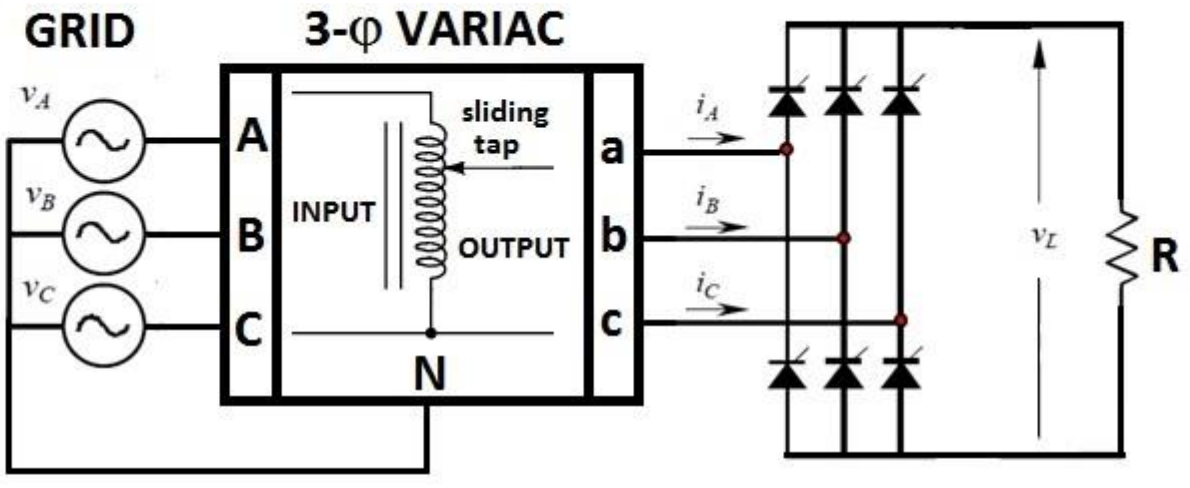


Fig. 1.4. *Resistive Load Schematic*

1- Observe how firing angle changes with changing control signal voltage. Determine the voltages that yields **0˚, 60˚ and 75˚ firing angles.** Fill the table at the end.

2- At **0˚ and 60˚** degrees of firing angle, observe and record the oscilloscope waveforms for:

- Input voltage (CH1), input current (CH2), output voltage (CH3) and output current (CH4) (same screen).

3- Also, fill the related part of the results table provided at the end of the manual for **0˚and 60˚** of firing angle.

4- **Take notes** about power factor, THD, output voltage ripple and power relation with firing angle. Note the appearing line current harmonic numbers.

1.3.3 Three-Phase Full-Bridge Controlled Rectifier Feeding an R-L Load

Now connect the inductive load bank in series with the resistive load to make RL load.

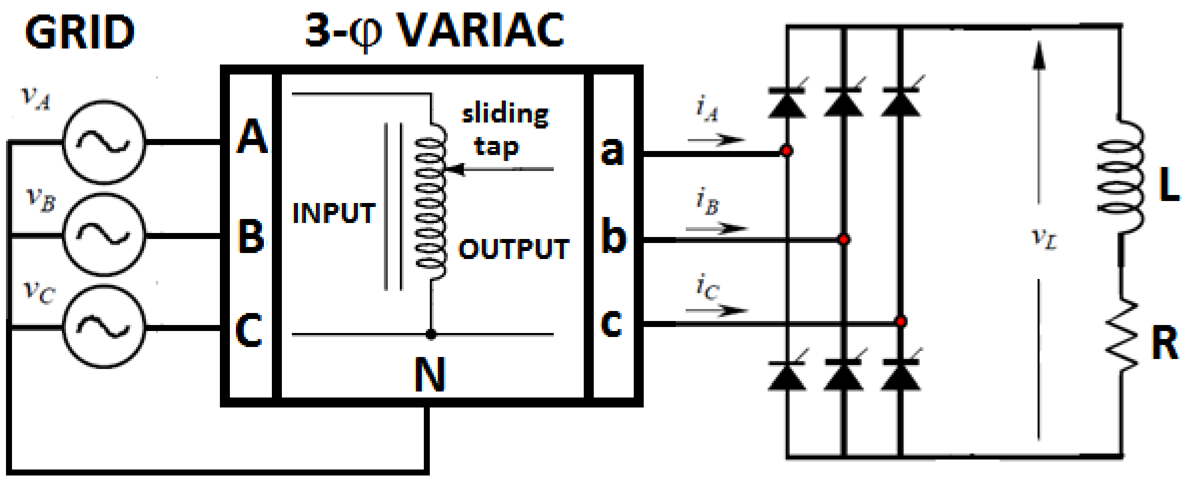


Fig. 1.5. *RL Load Schematic*

1- At **0˚, and 60˚** degrees of firing angle, observe and record the oscilloscope waveforms for:
- Input voltage (CH1), input current (CH2), output voltage (CH3) and output current (CH4) (same screen).
- Thyristor voltage and line current (same screen). (Note that it is not physically applicable to utilize the current probe on a thyristor to observe its current. Therefore, record line current considering that half cycle of line current gives thyristor current)

2- Also, fill the related part of the results table provided at the end of the manual for **0˚ and 60˚** of firing angle.

3- **Take notes** about inductance effect on current, power factor, THD, thyristor voltage, output voltage mean and peak-to-peak relation with firing angle. Note the appearing line current harmonic numbers. Compare these notes with R load case.

4- At the end of this step, **observe** the output voltage by slowly changing angle from 0˚ to 75˚. **Try to understand** what is happening.

1.3.4 Three-Phase Full-Bridge Controlled Rectifier Feeding an R-L Load with AC Line Reactor

Insert the ac line reactor between autotransformer output and the rectifier. Other connections remain same.
U-X, V-Y, W-Z are the three line inductors. Use U-V-W ports for variac connection and X-Y-Z ports for rectifier connections.

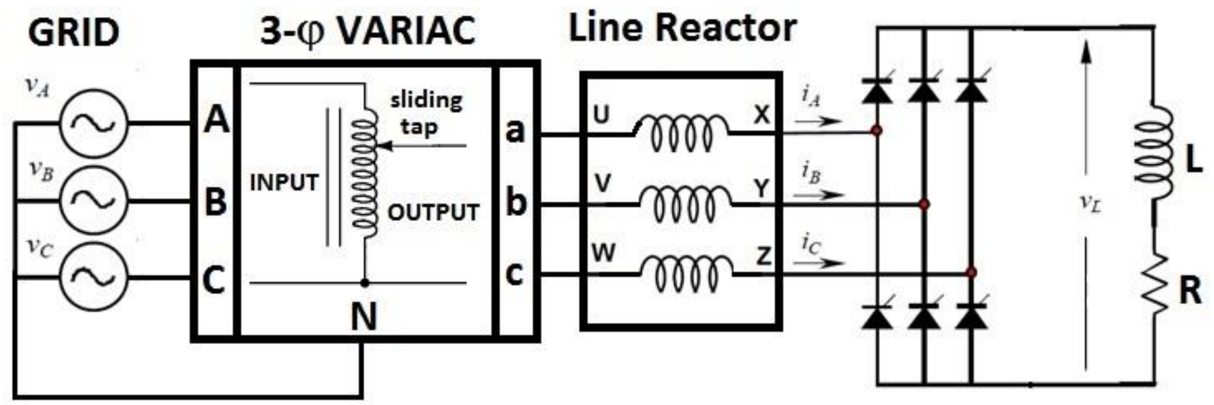


Fig. 1.6. *RL Load with AC Line Reactor Schematic*

1- At **0˚, 60˚ and 75˚** degrees of firing angle, record the oscilloscope waveforms for:
   - Input voltage (CH1), input current (CH2), output voltage (CH3) and output current (CH4) (same screen).
   - Thyristor voltage and line current at turn-off instant (same screen). (Note that it is not physically applicable to utilize the current probe on a thyristor to observe its current. Therefore, record line current considering that half cycle of line current gives thyristor current)

2- Also, fill the related part of the results table provided at the end of the manual for **0˚, 60˚ and 75˚** of firing angle.

3- **Take notes** on power factor, THD, thyristor voltage, output voltage mean and peak-to-peak relation with firing angle. Here, pay attention to the effect of line reactor on line current quality (power factor, THD), rectifier output voltage and grid voltage (measured both variac side and rectifier side). Observe the overlap angle and overlap effect. Also see the notch filtering effect of line reactor. Note the appearing line current harmonic numbers. Compare the notes with previous RL load case.

4- At the end of this step, **observe** the output voltage by slowly changing angle from 0˚ to 75˚. **Try to understand** what is happening.

1.3.5 Three-Phase Full-Bridge Half-Controlled Rectifier Feeding an R-L Load with AC Line Reactor and Free-Wheeling Diode

Make the connection between port 7 and 8 on the setup to enable the free-wheeling diode as shown in Fig.1.8.

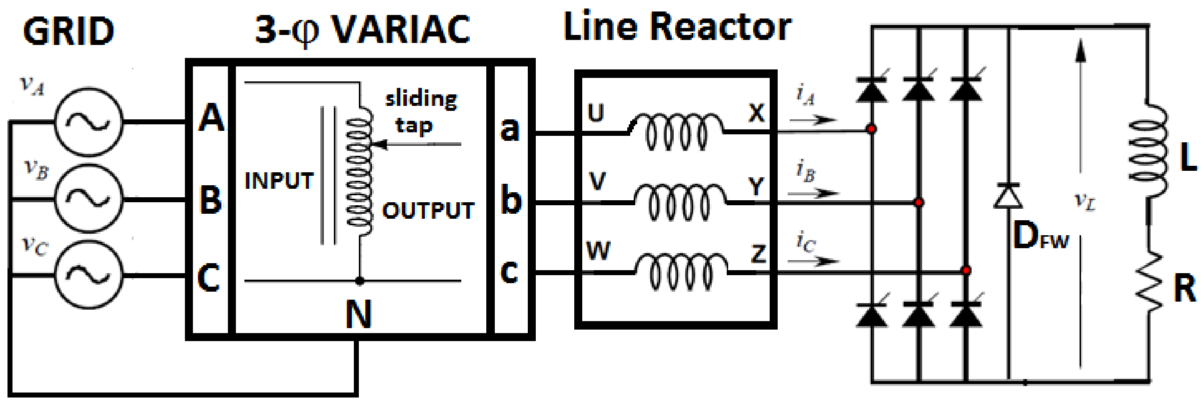
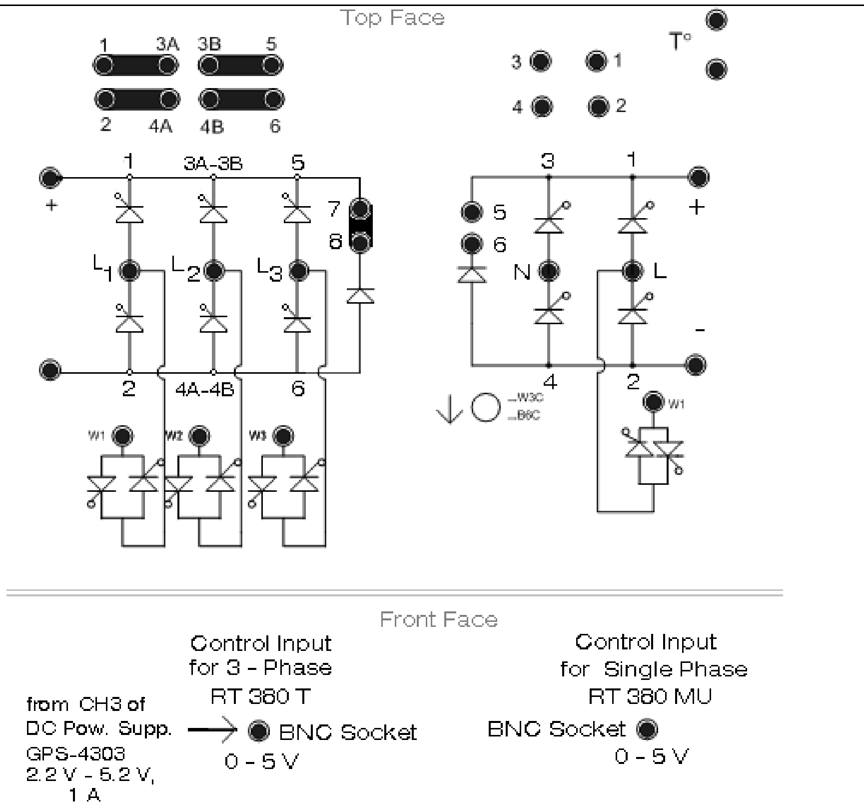


Fig. 1.7. *RL Load with Freewheeling Diode Schematic*

1- At **0°, 60° and 75°** degrees of firing angle, record the oscilloscope waveforms for:
   - Input voltage (CH1), input current (CH2), output voltage (CH3) and output current (CH4) (same screen).

2- Also, fill the related part of the results table provided at the end of the manual for **0°, 60° and 75°** of firing angle.

3- Take notes about power factor, THD, thyristor voltage, output voltage mean and peak-to-peak relation with firing angle. Here pay attention to the effect of free-wheeling diode on output voltage and current and line current THD and power factor. Note the appearing line current harmonic numbers. Compare with previous case.

<table>
<tr><td>Fully controllable 3-ø bridge rectifier with free-wheeling diode (B6CF)</td><td></td></tr>
<tr><td>
</td><td><u>Input</u>
L1, L2, L3

<u>Output</u>
+ of 3 ø bridge

<u>Control Input</u>
0-5 of RT 380T

<u>Jumpers</u>
1-3A
2-4A
3B-5
4B-6
7-8

<u>Minidip</u>
Position OFF</td></tr>
</table>

Fig.1.8. *Thyristor converter module and connections required for three-phase full-wave rectifier operation with free-wheeling diode.*

1.4 RESULTS and CONCLUSIONS

Prepare proper models and run simulations for each step carried out in the lab. Compare lab results with simulation results. Prepare a report which emphasizes on the following important and fundamental concepts (in a comparative manner when applicable):

- The effects of change in R load to RL load to measurements
- Comparison of commutation angle in theoretical, simulation and test results
- Line inductance effect on power quality (power factor and THD) and commutation angle
- Freewheeling diode effect
- Firing angle variation effect on power quality (power factor and THD) and output voltage for distinct load types.

Report should **not** be composed of **only** scope photos, graphs, measurement table. In addition to scope photo and measurement table, please explain the fundamentals and emphasize what you learnt and you think interesting.

During the experiment all changes in variables such as adding L to load or changing firing angle have effects on current, voltage, power, THD and power factor. Examine the table that you fill during experiment. Reason the differences when circuit topology changed from one part to another. Do not miss the fundamental facts and results.

The notes taken during experiment will be helpful while you are preparing the report.

	Firing angle (deg)		
	0°	**60°**	**75°**
Control signal (V)			

		AC SIDE (INPUT) MEASUREMENTS								DC SIDE (OUTPUT) MEASUREMENTS				
		V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	Q_{IN} (VAR)	P.F	Φ	I_{IN} THD-F (%)	I_{IN} THD-R (%)	V_{OUT} (V_{AVG})	$V_{O,RIPPLE}$ (V_{P-P})	I_{OUT} (A_{AVG})	P_{OUT} (W)	
R Load	$\alpha = 0^\circ$													
	$\alpha = 60^\circ$													
R-L Load	$\alpha = 0^\circ$													
	$\alpha = 60^\circ$													**Commutation interval (μs)**
R-L Load and L_{AC}	$\alpha = 0^\circ$													
	$\alpha = 60^\circ$													
	$\alpha = 75^\circ$													
R-L Load and L_{AC} with F.W.D.	$\alpha = 0^\circ$													
	$\alpha = 60^\circ$													
	$\alpha = 75^\circ$													