EEE 463 POWER ELECTRONICS –I

EXPERIMENT 3

SINGLE-PHASE FULL-BRIDGE THYRISTOR 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.**

1.1 OBJECTIVE

The objective of the experiment is to investigate the operation of the single-phase full-bridge thyristor rectifier under various firing angle conditions for resistive and resistive-inductive loads. Important rectifier variations such as presence of line inductance, effect of adding a free-wheeling diode are also considered. The effect of snubbers on semiconductor switch performance, in regard to reducing the peak stresses on the devices and the reverse recovery phenomenon are investigated.

1.2 EQUIPMENT LIST

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

Component /Instrument	Qty.	Specifications
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 Rating: 1200V 55A, Diode Rating: 1200V 47A.
RC Snubber	1	C=100nF, R=68Ω
DC Power Supply	1	GW Instek, 40V 5A
Inductor	1	3ϕ, 5 mH, 7A

1.3 PROCEDURE

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

Notes on 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 0-5 V to the control input from the DC power supply, 180-0 degrees of delay 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 Single-Phase Full-Bridge Fully-Controlled Thyristor Rectifier Feeding a Resistive Load

For the single-phase full-bridge fully-controlled thyristor rectifier experiment, first make sure that the switch connections of the thyristor teaching module are configured according to Fig.1.1. Connection diagram for the experiment is given in Figure 1.2. Utilize voltage probes across a thyristor pair and load to see the related voltage waveforms on the oscilloscope screen. Enable all four resistors on any phase of the resistive load bank (four resistors are thus connected in parallel yielding 192/4=48Ω resistance). Increase the autotransformer output to 200V peak. At 0 and 60 degrees of firing angle, record the oscilloscope waveforms for:

- Output voltage, output current, line voltage and line current (same screen).
- Thyristor voltage and line current (same screen). (Note that it is not physically suitable to utilize the current clamp on a thyristor to observe its current. Therefore, record line current considering that half cycle of line current gives thyristor current)

Also, fill the related part of the results table provided at the end of the manual.

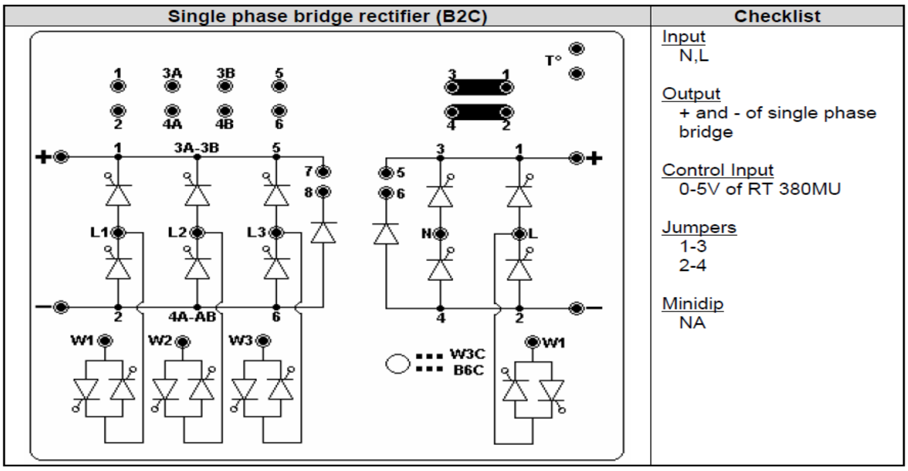


__Fig.1.1.__ Thyristor converter module and connections required for single-phase full-bridge thyristor rectifier operation.

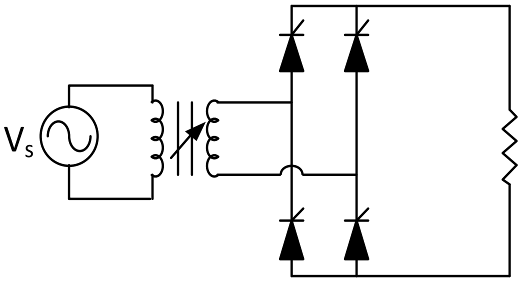


__Fig.1.2.__ Connection diagram for the part 1.3.1.

1.3.2 Single-Phase Full-Bridge Fully-Controlled Thyristor Rectifier Feeding an R-L Load

Now connect the inductive load bank in series with the resistive load (Fig. 1.3). All four switches on, utilize two phases in parallel to each other for the resistive load (which corresponds to 48/2=24Ω). For the inductive load bank, connect inductive phases in series to each other with all four switches on (three inductance values of 0.61H/4 connected in series yielding 0.4575H). Connection diagram for the load banks are depicted in Fig.1.4. Repeat the procedure of 1.3.1. Also, for 0 and 60 degrees of firing angle, utilize snubbers across thyristors and record the thyristor voltage and line current to observe the effects of snubbers on converter operation.

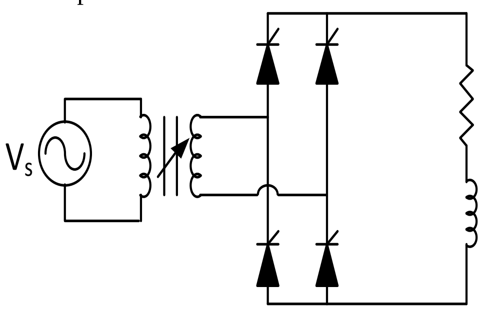
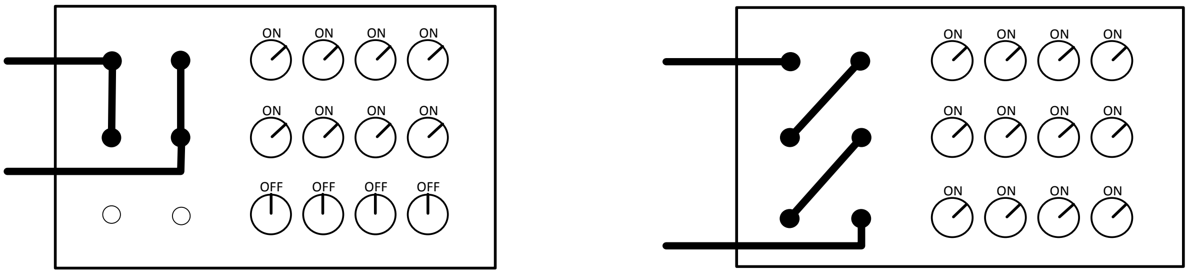


__Fig.1.3.__ Connection diagram for the part 1.3.2.



(a) Resistive **(b) Inductive**

Fig.1.4. *Connection diagram for resistive (a) and inductive (b) load banks.*

1.3.3 Single-Phase Full-Bridge Fully-Controlled Thyristor Rectifier Feeding an R-L Load with AC Line Reactor

Insert the ac line reactor provided to you by your assistant between autotransformer output and the rectifier (Fig. 1.5). Other connections remaining same, repeat 1.3.2. In this experiment, pay attention to the line current, rectifier output voltage and grid voltage (pre and post L_{AC} voltages), observe (and record) the overlap angle and overlap effect, record the necessary waveforms and compare with analytical calculations.

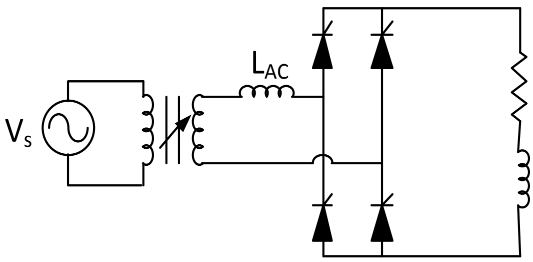


Fig.1.5. *Connection diagram for the part 1.3.3.*

1.3.4 Single-Phase Full-Bridge Thyristor Rectifier Feeding an R-L Load with AC Line Reactor and Free-Wheeling Diode (Half-Controlled)

Modify the thyristor module as suggested in Fig.1.6 that is; enable the connection between ports number 5 and 6 on the single phase side of the module to implement the free-wheeling diode as depicted in Fig.1.7. Repeat the previous step.

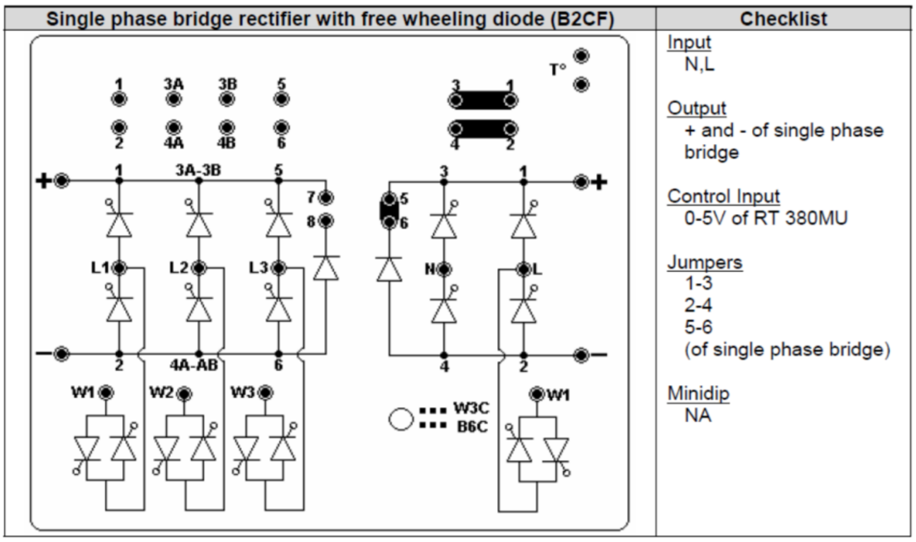


Fig.1.6. *Thyristor converter module and connections required for single-phase full-bridge thyristor rectifier operation with free-wheeling diode.*

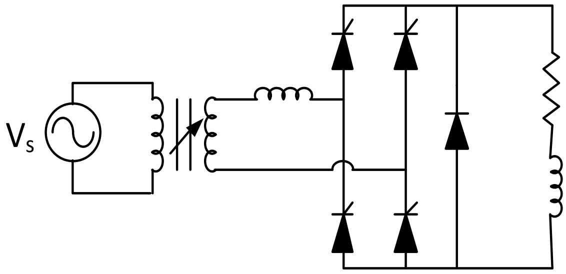


Fig.1.7. *Connection diagram for the part 1.3.4.*

1.4 RESULTS

Prepare a report which includes and systematically introduces the waveforms and measurements obtained in the laboratory. Clearly explain the converter operation which yields such waveforms.

1.5 CONCLUSIONS

Along the laboratory test results, provide a theoretical approach explaining converter behavior, compare the lab results to analytical expectations and comment on the discrepancies if there are any. Important issues in this experiment, such as the effect of line inductance (overlap) and free-wheeling diode on converter behavior, effect of single phase rectification on line power quality and snubber utilization should be stressed in the reports.

		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 (%)	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	$\alpha = 0^\circ$											
	$\alpha = 60^\circ$											
R-L Load and L_{AC}	$\alpha = 0^\circ$											
	$\alpha = 60^\circ$											
R-L Load and L_{AC} with F.W.D	$\alpha = 0^\circ$											
	$\alpha = 60^\circ$											