EE463 POWER ELECTRONICS –I
EXPERIMENT 2

THREE-PHASE AC CHOPPER

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 three-phase ac chopper under various firing angle conditions for resistive and resistive-inductive loads. Operation with/without neutral wire is considered to cover the per-phase and three-phase coupled operating modes.

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: 1200V 55A, Diode: 1200V 47A.
DC Power Supply	1	GW Instek, 40V 5A

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. **Set voltage limit to 5V to avoid unintentional over-voltage.**

Also, note that the thyristor module that will be used in the experiment **does not respond to voltages which have a peak of 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 are heavy equipment and 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 to limit the current and avoid short circuit.

- Resistive load banks shall not be covered with any material as they generate large amount of heat during operation. 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 (R and L 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 switch off inductors and do not switch on capacitors when the system is live!!!

1.3.1 Three-Phase AC Chopper Feeding a Resistive Load with Neutral Wire Connected

In this experiment, a thyristor based converter module will be used. Front view of the system is depicted in Figure 1.1. Note that, the module is designed to enable the demonstrations of various converters that can be created by different connections of thyristors (single-phase or three-phase rectifiers with or without free-wheeling diodes, choppers etc…). For the three-phase AC chopper experiment, the switch connections should be configured according to the three-phase ac chopper topology. Necessary connections for three phase AC chopper operation are also depicted in Figure 1.1.

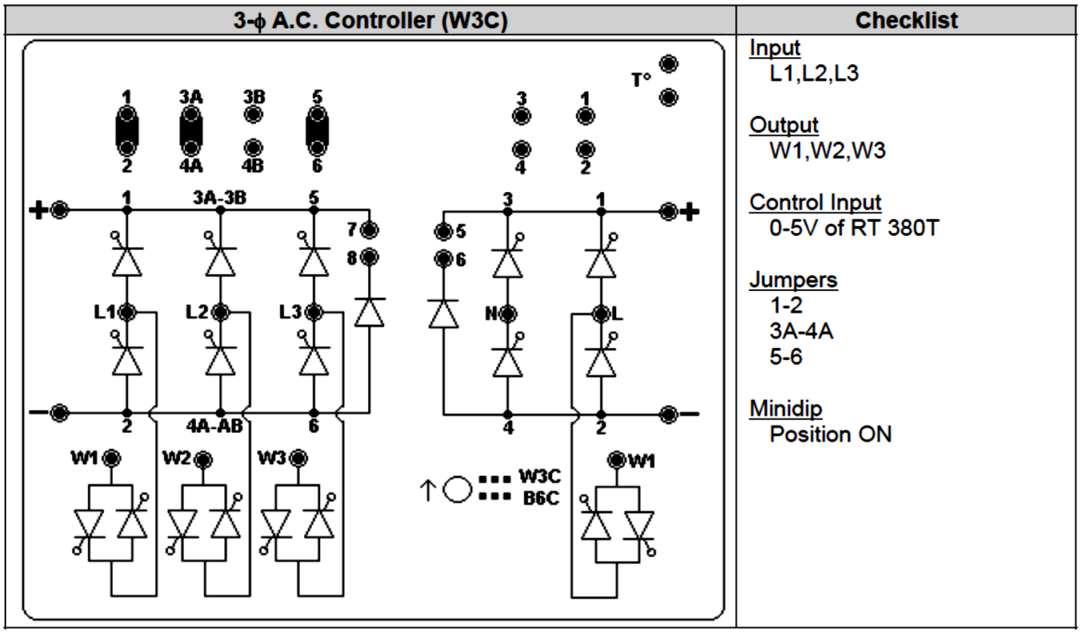

Fig.1.1. Thyristor converter module and connections required for three phase AC chopper operation.

Connection diagram for the experiment is given in Figure 1.2. For each phase, enable all four resistors on the load bank. Make sure that neutral point of the Y connected load is wired to the neutral point of the autotransformer.

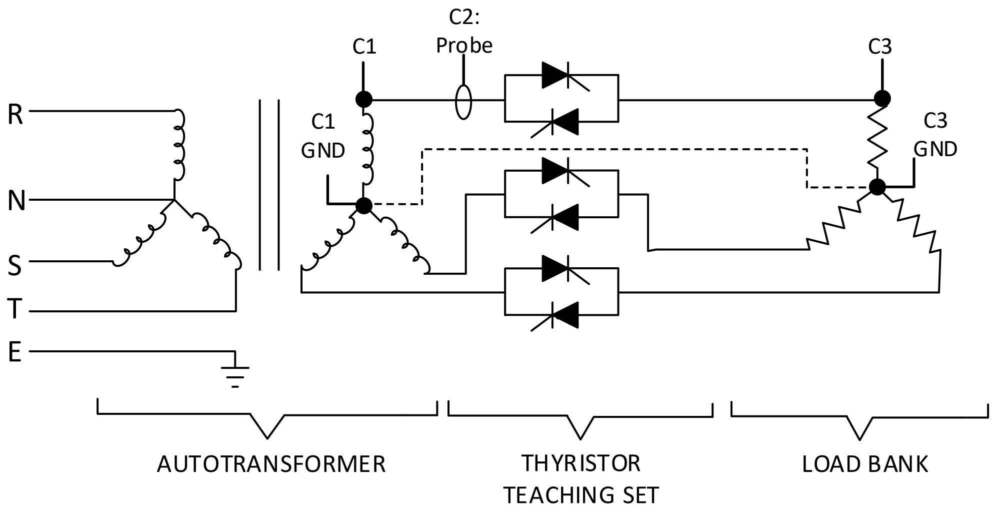

Fig.1.2. Connection diagram for the experiment.

***Hint**:* Follow these instructions for your oscilloscopes:

- Use channel 1 for V_{IN} , channel 3 for V_{OUT} and channel 2 for current sensing, as depicted in Fig 1.2.
- Make channel arrangements (20x for voltage, 10A/V for current probes) if necessary.
- Turn on the current probe and adjust its zero offset.
- Utilize bandwidth limits on all of the channels (200 MHz → 20 MHz).
- From the “Acquire” button, choose “Average” and set the number of averaging to “4”.

After completing the connections, increase the autotransformer output to 250V peak. Fill the “**R load with neutral wire**” part of the table given at the end of the manual.

Hint: While filling the table, you will use "**Measure**" and "**Application**" buttons on the oscilloscope. Under "**Application**", explore **Power Analysis**, **Waveform Analysis** and **Harmonics** tabs.

After recording the data to the table, arrange a clear vision on the oscilloscope and record the following waveforms.

- V_{IN}, V_{OUT}, I_{LINE}
- V_{IN}, V_{OUT}, $I_{NEUTRAL}$

1.3.2 Three-Phase AC Chopper Feeding a Resistive Load with Neutral Wire Disconnected

Now remove the neutral connection (between Y connected load and autotransformer). Record the same measurements.

1.3.3 Three Phase AC Chopper Feeding a Series R-L Load with Neutral Wire Connected

Connect the inductive load bank in series to the resistive load bank. For each phase, enable all four inductors on the inductive load bank. Leave the resistive load bank unchanged. Take the same measurements.

1.4 REPORTING THE RESULTS & CONCLUSIONS

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.

With the same electrical quantities you experimented in the laboratory, run **computer simulations** for cases 1.3.1, 1.3.2 and 1.3.3. Plot waveforms for V_{IN}, V_{OUT}, I_{LINE} on the same graph. Compare these to the oscilloscope waveforms you recorded during the experiment.

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. Put emphasize on the following important and fundamental concepts (in a comparative manner when applicable):

-Firing angle variation effect on power quality (power factor and THD) and output voltage for distinct load types
-Effect of neutral wire connection/disconnection
-Effect of load type

It is strongly advised that your comments include analytical background in conjunction with the results obtained.

		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	$\alpha = 60^\circ$									
	$\alpha = 120^\circ$									
R load without neutral wire	$\alpha = 60^\circ$									
	$\alpha = 120^\circ$									
RL load with neutral wire	$\alpha = 60^\circ$									
	$\alpha = 120^\circ$									