EEE213 Power Electronics

Lab Script

Notice:

- The lab report will take 10% in final mark
- Soft copy and hard copy submission is required
  - Soft copy to ICE submission link
  - Hard copy to submission box in front of room EE520
- Deadline: May 5th, 23:55pm.
- A formal report is required.
  - The report should include the "Introduction", "Background knowledge", "Experiment procedure and results", "Result analysis and discussion", and "conclusions".
  - Individual report (one report from each student).

1. Objective
   (1) To be familiar with the firing circuits and the commissioning of the firing pulses.
   (2) To study the characteristics of single-phase half-wave controlled rectification circuit with R and RL loading.
   (3) To study the principle of single-phase full-controlled rectification/inversion circuit.
   (4) To study the rectification process of single-phase bridge conversion circuit.

2. Equipment
   THMPE-2 Power Electronics Lab System
   Dual-channel oscilloscope
   Multimeter
   Screwdriver

3. Requirements & Safety Operation
   (1) Operating instructions
   - Be familiar with the objective, contents, and calculations of relative topic;
   - Be familiar with relative devices, and master the functions and usage;
   - Operate in groups of 3 persons for coordinated operation;
   - Make wiring according to the connection diagram in wiring rules;
   - Check your connection carefully before you provide power to the circuit;
   - Conduct the experiment according to the operating instructions;
   - Record experimental data and waveform. Turn off the power supply to the system with the instructor's permission, and then return all the accessories.

(2) Safety Operation Regulations

- Never touch any two output terminals of "3-phase AC voltage output" on the power control panel with both hands during the experiment.
- The operation of connecting or disconnecting wires should be performed after power being cut off.
- Carefully check the circuit after performing connection or changing connection, and turn on the power supply with instructor's permission.
- Once the system alarms, turn off the power supply immediately, carefully check the circuit connection and adjust the potentiometer, then conduct the experiment again.
- Select optimal range for measuring instruments to avoid damage to the instrument, power source, or load.
- All fuse specifications have been determined by factory, please use required fuse to avoid unpredictable consequences.
- Adjust the load resistor to maximum and decrease the setpoint voltage to zero before starting the system.

4. Experiment 1 – Single-phase Half-wave Controlled Rectification Circuit

(1) Equipment used in this part

No.	Description
1	MPE-01 Power control panel
2	MPE-12 Firing circuit of single-phase converter (I)
3	MPE-25 Experiment component
4	Dual-channel oscilloscope
5	Multimeter
6	Screwdriver

(2) Principle

The principle of UJT firing circuit has been introduced in appendix B. The connection diagram for single-phase half-wave controlled rectification circuit is shown in Fig.4-1, where the output terminals G and K of UJT firing circuit on MPE-12 unit are connected to the gate and cathode of any one of thyristors on MPE-25 unit; R is two parallel-connected resistors (R2 from XDMPE03 unit, 900Ω); Ld (700 mH), DC voltmeter, and ammeter are all selected from the power control panel XDMPE03 unit. The source voltage for this circuit is the voltage between AB, which is 220V/50Hz, noted as U2.

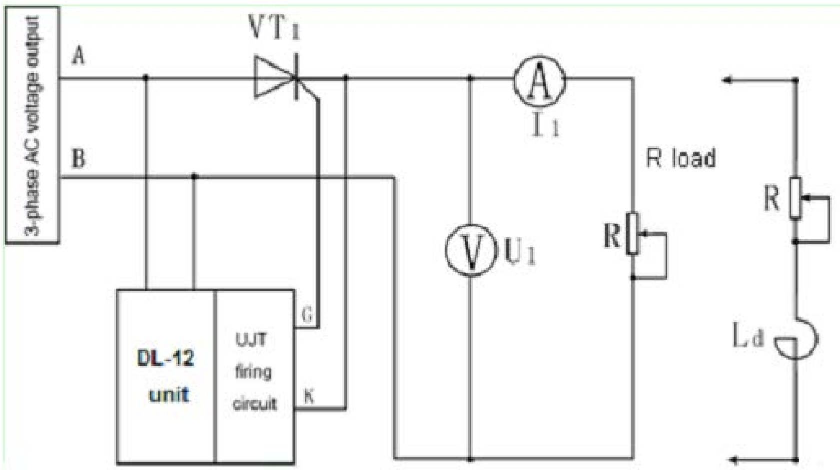

Fig.4-1 Single-phase half-wave controlled rectification circuit

(3) Experimental contents

- Commissioning of UJT firing circuit
- Characteristics determination of single-phase half-wave controlled rectification circuit on R load
- Characteristics determination of single-phase half-wave controlled rectification circuit on RL load

(4) Pre-lab

- Read the knowledge about unijunction transistor, and master the procedure of how to use UJT firing circuit.

- Review the knowledge about single-phase half-wave controlled rectification circuit, and master the operating waveforms of single-phase half-wave controlled rectification circuit on R load or on RL load respectively.
- Master the calculation of average voltage Ud in a single-phase half-wave controlled rectification circuit on various loads.

(5) Operating instructions

a) Commissioning of UJT firing circuit

Apply a line voltage output from the power control panel to the "IN~220V" terminal on MPE-12. Press down "Start" button on power control panel, and switch on MPE-12 unit to activate all the firing circuits. Monitor the 60V sync signal with one channel of dual-channel oscilloscope, leaving the other channel for observing waveform at TP1, TP2, TP3, TP4, and TP5 respectively. Observe the waveform variation at TP4 and TP5 during adjusting RP1. Check whether the firing voltage at terminals G and K can shift in range of 30°~170°.

b) Single-phase half-wave controlled rectification circuit on R load

After commissioning of UJT firing circuit, connect a single-phase half-wave controlled rectification circuit with R load as shown in Fig.4-1, and adjust the resistor to maximum. Press down "Start" button, observe the waveforms of load voltage Ud and thyristor voltage U_{VT} with a dual-channel oscilloscope while adjusting RP1 to change α from 30° to 150°, then measure and record the values of Ud and source voltage U2 when α = 30°/60°/90°/120°/150°.

α	30°	60°	90°	120°	150°
U_2					
U_d (practical value)					
U_d/U_2					
U_d (theoretical value)					

c) Single-phase half-wave controlled rectification circuit on RL load

Power off the above circuit, and then change the R load to RL load (made up of a resistor R and a reactor Ld connected in series). Then repeat the measurement of process (b) during adjusting the resistor R to change the impedance angle [impedance angle $\varphi = \tan^{-1}(\omega L/R)$]. Please record the values of Ud and U2 in the following table.

α	30°	60°	90°	120°	150°
U_2					
U_d (practical value)					

(5) Questions

- What are the waveforms of Ud and U_{VT} when $\alpha = 90°$.
- Plot the curve of $Ud/U2 = f(\alpha)$ when the circuit works on resistive load and inductive load.
- Analyze the experimental phenomena.

(6) Important notes

- The two probes of a dual channel oscilloscope should be connected to common ground to avoid an electric short circuit fault.
- To reduce the observation error caused by capacitance, it is required to connect terminals G and K to gate and cathode of thyristor respectively when observing the waveforms of output pulse voltage.
- In this exercise UJT firing circuit is utilized, also a linear firing angle control circuit can be used to perform this exercise.
- To protect the thyristor from damage, please operate as follows:
  - Commissioning the firing circuit before powering on the main circuit.
  - Decrease Uct to zero and adjust the load resistor to maximum before powering on the main circuit.
  - Select optimal resistance and inductance as the load to avoid overcurrent fault.
- To ensure a normal operation of a thyristor, the load current should be more than 50mA.
- When connect a main circuit, please pay more attention to the phase relationship between synchronous voltage and firing pulse.
- The current flowing through the reactor should be less than 1A for linearity.

5. Experiment 2 – Single-phase Full-controlled Rectification/Inversion Circuit

(1) Equipment used in this part

No.	Description
1	MPE-01 Power control panel
2	MPE-12 Firing circuit of single-phase converter (I)
3	MPE-11 3-phase controllable rectificer (I)
4	Dual-channel oscilloscope
5	Multimeter
6	Screwdriver

(2) Principle

Fig.4-3 shows a single-phase bridge rectifier with a RL load, where R is two parallel-connected resistors (R2 from XDMPE03 unit, 900Ω); Ld is 700mH; the firing pulses are offered by the linear firing angle control circuits I and II on MPE-12.

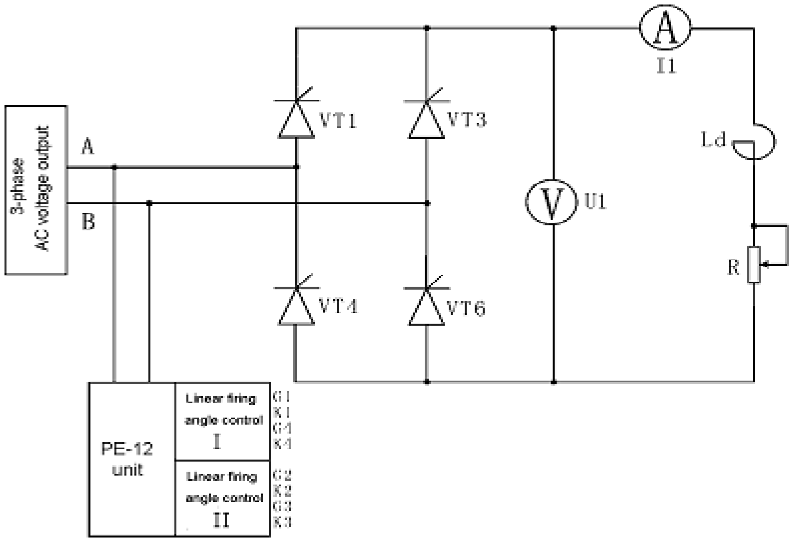

Fig.4-3 Single-phase full-controlled bridge rectifier

Notes: the firing pulses G1K1 and G4K4 output from MPE-12 should be connected to VT3 and VT4 of MPE-11, while G2K2 and G3K3 to VT1 and VT6 respectively.

(3) Experiment content

- Single-phase full-controlled rectifier with R and RL load
- Single-phase bridge active inverter with RL load

(4) Pre-lab

- Read the knowledge about linear firing angle control in Appendix B, and master the procedure of how to use liner firing angle control circuit.
- Review the knowledge of single-phase full-controlled bridge rectifier, and master the operating waveforms of it on R load or on RL load respectively.
- Master the calculation of average voltage Ud in a single-phase full-controlled rectification circuit on various loads.

(5) Operating instructions

a) Commissioning of firing circuit

Apply a line voltage output from the power control panel to the "IN~220V" terminal on MPE-12. Press down "Start" button on power control panel, and switch on MPE-12 unit to activate all the firing circuits, and then observe the waveforms at each test point of linear firing angle control circuits with a dual-channel oscilloscope.

Adjust RP2 CCW (counter-clock wise) to the end (Uct=0), observe the waveforms of synchronous voltage and the voltage at test point 7 with a dual-channel oscilloscope, then adjust RP3 for a firing angle of 180°.

Connect the output of linear firing angle control circuit to the gate and cathode of the thyristors on the full-controlled bridge (pay much attention to the polarity), then turn off the switches of positive and negative firing pulses on MPE-11 unit.

b) Single-phase full-controlled bridge rectifier on R load

The connection diagram is shown in Fig.4-3, but only R (parallel R2) is connected in the circuit as the pure resistive loading. Adjust the resistor to maximum, and then press down "Start" button. Keep the resistance of RP3 as a constant, then observe the waveforms of rectification voltage Ud and thyristor voltage Uvt during adjusting RP2, and adjust RP1 and RP3 for observing.

α	30°	60°	90°	120°
U_2				
U_d (practical value)				
U_d (theoretical value)				

c) Single-phase full-controlled bridge rectifier on RL load

Then connect Ld (700 mH) to the circuit, to form an RL load. Adjust the resistor to maximum, and then press down "Start" button. Keep the resistance of RP3 as a constant, then observe the waveforms of rectification voltage Ud and thyristor voltage Uvt during adjusting RP2, and adjust RP1 and RP3 for observing.

α	30°	60°	90°	120°
U_2				
U_d (practical value)				
U_d (theoretical value)				

(6) Questions

- What are the waveforms of Ud and U_{VT} when α = 90° and 120°.
- Plot the phase-shift characteristic curve Ud=f(α).
- Analyze the experimental phenomena.

(7) Important notes

- Please refer to the notes in Experiment 1.
- To avoid mis-triggering, the switch of corresponding firing pulse should be turned off when the firing pulse is applied to the gate and cathode of a thyristor on MPE-11 unit.
- The power supplied to MPE-12 and to the main circuit must be in phase and the same in magnitude.
- The resistance of R should be optimal to avoid overcurrent fault and reliable conduction of the thyristor.

Appendix A

Introductions to THMPE-2 Power Electronics Lab System

1-1 General Description

1. Features

(1) Modular design, able to perform various experiments covering courses of power electronics, semiconductor converter technology, etc.

(2) Cost effective due to its small size and less infrastructure investment, working under 3-phase 4-wire power supply.

(3) Nice outlook, clear print on front panel, various connecting wires with banana connectors, castor and fixing mechanism design for the workbench.

(4) Excellent protection system, including 3-phase isotating transformer, voltage-type leakage protection device, and current-type leakage protection device.

(5) Safety sockets installed on front panel, and different type sockets used according to functions.

(6) Typical experimental circuits to fulfil the teaching requirements.

2. Specifications

(1) Power supply: 3-phase 4-wire 380V±10% 50Hz

(2) Ambient temperature: -5~40℃

(3) Relative humidity: ≤75%

(4) Altitude: ≤1000m

(5) Power capacity: ≤1.0kVA

1-2 MPE-01 Power Control Panel

The power control panel comes with various power supplies, and measuring instruments. Two stainless steel tubes are available on the groove for mounting the experimental units, at the bottom several sockets are mounted to provide power to the units. Note at both sides of the equipment there are sockets for single-phase 3-wire 220V voltage and 3-phase 4-wire 380V voltage respectively.

1. XDMPE01 faceplate

(1) 3-phase power mains indication

Operate the “Line voltage sel.” switch to check whether the 3-phase power mains are balance.

(2) Power control components

The power control components include a main power switch, a start button (illuminated green), and a stop button (illuminated red). The power control panel has two modes: stand by and be in motion. Turning on the “Main power” switch takes the panel into standby mode, with the red lamp on; pressing down the “Start” button enables the panel to go into motion mode, with the red lamp off and green lamp on, and now both the “3-phase AC Voltage Output and Excitation Power Supply” are active.

(3) 3-phase AC voltage output

The 3-phase AC voltage output module supplies three line voltages of 220V/1.5A, each indicated by a color-coded LED, furthermore, electronic overcurrent protection is available for all outputs, which will activate the sound and light alarm system and cut off the main power once an overcurrent fault occurs.

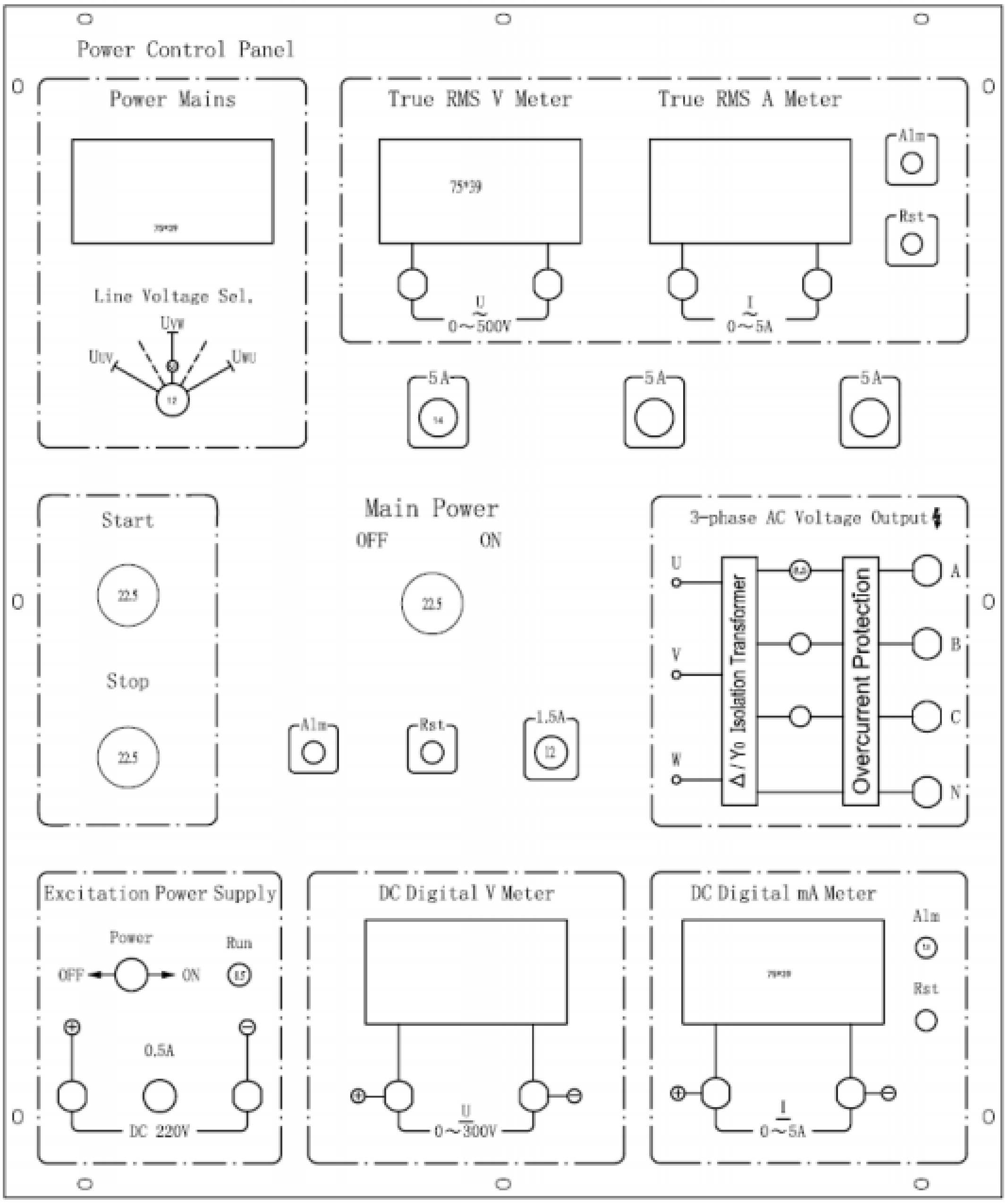

Fig.1-1 Faceplate of XDMPE01 unit

(4) Excitation power supply

Turn on the “Main power” switch, press down “Start” button, and turn on the switch of excitation power supply, then a fixed DC220V is output. A fuse at 0.5A protects the output from short circuit and an indicator indicates the output status. Note it cannot be used as a high-capacity source.

(5) Measuring instruments

The instruments comprise a DC digital voltmeter (-300V~0~+300V), a DC digital ammeter (0~±5A), a true RMS voltmeter (0~500 V), and a true RMS ammeter (0~5A). The accuracy of all the meters is 0.5%.

2. XDMPE02 faceplate

This unit provides a setpoint circuit, a 3-phase rectifier, and a single-phase autotransformer circuit.

(1) Setpoint: the setpoint circuit is composed of two potentiometers (RP1 for positive output adjustment while RP2 for negative output adjustment) and two toggle switches (S1 for positive/negative output while S2 for enabling/disabling output). The output voltage ranges from 0 to ±l5V and is indicated by a DC voltmeter.

Note: it is forbidden to make the setpoint output short to ground for a long time, especially in a high voltage output, otherwise potentiometers RP1 and RP2 will be damaged.

(2) Rectifier: the rectifier converters the AC voltage to DC voltage, with a fuse at 2A protected.

(3) Single-phase autotransformer

This single-phase autotransformer provides a single-phase adjustable AC voltage in range of 0～250V/0.5kVA. The maximum output current is 2A, electronic overcurrent protection is available for the output, which will activate the sound and light alarm system and cut off the main power once an overcurrent fault occurs.

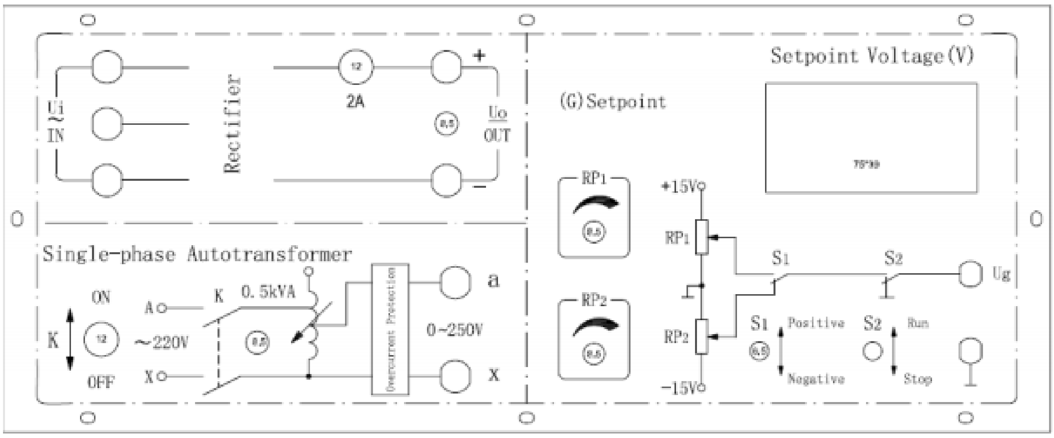

Fig.1-2 Faceplate of XDMPE02 unit

3. XDMPE03 faceplate

The XDMPE03 unit includes an analog DC voltmeter, an analog DC ammeter, a smoothing reactor, a 3-phase core-type transformer, and rheostats.

(1) Analog DC voltmeter and ammeter

Analog DC voltmeter: measuring range: 0~±300V, accuracy: 1.0%

Analog DC ammeter: measuring range: 0~± 2A, accuracy: 1.0%

(2) Smoothing reactor

The smoothing reactor mounted within the power control panel has three inductances (l00mH, 200mH, 700mH) which are linear under a current of 1A. All terminals have been brought out to the faceplate. Furthermore, the reactor circuit is protected by a fuse at 3A.

(3) 3-phase core-type transformer

It has two sets of secondary windings, the primary and secondary phase voltages are 127V/63.5V/31.8V (line voltages are 220V/110V/55V respectively if transformer is connected in Y/Y/Y mode). Usually the transformer is used as a step-up transformer in inversion experiment.

(4) Ceramic disk rheostat

There are three coaxial ceramic disk rheostats, one of 90Ω/1.3A and two of 900Ω/0.41A.

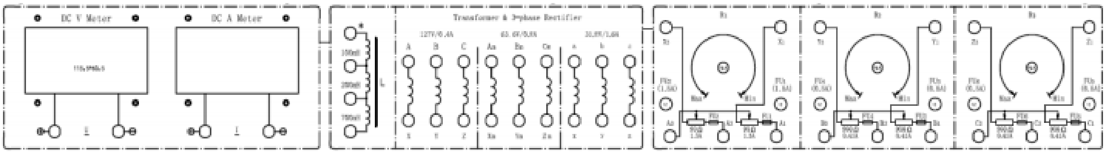

Fig.1-3 Faceplate of XDMPE03 unit

Appendix B

Thyristor Firing Circuits

(Please refer to the attached file “Appendix B. Firing circuits”)