Experiment 2: Study of Three-Phase Three Pulse Rectifiers using Power Diodes

Objectives:

- To become familiar with three phase three pulse diode rectifier.
- To observe the output waveforms and the characteristics of the rectifier.

Theory:

Rectifier is an electrical device which converts an alternating current into a direct one by allowing a current to flow through it in one direction only.

The three phase rectifier circuit offers several advantages over a single phase rectifier. Using Figure 2-1, we will analyze the operation of such a circuit in order to fully understand these advantages.

You will notice in Figure 2-1(a) that the circuit consists simply of three diodes (one for each of the three phases), the three phase source and the load. The waveforms of the three line voltages and the load voltages are also shown in Figure 2-1(b). The output voltage E_O is that of point X, measured with respect to the neutral line N.

At the origin, the phase angle of E_{1N} is 0° as shown in Figure 2-1(b). We find that,

$E_{1N} = 0$ and D_1 does not conduct because the voltage across it is zero

$E_{2N} < 0$ and D_2 does not conduct because it is reverse biased

$E_{3N} > 0$ and D_3 conducts because it is forward-biased.

Since D_3 conducts, the voltage at X is the same as that at terminal 3.

When the phase angle of E_{1N} exceeds 30°,

$E_{1N} > E_{3N}$ and D_1 conducts because it becomes forward biased

$E_{2N} < E_{1N}$ and D_2 stays off because it is reverse biased

$E_{3N} < E_{1N}$ and D_3 does not conduct because it becomes reverse biased.

Since D_1 conducts, current flow is now through D_1, Instead of D_3. The voltage at X is the same as that at terminal 1.

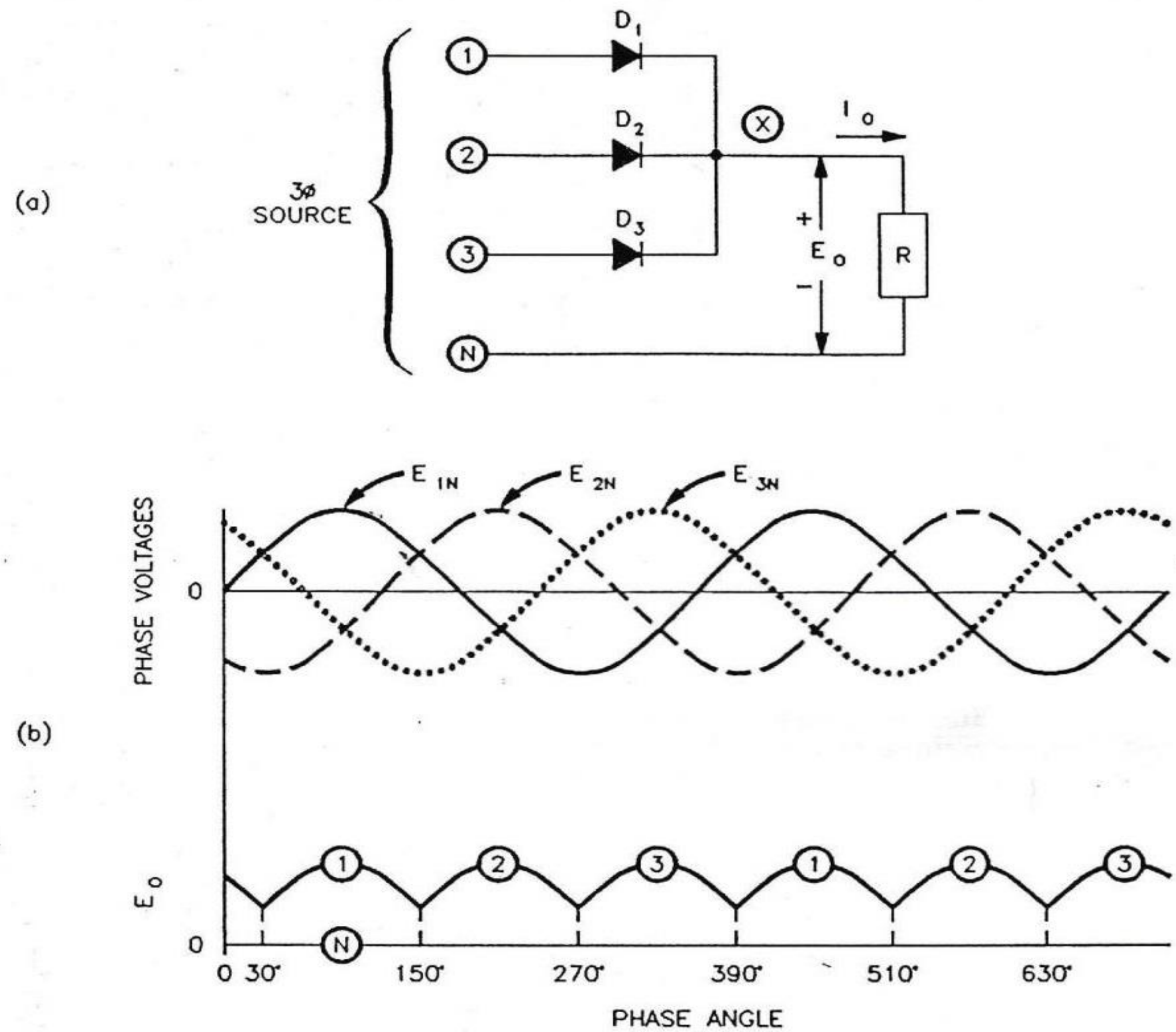


Figure 2-1. A three-phase, three-pulse rectifier circuit using diodes.

When the phase of E_{1N} has increased by 120° to just over 150°,

$E_{2N} > E_{1N}$ and D_2 comes on because of forward-bias
$E_{3N} < E_{2N}$ and D_3 stays off because of reverse-bias
$E_{1N} < E_{2N}$ and D_1 goes off because it becomes reverse-biased.

Since D_2 is now on, current flow is through this diode and the voltage at X is the same as that at terminal 2.

When the phase increases another 120° to just over 270°

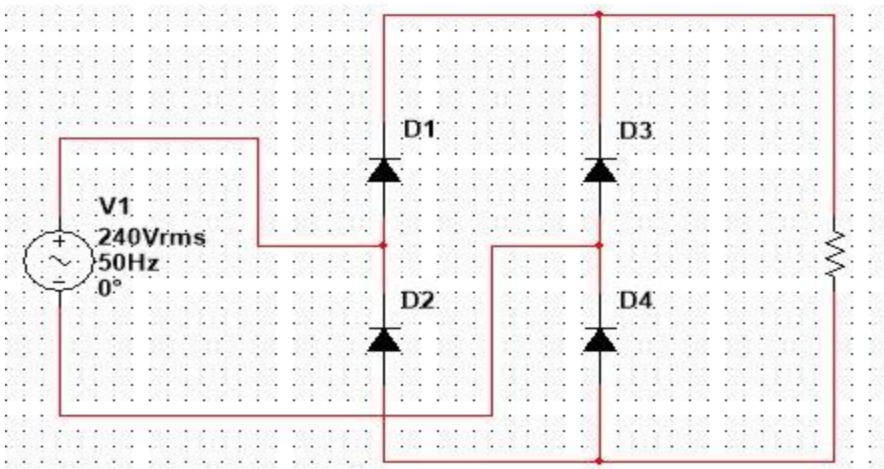
$E_{3N} > E_{2N}$ and D_3 comes on because of forward-bias
$E_{1N} < E_{3N}$ and D_1 stays off because of reverse-bias
$E_{2N} < E_{3N}$ and D_2 goes off of reverse-bias.

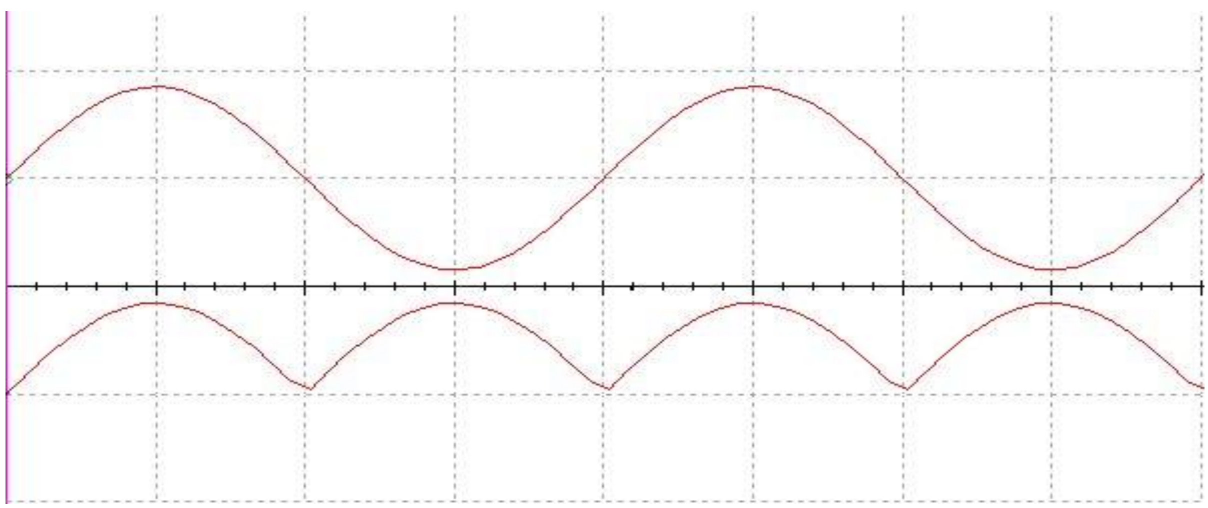
Since D_3 is on again, the voltage at X is equal to that of terminal 3.

When the phase increases another 120^0 to just over 390^0, we return to the situation at the beginning (30^0). The cycle thus repeats itself indefinitely, and the voltage at X contains **pulsations or ripple** as shown in Figure 2-1(b).

Ripple (specifically ripple voltage) in electronics is the residual periodic variation of the DC voltage within a power supply which has been derived from an alternating current (AC) source. This ripple is due to incomplete suppression of the alternating waveform after rectification. Ripple voltage originates as the output of a rectifier or from generation and commutation of DC power.

A single phase rectifier and its output characteristics is given below:





Notice however, that the amount of ripple obtained with a three phase rectifier is less than the ripple obtained with a single phase rectifier.

It is important to note that the amount of ripple decreases as ripple frequency increases.

The on-time of each diode is 120^0 for three phase circuits, compared to 180^0 for single phase circuits. These two differences allow using similar, less powerful semiconductor devices.

The average value of E_O for three phase three pulse rectifier can be calculated with the equation:

$E_O = 0.675\ E_S$, where E_S = line to line voltage of the source [V ac]

Procedure summary

In the first part of the exercise, you will set up the equipment.

In the second part, you will set up a three-phase, three-pulse rectifier, observe the waveforms, and measure the output parameters.

EQUIPMENT REQUIRED

Refer to the Equipment Utilization Chart, in Appendix C of this manual, to obtain the list of the equipment required to carry out this exercise.

PROCEDURE

CAUTION!

High voltages are present in this laboratory exercise! Do not make or modify any banana jack connections with the power on unless otherwise specified!

Setting up the equipment

☐ 1. Install the Power Supply, the Enclosure / Power Supply, the Resistive Loads, the Smoothing Inductors, the DC Voltmeter/Ammeter, the AC Ammeter, and the Power Diodes modules in the Mobile Workstation.

☐ 2. Install the Current/Voltage Isolators in the Enclosure / Power Supply.

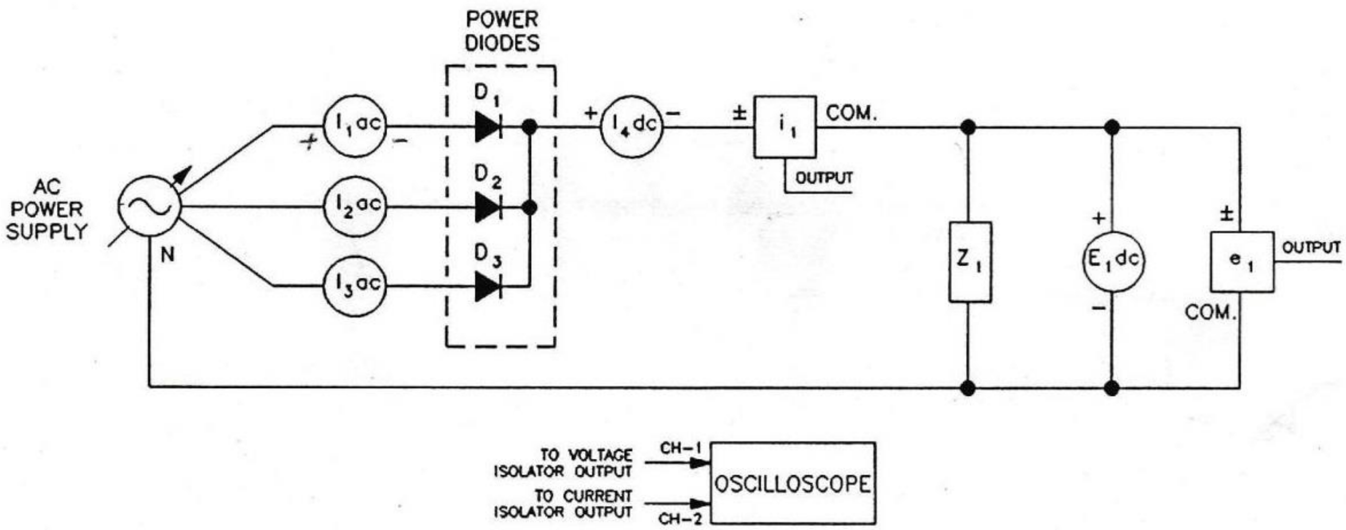
☐ 3. Make sure that the main power switch of the Power Supply is set to the O (OFF) position. Set the voltage control knob to 0. Connect the Power Supply to a three-phase wall receptacle.

☐ 4. Plug the Enclosure / Power Supply line cord into a wall receptacle. Set the rocker switch of the Enclosure / Power Supply to the I (ON) position.

☐ 5. Make sure that the toggle switches on the Resistive Load are all set to the O (open) position.

Three-phase, three-pulse rectifier

☐ 6. Set up the circuit of Figure 2-4 using the resistive load Z_1(a).



LINE VOLTAGE (Vac)	I_{1-3} ac (A)	I_4dc (A)	i_1 (A)	E_1dc (V)	e_1 (V)	Z_1(a) R	Z_1(b) R L
120	2.5	2.5	10	150	300	R=150 Ω	R=150 Ω, L=0.2 H (3Adc max.)
220	1.5	1.5	5	300	600	R=550 Ω	R=550 Ω, L=0.8 H (1.5Adc max.)
240	1.5	1.5	5	300	600	R=600 Ω	R=600 Ω, L=0.8 H (1.5Adc max.)

Figure 2-4. Three-phase, three-pulse rectifier circuit.

☐ 7. Make the following settings:

On the Power Supply

Voltage Selector 4-5

On the Oscilloscope

Channel-1 Sensitivity . . . . 2 V/DIV. (DC coupling)
Channel-2 Sensitivity . . . . 0.5 V/DIV. (DC coupling)
Time Base . . . . 5 ms/DIV.
Trigger . . . . LINE

☐ 8. On the Power Supply, make sure that the voltage control knob is set to the 0 position then set the main power switch to I (ON). Set the voltage control knob so that the voltage indicated by the Power Supply voltmeter is equal to 90 % of the nominal line-to-line voltage.

Sketch the voltage and current waveforms in Figure 2-5. Record the ripple frequency.

Ripple frequency = ______ Hz

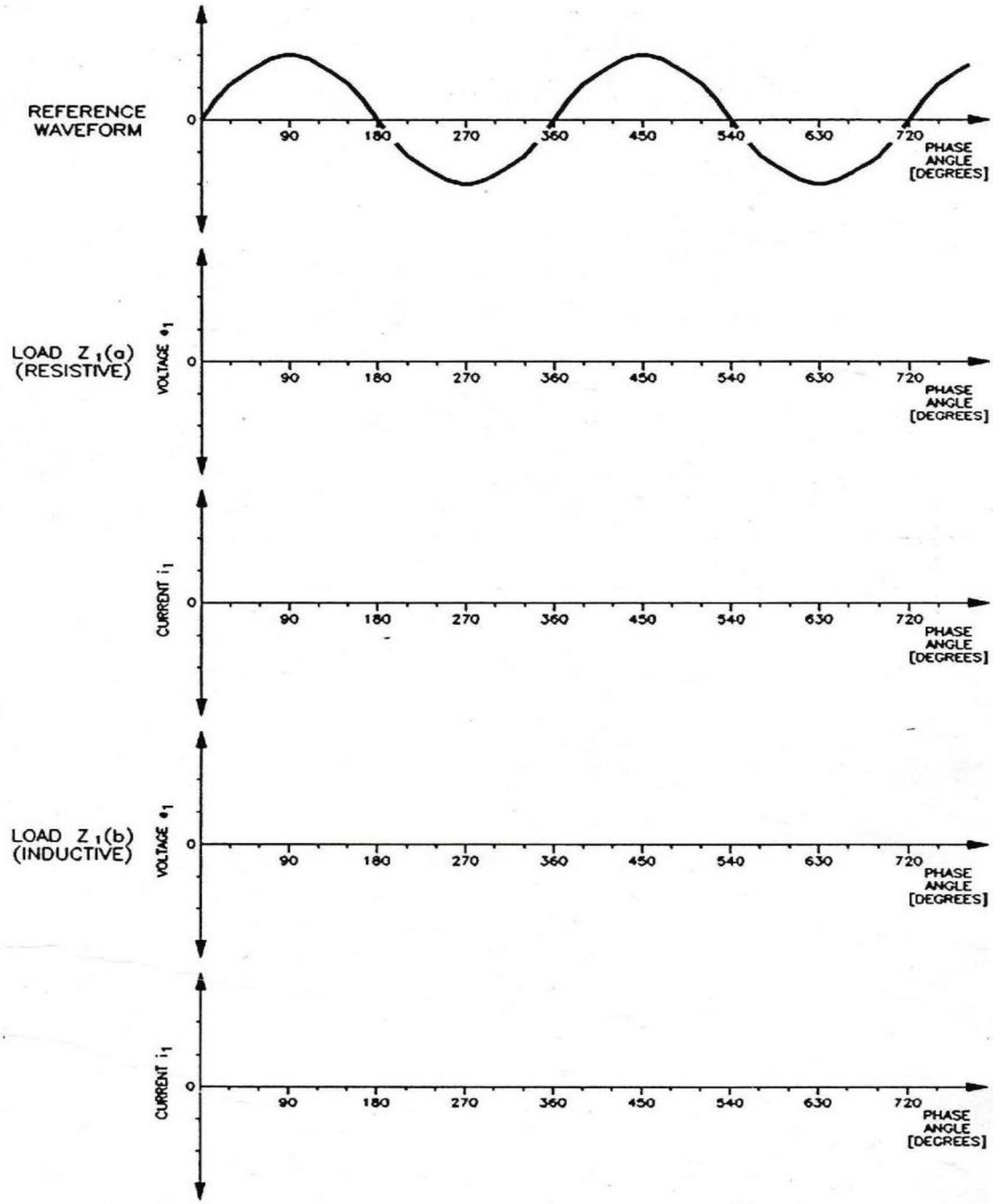


Figure 2-5. Voltage and current waveforms for three-phase, three-pulse rectifier.

Record the input &output voltage, current and power of the rectifier circuit in the first row of Table 2-1.

Load Z_1	Input Voltage dc	Output Voltage E_1 dc	Output Current I_4 dc	Output Power $P_O = E_1 \times I_4$	T_{ON}	T	Conduction Angle $(T_{ON}/T)*360$
	V	V	A	W			degrees
a)Resistive							
b)Inductive							

Table 2-1. Measurements for three-phase, three-pulse rectifier circuit.

☐ 9. To determine the diode conduction angle, connect the current isolator in series with diode D_1. Before changing any connections, set the voltage control knob on the Power Supply to 0, then set the main power switch to O (OFF).

☐ 10. With the power off, change the load in the circuit to the inductive load Z_1(b). Repeat the procedure steps necessary to complete Table 2-1 and Figure 2-5.

What is the effect of the inductive load on the operation of the circuit?

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Compare the following characteristics of a three-phase, three-pulse rectifier to those of a single-phase bridge rectifier.

Diode conduction angle: ______________________________

____

Ripple frequency: ______________________________

____

Average output voltage: ______________________________

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Compare the output voltage of the circuit to the theoretical value.

Theoretical Value:

$E_O = 0.675\ E_S =$ ___________ V dc

Measured Value:

$E_1 =$ ___________ V dc.

☐ 11. On the power supply, set the voltage control knob to 0 then set the main power switch to 0 (OFF). Set the rocker switch on the enclosure/ power supply to the O position. Remove all the leads and cables.

Review Questions:

1. What is the diode conduction angle in a three phase three pulse rectifier?
2. What is the output voltage of a three phase three pulse rectifier operating on a line to line voltage of 220V?
3. What is the output voltage of a three phase three pulse rectifier operating on a line to neutral voltage of 220V?
4. With reference to a three phase supply, draw the voltage drops across Diodes D1, D2 and D3 respectively (from 0° to 390°). Consider the diodes to be silicon diodes.
5. With reference to a three phase supply, draw the current waveforms through Diodes D1, D2 and D3 respectively (from 0° to 390°).
6. What are the advantages of a three pulse rectifier over a single pulse rectifier?