EEE 421 STATIC POWER CONVERSION LAB.

EXPERIMENT 1

SINGLE-PHASE HALF-WAVE UNCONTROLLED RECTIFIER

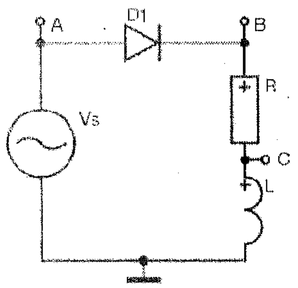
Object:
To investigate the operation of a single-phase half-wave uncontrolled rectifier by measurement and observation of the waveforms.

Equipment:
TecQuipment NE9023 thyristor and diode circuit teaching unit.
Resistive load bank, 9A max, variable R
CRO
Digital multimeter.

Preliminary Work:

1) For the circuit as shown in the following, by neglecting the diode voltage drop, determine the current waveform in mathematical form, the mean load voltage and the mean current for a load of

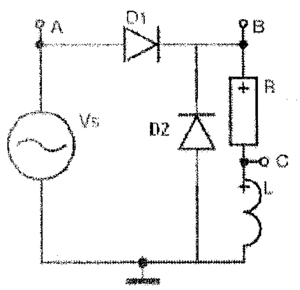
a. a pure resistor of 1 Ω,
b. an inductance of 1 mH in series with a 1 Ω resistor.



$V_{eff} = 220$ V effective voltage of mains
$f = 50$ Hz frequency of mains

2) Build the same diode rectifier in Matlab/Simulink. Run the simulation to obtain the rectified and inductor voltages (V_B, V_L) and current waveforms (I_L) through the load of R=1Ω and also for the load of R=1Ω, L=1mH for $0 \leq t \leq 60$ms. Present these curves in your preliminary report.

3) What is free-wheeling diode? Explain its function.



$V_{eff} = 220$ V effective voltage of mains
$f = 50$ Hz frequency of mains
R=1 Ω
L=1 mH

Run the simulation for the circuit as shown in above to obtain the I_{D1}, I_{D2}, I_{Load}, V_{D1}, V_{D2}, and V_{Load} curves for $0 \leq t \leq 60$ms. Present these curves in your preliminary report.

4) For the source current in steps (2) by using Matlab/Simulink,

a) Determine the harmonic spectrum using the FFT function.
b) Determine the THD.

PERFORMANCE PARAMETERS OF ______________________ RECTIFIER

1. The average value of *output (load) voltage* given as $\mathbf{V}_{dc}$

2. The average value of *output (load) current* given by $\mathbf{I}_{dc}$

3. The *output dc power* given by $\mathbf{P}_{dc} = \mathbf{V}_{dc}\mathbf{I}_{dc}$

4. The *rms value of output voltage* given as $\mathbf{V}_{rms}$

5. The *rms value of output current* given as $\mathbf{I}_{rms}$

6. The *output ac power* given by $\mathbf{P}_{ac} = \mathbf{V}_{rms}\mathbf{I}_{rms}$

7. The *efficiency* or *rectification ratio* of a rectifier given by $\eta = \frac{P_{dc}}{P_{ac}}$

8. The output voltage consists of two components an ac component and a dc component. The *effective* or (rms) value of the ac component of output voltage is given by

$$V_{ac} = \sqrt{V_{rms}^2 - V_{dc}^2}$$

9. The *form factor* which is a measure of the shape of the output voltage is given by

$$FF = \frac{V_{rms}}{V_{dc}}$$

10. The *ripple factor* which is a measure of the ripple content is given by

$$RF = \frac{V_{ac}}{V_{dc}} = \frac{\sqrt{V_{rms}^2 - V_{dc}^2}}{V_{dc}} = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} = \sqrt{FF^2 - 1}$$

11. The *transformer utilization factor* is defined as

$$TUF = \frac{P_{dc}}{V_s I_s}$$

where $\mathbf{V}_s$ and $\mathbf{I}_s$ are the rms voltage and rms current of the transformer secondary respectively.

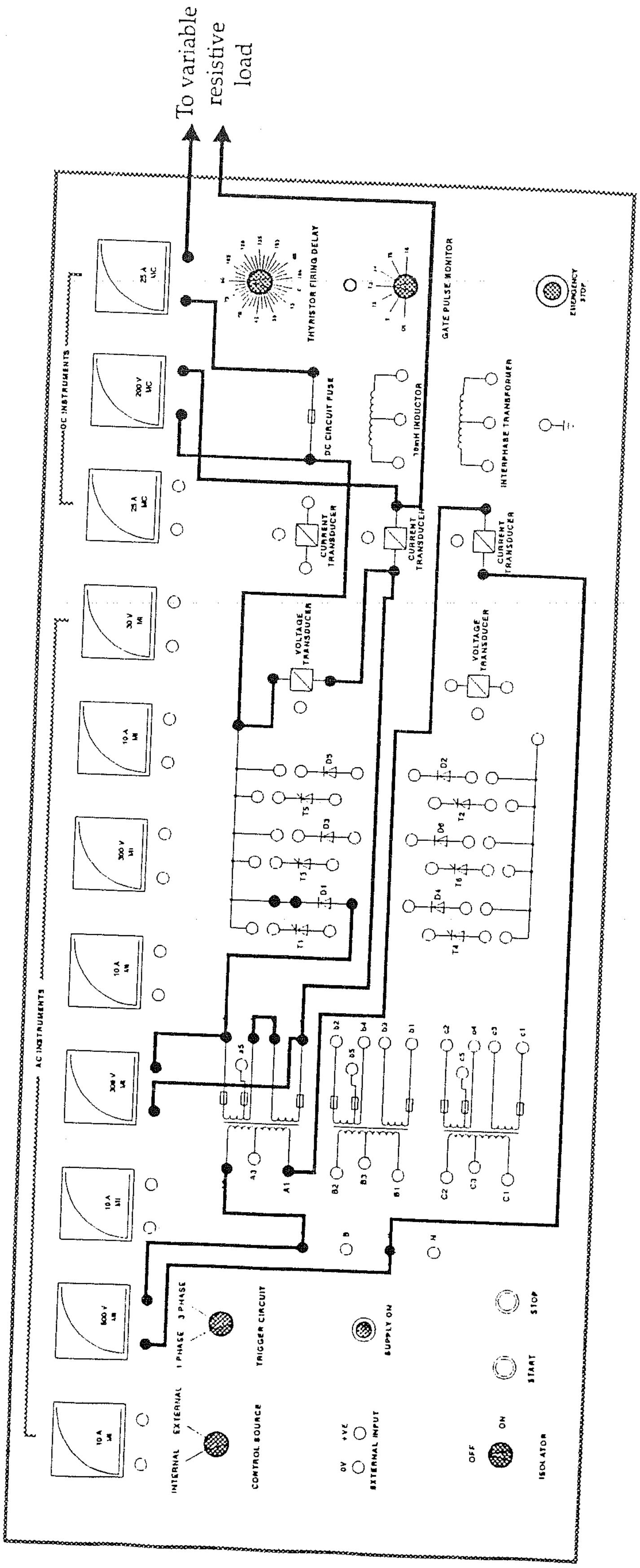


Figure 5.1.1 Single-phase, Half-wave Rectifier Circuit

Experimental Procedure:

1. Connect the single-phase half-wave circuit as in figure 1, including a current transducer on the transformer primary and secondary sides which will allow the supply current waveform to be observed on a CRO with earthed frame. With a resistive load connected, and taking only about 0.5 A or less to establish diode conduction, measure the AC supply and DC supply voltages. Using a double trace CRO, observe the output voltage and the load current waveforms. Sketch the waveforms.
2. Then turn off the circut and connect CRO inputs to the transformer primary side current transducer and secondary side current transducer. Observe and sketch the waveforms.
3. Repeat the CRO connections in steps 1and 2 increasing the load current to about 5 A and make the readings. Sketch the CRO waveforms of output voltage, current and primary side current.
4. Turn off the circuit and connect 10 mH inductive load in series with the resistive load. Repeat the procedures in steps 1, 2 and 3.
5. Turn off the circuit and connect the free-wheeling diode inverse paralel with the load. Repeat the procedures in steps 1, 2 and 3.

Results and Discussion:

1. For each test, calculate the average and rms value of the output voltage and current from a knowledge of the waveforms and the value of supply voltage. Put these results in a table together with the measured values.
2. For each test, calculate the the transformer utilization factor, form factor the efficiency
3. What is the effect of inductance connected in series with the resistive load?
4. What is the effect of free-wheeling diode? Comment on the advantages and disadvantages of it.

EEE 421 STATIC POWER CONVERSION LAB.

EXPERIMENT 2

SINGLE-PHASE FULL-WAVE CENTER-TAPPED RECTIFIER

Object:

To investigate the operation of a single-phase full-wave center-tapped rectifier by measurement and observation of the waveforms.

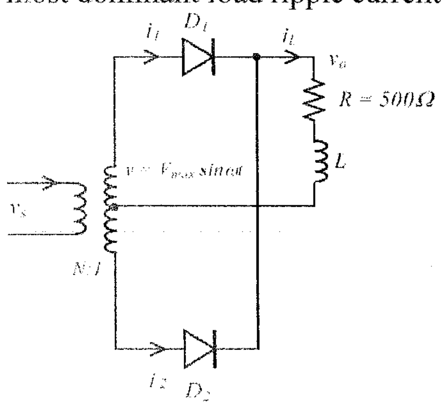
Equipment:

TecQuipment NE9023 thyristor and diode circuit teaching unit.
Resistive load bank, 9A max, variable R
Inductor
CRO
Digital multimeter.

Preliminary Work:

1. Build the single-phase centre-tap rectifier circuit in Matlab/Simulink. The input to the rectifier is 220 V,50 Hz. Run the simulation for $0 \le t \le 60$ms to obtain the rectified load and inductor voltages (V_O, V_L) and current waveforms (I_L) through the loads of; Z1=10Ω, Z2=10+jw0.1Ω, Z3=10+jw1Ω. Present the curves in your preliminary report.

2. The single-phase centre-tap rectifier circuit of the following figure, calculate the inductance L required to reduce the ripple current in the load to 5% of Id. Include only the most dominant load ripple current neglecting all others. Given: $v = 340 \sin(2\pi 50t)$ V.



Experimental Procedure:

1. Connect the single-phase full-wave center-tapped rectifier circuit, including a current transducer on the transformer primary and secondary sides which will allow the supply current waveform to be observed on a CRO with earthed frame. With a resistive load connected, and taking only about 0.5 A or less to establish diode conduction, measure the AC output and DC output voltages. Using a double trace CRO, observe the output voltage and the load current waveforms. Sketch the waveforms.

2. Then turn off the circut and connect CRO inputs to the transformer primary side current transducer and secondary side current transducer. Observe and sketch the waveforms.

3. Repeat the CRO connections in steps 1and 2 increasing the load current to about 5 A and make the readings. Sketch the CRO waveforms of output voltage, current and primary side current.

4. Turn off the circuit and connect 10 mH inductive load in series with the resistive load. Repeat the procedures in steps 1, 2 and 3.

PERFORMANCE PARAMETERS OF ______________________ RECTIFIER

1. The average value of *output (load) voltage* given as $\mathbf{V}_{dc}$

2. The average value of *output (load) current* given by $\mathbf{I}_{dc}$

3. The *output dc power* given by $\mathbf{P}_{dc} = \mathbf{V}_{dc}\mathbf{I}_{dc}$

4. The *rms value of output voltage* given as $\mathbf{V}_{rms}$

5. The *rms value of output current* given as $\mathbf{I}_{rms}$

6. The *output ac power* given by $\mathbf{P}_{ac} = \mathbf{V}_{rms}\mathbf{I}_{rms}$

7. The *efficiency* or *rectification ratio* of a rectifier given by $\eta = \mathbf{Pdc/Pac}$

8. The output voltage consists of two components an ac component and a dc component. The *effective* or (rms) value of the ac component of output voltage is given by

$$V_{ac} = \sqrt{V_{rms}^2 - V_{dc}^2}$$

9. The *form factor* which is a measure of the shape of the output voltage is given by

$$FF = \frac{V_{rms}}{V_{dc}}$$

10. The *ripple factor* which is a measure of the ripple content is given by

$$RF = \frac{V_{ac}}{V_{dc}} = \frac{\sqrt{V_{rms}^2 - V_{dc}^2}}{V_{dc}} = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} = \sqrt{FF^2 - 1}$$

11. The *transformer utilization factor* is defined as

$$TUF = \frac{P_{dc}}{V_s I_s}$$

where $\mathbf{V}_s$ and $\mathbf{I}_s$ are the rms voltage and rms current of the transformer secondary respectively.

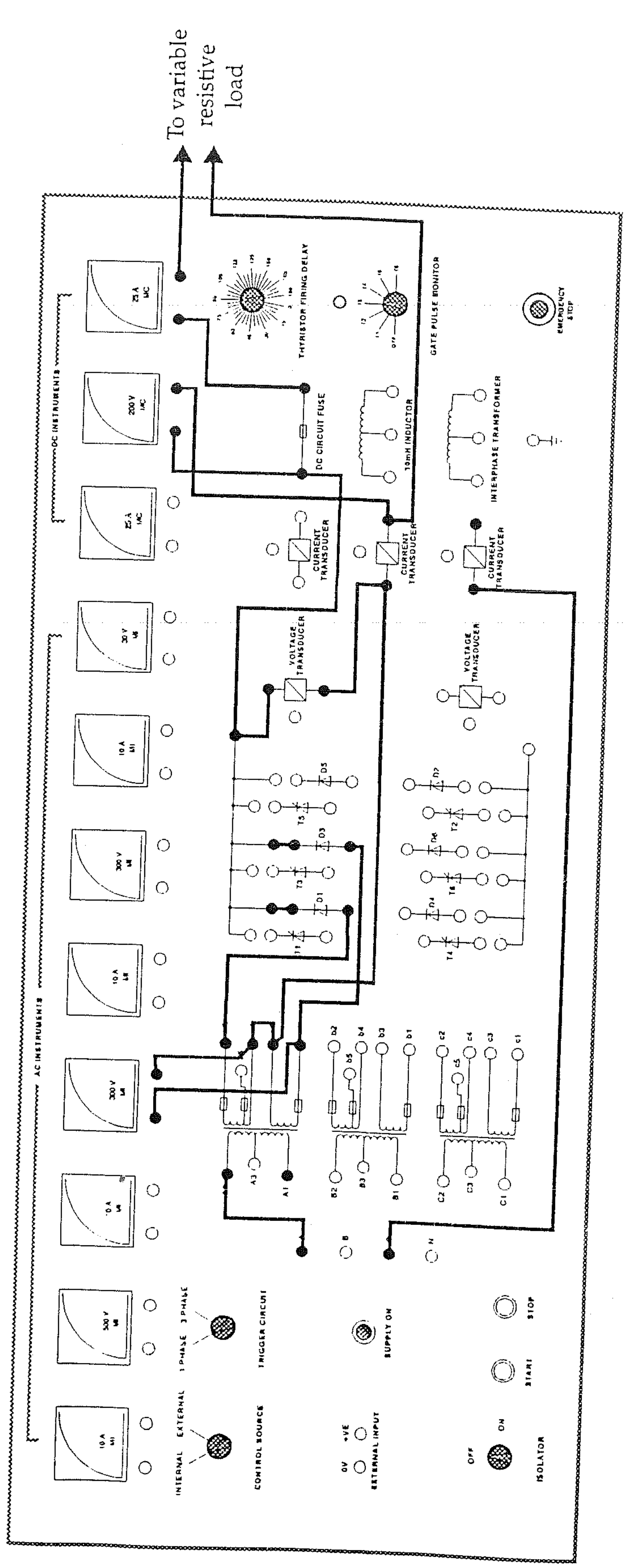


Figure 5.1.2 Single-phase, Biphase (centre-tap) Full Wave Rectifier Circu

Results and Discussion:

1. For each test, calculate the theoretical mean output voltage from a knowledge of the waveforms and the value of supply voltage. Put these results in a table together with the measured values.
2. For each test, calculate the transformer utilization factor, form factor and the efficiency. Put these results in a tabular form.
3. Comment on the effect of inductive load on the mean output voltage relative to that with resistive load. Explain its effect on load current.

EEE 421 STATIC POWER CONVERSION LAB.

EXPERIMENT 3

SINGLE-PHASE FULL-WAVE DIODE BRIDGE RECTIFIER

Object:
To investigate the operation of a single-phase full-wave bridge rectifier by measurement and observation of the waveforms.

Equipment:
TecQuipment NE9023 thyristor and diode circuit teaching unit.
Resistive load bank, 9A max, variable R
Inductor
CRO
Digital multimeter.

Preliminary Work:

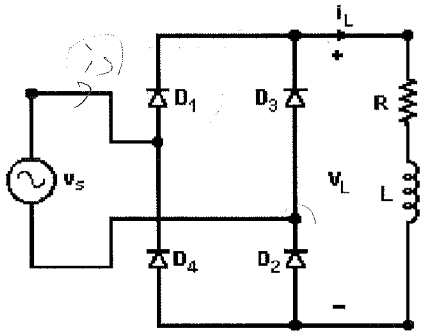
1. Simulate a full wave diode bridge rectifier in Matlab /Simulink. The input to the rectifier is 220 Vrms,50 Hz. The load is resistive with R = 10 ohms.

a) Simulate the circuit and find the dc value of the output current. Analyze the circuit theoretically and compare the results with the simulation. Also observe the obtained waveforms of the diode currents, source current, output current and voltage.

b) Simulate the circuit now with an R-L load with inductance of 150 mH. Calculate the dc value of the output current and the harmonic content.

c) Repeat part b for L = 1 H. Compare reults with the part (b).

d) Repeat part c with a source inductance of 10 mH and calculate the harmonic content of the load current and the source current. What is the effect of source inductance?



$i_s = i_1 - i_4$

2. A highly inductive dc load requires 12 A at 150 V from a $V_{primary}$=240 V single –phase ac supply. Give the design details (think for the ratings of the transformers and diodes)for this requirement using
a) center-tapped rectifier
b) diode bridge rectifier.
Assume each diode to have a voltage drop of 0.7V. Make comparison between the two designs.

PERFORMANCE PARAMETERS OF ______________________ RECTIFIER

1. The average value of *output (load) voltage* given as $\mathbf{V}_{dc}$

2. The average value of *output (load) current* given by $\mathbf{I}_{dc}$

3. The *output dc power* given by $\mathbf{P}_{dc} = \mathbf{V}_{dc}\mathbf{I}_{dc}$

4. The *rms value of output voltage* given as $\mathbf{V}_{rms}$

5. The *rms value of output current* given as $\mathbf{I}_{rms}$

6. The *output ac power* given by $\mathbf{P}_{ac} = \mathbf{V}_{rms}\mathbf{I}_{rms}$

7. The *efficiency* or *rectification ratio* of a rectifier given by $\eta = \frac{P_{dc}}{P_{ac}}$

8. The output voltage consists of two components an ac component and a dc component. The *effective* or (rms) value of the ac component of output voltage is given by

$$V_{ac} = \sqrt{V_{rms}^2 - V_{dc}^2}$$

9. The *form factor* which is a measure of the shape of the output voltage is given by

$$FF = \frac{V_{rms}}{V_{dc}}$$

10. The *ripple factor* which is a measure of the ripple content is given by

$$RF = \frac{V_{ac}}{V_{dc}} = \frac{\sqrt{V_{rms}^2 - V_{dc}^2}}{V_{dc}} = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} = \sqrt{FF^2 - 1}$$

11. The *transformer utilization factor* is defined as

$$TUF = \frac{P_{dc}}{V_s I_s}$$

where $\mathbf{V}_s$ and $\mathbf{I}_s$ are the rms voltage and rms current of the transformer secondary respectively.

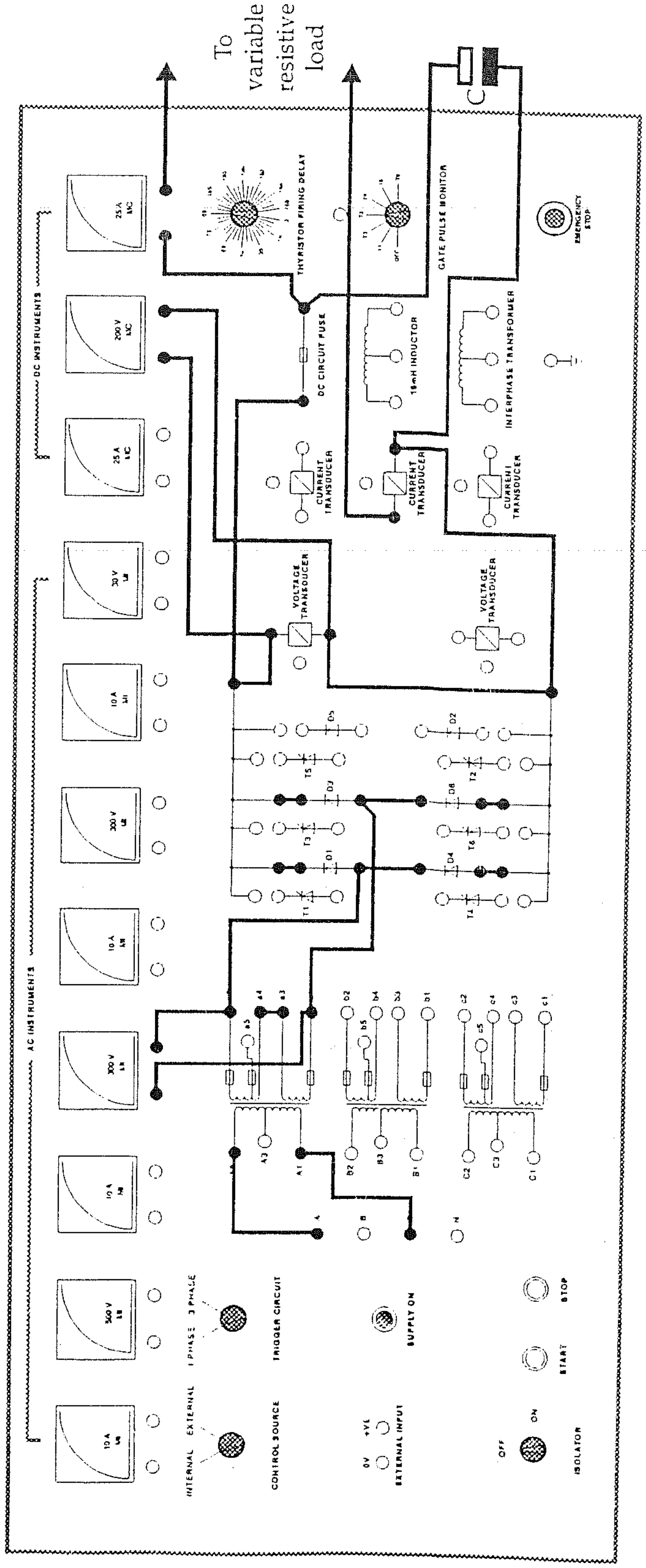


Figure 5.9 Rectifier Smoothing Methods Single-phase

Experimental Procedure:

1. Connect the single-phase full-wave diode bridge rectifier circuit, including a current transducer on the transformer primary and secondary sides which will allow the supply current waveform to be observed on a CRO with earthed frame. With a resistive load connected, and taking only about 0.5 A or less to establish diode conduction, measure the AC output and DC output voltages. Using a double trace CRO, observe the output voltage and the load current waveforms. Sketch the waveforms.
2. Then turn off the circuit and connect CRO inputs to the transformer primary side current transducer and secondary side current transducer. Observe and sketch the waveforms.
3. Repeat the CRO connections in steps 1and 2 increasing the load current to about 5 A and make the readings. Sketch the CRO waveforms of output voltage, current and primary side current.
4. Turn off the circuit and connect 10 mH inductive load in series with the resistive load. Repeat the procedures in steps 1, 2 and 3.
5. Turn off the circuit and connect freewheeling diode across the load. Repeat the procedures in steps 1, 2 and 3.

Results and Discussion:

1. For each test, calculate the theoretical mean output voltage from a knowledge of the waveforms and the value of supply voltage. Put these results in a table together with the measured values.
2. For each test, calculate the transformer utilization factor, form factor and the efficiency. Put these results in a tabular form.
3. Comment on the effect of inductive load on the mean output voltage relative to that with resistive load. Explain its effect on load current.
4. Comment on the difference between the diode bridge rectifier and center-tapped rectifier.

EEE 421 STATIC POWER CONVERSION LAB.

EXPERIMENT 4

THREE-PHASE HALF-WAVE RECTIFIER

Object:

To investigate the operation of a three-phase half-wave uncontrolled rectifier by measurement and observation of the waveforms.

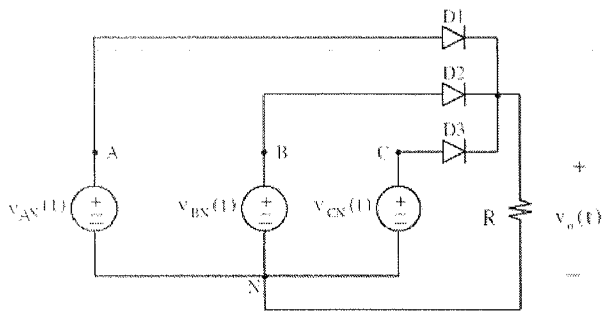
Equipment:

TecQuipment NE9023 thyristor and diode circuit teaching unit.
Resistive load bank, 9A max, variable R
CRO
Digital multimeter.

Preliminary Work:

1) Calculate the performance parameters of three-phase half-wave uncontrolled rectifier.

2) Perform the Simulink simulation on the following circuit. Use a 50-Hz variable source for the source voltage vs(t) with a per-phase maximum value V_{MAX} of about 220 V. R is about 200 Ω.



a) On one graph, plot the output voltage and the phase-A , B, C voltages. On the second graph, plot the current through and the voltage across the diode D1.

b) Perform the Fourier analysis of the output voltage and sketch its components. Determine the amplitude of the first five non-zero components of the Fourier series.

c) Repeat the above procedure with R=200 Ω. and L= 0.2 H. Comment on the results.

Experimental Procedure:

1. Connect the experimental circuit. With a resistive load connected, and taking only about 0.5 A or less to establish diode conduction, measure the AC bridge supply and mean DC output voltages.
2. With resistive load increase the load current to 8A and take the all readings. Sketch the voltage and current waveforms. Note that, the diode and bridge supply waveforms must be observed separately from any others on CRO.
3. Repeat the above procedures with RL load.

Results and Discussion:

1. Explain the differences between the theoratical expectations and experimental results if there exists.
2. Explain the effect of increasing the pulse number of a rectifier on the output voltage and on the input ac supply current.
3. Comment on the ripple contents of the output voltage and current waveforms.

PERFORMANCE PARAMETERS OF ______________________ RECTIFIER

1. The average value of *output (load) voltage* given as $\mathbf{V_{dc}}$

2. The average value of *output (load) current* given by $\mathbf{I_{dc}}$

3. The *output dc power* given by $\mathbf{P_{dc}} = \mathbf{V_{dc}I_{dc}}$

4. The *rms value of output voltage* given as $\mathbf{V_{rms}}$

5. The *rms value of output current* given as $\mathbf{I_{rms}}$

6. The *output ac power* given by $\mathbf{P_{ac}} = \mathbf{V_{rms}I_{rms}}$

7. The *efficiency* or *rectification ratio* of a rectifier given by $\eta = \frac{P_{dc}}{P_{ac}}$

8. The output voltage consists of two components an ac component and a dc component. The *effective* or (rms) value of the ac component of output voltage is given by

$$V_{ac} = \sqrt{V_{rms}^2 - V_{dc}^2}$$

9. The *form factor* which is a measure of the shape of the output voltage is given by

$$FF = \frac{V_{rms}}{V_{dc}}$$

10. The *ripple factor* which is a measure of the ripple content is given by

$$RF = \frac{V_{ac}}{V_{dc}} = \frac{\sqrt{V_{rms}^2 - V_{dc}^2}}{V_{dc}} = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} = \sqrt{FF^2 - 1}$$

11. The *transformer utilization factor* is defined as

$$TUF = \frac{P_{dc}}{V_s I_s}$$

where $\mathbf{V_s}$ and $\mathbf{I_s}$ are the rms voltage and rms current of the transformer secondary respectively.

EEE 421 STATIC POWER CONVERSION LAB.

EXPERIMENT 5

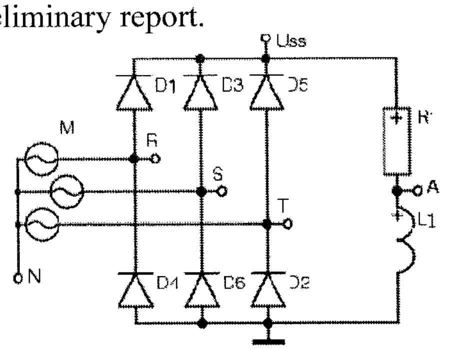
THREE-PHASE FULL-WAVE UNCONTROLLED RECTIFIER

Object:
To investigate the operation of a three-phase full-wave uncontrolled rectifier by measurement and observation of the waveforms.

Equipment:
TecQuipment NE9023 thyristor and diode circuit teaching unit.
Resistive load bank, 9A max, variable R
CRO
Digital multimeter.

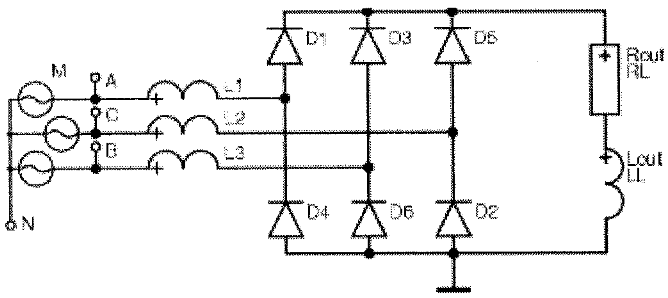
Preliminary Work:

1. Build the the circuit as shown in the following, in Matlab/Simulink. The rectifier is supplied from a balanced three-phase supply with sinusoidal input voltages of a peak value V_{peak} per phase and a frequency f. Run the simulation to obtain the rectified voltage (Uss), voltage across the diode (V_{D5}),voltage across the inductor (V_L), $V_{RS,}$ and current through the load (I_L), diodes (I_{D5} I_{D3} I_{D1}) of the bridge rectifier for $0 \leq t \leq 40$ms. Present these curves in your preliminary report.



$V_{eff} = 220$ V	effective voltage of mains
$f = 50$ Hz	frequency of mains
$R_L = 200\Omega$	load resistances
$L_L = 0.2$H	load inductances

2. Build the the circuit as shown in the following, in Matlab/Simulink. The rectifier is supplied from a balanced three-phase supply with sinusoidal input voltages of a peak value V_{peak} per phase and a frequency f. Run the simulation to obtain the rectified voltage (Uss), voltage across the diode (V_{D5}),voltage across the inductor (V_L), V_{AC},V_{BC} and current through the load (I_L), diodes (I_{D5} I_{D3} I_{D1}) of the bridge rectifier for $0 \leq t \leq 40$ms.



$V_{eff} = 220$ V	effective voltage of mains
$f = 50$ Hz	frequency of mains
$L_{line} = 1$mH	line inductances
$R_L = 200\Omega$	load resistances
$L_L = 0.2$H	load inductances

Explain the effect of source inductance on the waveforms.

3) For the source current in steps (1),by using Matlab/Simulink,

a) Determine the harmonic spectrum using the FFT function.
b) Determine the THD.

Experimental Procedure:

1. Connect the experimental circuit. With a resistive load connected, and taking only about 0.5 A or less to establish diode conduction, measure the AC bridge supply and mean DC output voltages.
2. With resistive load increase the load current to 8A and take the all readings. Sketch the voltage and current waveforms. Note that, the diode and bridge supply waveforms must be observed separately from any others on CRO.
3. Repeat the above procedures with RL load.

Results and Discussion:

1. Comment on the ripple contents of the output voltage and current waveforms.
2. What would be the ripple frequency of a three-phase diode bridge rectifier when the ac source frequency is 100Hz, 1kHz, n Hz?
3. Compare the three-phase midpoint rectifier with the bridge rectifier. List their relative advantages and disadvantages.

PERFORMANCE PARAMETERS OF ______________________ RECTIFIER

1. The average value of *output (load) voltage* given as $\mathbf{V_{dc}}$

2. The average value of *output (load) current* given by $\mathbf{I_{dc}}$

3. The *output dc power* given by $\mathbf{P_{dc}} = \mathbf{V_{dc}I_{dc}}$

4. The *rms value of output voltage* given as $\mathbf{V_{rms}}$

5. The *rms value of output current* given as $\mathbf{I_{rms}}$

6. The *output ac power* given by $\mathbf{P_{ac}} = \mathbf{V_{rms}I_{rms}}$

7. The *efficiency* or *rectification ratio* of a rectifier given by $\eta = \frac{P_{dc}}{P_{ac}}$

8. The output voltage consists of two components an ac component and a dc component. The *effective* or (rms) value of the ac component of output voltage is given by

$$V_{ac} = \sqrt{V_{rms}^2 - V_{dc}^2}$$

9. The *form factor* which is a measure of the shape of the output voltage is given by

$$FF = \frac{V_{rms}}{V_{dc}}$$

10. The *ripple factor* which is a measure of the ripple content is given by

$$RF = \frac{V_{ac}}{V_{dc}} = \frac{\sqrt{V_{rms}^2 - V_{dc}^2}}{V_{dc}} = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} = \sqrt{FF^2 - 1}$$

11. The *transformer utilization factor* is defined as

$$TUF = \frac{P_{dc}}{V_s I_s}$$

where $\mathbf{V_s}$ and $\mathbf{I_s}$ are the rms voltage and rms current of the transformer secondary respectively.

! Use diodes instead of thyristors !

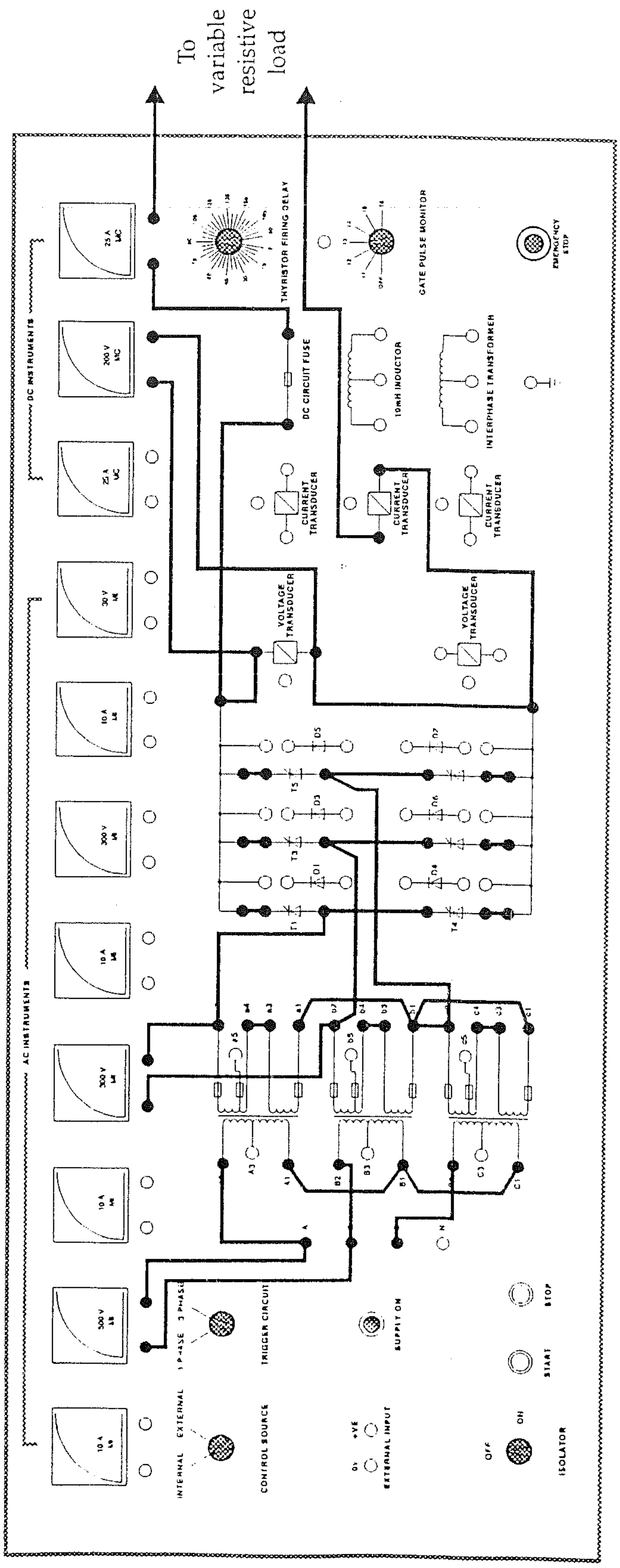


Figure 5.6 Three-phase, Fully Controlled Rectifier Bridge Circuit

EEE 421 STATIC POWER CONVERSION LAB.

EXPERIMENT 6

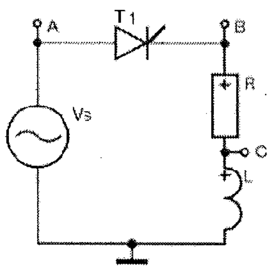
SINGLE-PHASE HALF-WAVE CONTROLLED RECTIFIER

Object:
To investigate the operation of a single-phase half-wave controlled rectifier by measurement and observation of the waveforms.

Equipment:
TecQuipment NE9023 thyristor and diode circuit teaching unit.
Resistive load bank, 9A max, variable R
CRO
Digital multimeter.

Preliminary Work:

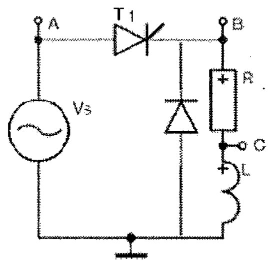
1) For the circuit as shown in the following, determine, the mean load voltage and the mean current and the rms load voltage as a function of firing angle for a load of a pure resistor.



$V_{eff} = 220$ V effective voltage of mains
$f = 50$ Hz frequency of mains

2) Build the above circuit in Matlab/Simulink. Run the simulation for the firing angles of 30° 90° 150° to obtain the rectified and inductor voltages (V_B, V_L) and current waveforms (I_L) through the load of R=10Ω and also for the load of R=10Ω L=0.1H for $0 \le t \le 60$ms. Present these curves in your preliminary report.

3) What is the function of the free-wheeling diode?



$V_{eff} = 220$ V effective voltage of mains
$f = 50$ Hz frequency of mains
R=10 Ω
L=0.1 H

Run the simulation for the circuit as shown in above for the firing angles of 30° 90° 150° and obtain the I_{T1}, I_D, I_{Load}, V_{T1}, V_D, and V_{Load} curves for $0 \le t \le 60$ms. Present these curves in your preliminary report.

Experimental Procedure:

1. Connect the single-phase half-wave controlled circuit, including a current transducer on the transformer primary and secondary sides which will allow the supply current waveform to be observed on a CRO with earthed frame. With the protractor set to give zero thristor firing delay and a resistive load connected, and taking only about 0.5 A or less, note the supply side and load side voltmeter readings. Any zero error in the protractor reading should be incorporated in the later setting of α. Take the readings of ac and dc output voltages for 0<α<180° (α; firing angle). Using a double trace CRO, observe the output voltage and the load current waveforms. Sketch the waveforms for α= 0°, 60°, 120°.

2. Then turn off the circut and connect CRO inputs to the transformer primary side current transducer and secondary side current transducer. Observe and sketch the waveforms.
3. Repeat the CRO connections in steps 1and 2 increasing the load current to about 5 A and make the readings. Sketch the CRO waveforms of output voltage, current and primary side current.
4. Turn off the circuit and connect 10 mH inductive load in series with the resistive load. Repeat the procedures in steps 1, 2 and 3.
5. Turn off the circuit and connect the free-wheeling diode inverse paralel with the load. Repeat the procedures in steps 1, 2 and 3.

Results and Discussion:

1. For each test, calculate the average and rms value of the output voltage from a knowledge of the waveforms and the value of supply voltage. Put these results in a table together with the measured values.
2. Compare this circuit with 1-Q half-wave uncontrolled rectifier.
3 What is the effect of increasing firing angle?
4. Comment on the effect of inductive load on the mean output voltage as relative to that resistive load.
5. Explain the function of free-wheeling diode considering the experimental result.

PERFORMANCE PARAMETERS OF ______________________ RECTIFIER

1. The average value of *output (load) voltage* given as $\mathbf{V_{dc}}$

2. The average value of *output (load) current* given by $\mathbf{I_{dc}}$

3. The *output dc power* given by $\mathbf{P_{dc} = V_{dc}I_{dc}}$

4. The *rms value of output voltage* given as $\mathbf{V_{rms}}$

5. The *rms value of output current* given as $\mathbf{I_{rms}}$

6. The *output ac power* given by $\mathbf{P_{ac} = V_{rms}I_{rms}}$

7. The *efficiency* or *rectification ratio* of a rectifier given by $\eta = \frac{P_{dc}}{P_{ac}}$

8. The output voltage consists of two components an ac component and a dc component. The *effective* or (rms) value of the ac component of output voltage is given by

$$V_{ac} = \sqrt{V_{rms}^2 - V_{dc}^2}$$

9. The *form factor* which is a measure of the shape of the output voltage is given by

$$FF = \frac{V_{rms}}{V_{dc}}$$

10. The *ripple factor* which is a measure of the ripple content is given by

$$RF = \frac{V_{ac}}{V_{dc}} = \frac{\sqrt{V_{rms}^2 - V_{dc}^2}}{V_{dc}} = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} = \sqrt{FF^2 - 1}$$

11. The *transformer utilization factor* is defined as

$$TUF = \frac{P_{dc}}{V_s I_s}$$

where $\mathbf{V_s}$ and $\mathbf{I_s}$ are the rms voltage and rms current of the transformer secondary respectively.

EEE 421 STATIC POWER CONVERSION LAB.

EXPERIMENT 7

SINGLE-PHASE THYRISTOR BRIDGE RECTIFIER

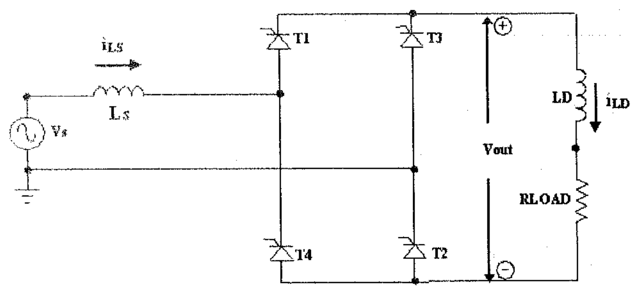
Object:
To investigate the behaviour of the single-phase thyristor bridge rectifier, and the phenomenon of discontinous and continuous conduction modes.

Equipment:
TecQuipment NE9023 thyristor and diode circuit teaching unit.
Resistive load bank, 9A max, variable R
CRO
Digital multimeter.

Preliminary Work:

1) Build the above circuit in Matlab/Simulink. Run the simulation for the firing angles of 30° 90° 150°

a) Obtain the rectified and inductor voltages (V_{out}, V_{LD}) and current waveforms (I_{LD}, I_{LS}) for $0 \leq t \leq 60$ms. Present these curves in your preliminary report.



Vs (rms) = 220 V at 50 Hz

Ls = 1 mH

RLOAD = 5Ω

Ld = 20 mH

b) Evaluate the dc average voltage (Vout) from the simulation and compare the same with the results obtained from the analytical expressions for the same.

2) Repeat the same simulation for Ls =Ld=0 and Ls=0. Observe V_{out}, V_{LD}, I_{LD}, I_{LS}. What is the effect of Ls, Ld?

Experimental Procedure

1. Connect the single-phase thyristor bridge rectifier circuit with resistive load, including a current transducer on the transformer primary and secondary sides which will allow the supply current waveform to be observed on a CRO with earthed frame.Adjust the value of R to give a 0.5A when firing angle of delay set to zero. Take the readings of ac and dc part of the output voltages for $0<\alpha<180°$ (α; firing angle), observe the output voltage and the load current waveforms on the CRO. Sketch the waveforms of output voltage and load current, transformer primary current, thyristor current and voltage for α= 30°, 150°.
2. Repeat the CRO connections in steps 1and 2 increasing the load current to about 5 A and make the readings
3. Turn off the circuit and connect 10 mH inductive load in series with the resistive load. Repeat the procedures in steps 1, 2 and 3.
4. Turn off the circuit and connect the free-wheeling diode inverse paralel with the load. Repeat the procedures in steps 1 and 3.

Results and Discussion:

1. For each test, calculate the average and rms value of the output voltage from a knowledge of the waveforms and the value of supply voltage. Put these results in a table together with the measured values.
2. Compare this circuit with 1-Q diode bridge rectifier.
3. What is the effect of increasing firing angle?
4. Comment on the effect of inductive load on the mean output voltage as relative to that resistive load.
5. Explain the function of free-wheeling diode considering the experimental result.
6. For step 1, calculate the form factor of the voltage and put these results in a tabular form. Ideally, what should be the value of FF? Comment on the experimental results.

PERFORMANCE PARAMETERS OF ______________________ RECTIFIER

1. The average value of *output (load) voltage* given as $\mathbf{V}_{dc}$

2. The average value of *output (load) current* given by $\mathbf{I}_{dc}$

3. The *output dc power* given by $\mathbf{P}_{dc} = \mathbf{V}_{dc}\mathbf{I}_{dc}$

4. The *rms value of output voltage* given as $\mathbf{V}_{rms}$

5. The *rms value of output current* given as $\mathbf{I}_{rms}$

6. The *output ac power* given by $\mathbf{P}_{ac} = \mathbf{V}_{rms}\mathbf{I}_{rms}$

7. The *efficiency* or *rectification ratio* of a rectifier given by $\eta = \frac{P_{dc}}{P_{ac}}$

8. The output voltage consists of two components an ac component and a dc component. The *effective* or (rms) value of the ac component of output voltage is given by

$$V_{ac} = \sqrt{V_{rms}^2 - V_{dc}^2}$$

9. The *form factor* which is a measure of the shape of the output voltage is given by

$$FF = \frac{V_{rms}}{V_{dc}}$$

10. The *ripple factor* which is a measure of the ripple content is given by

$$RF = \frac{V_{ac}}{V_{dc}} = \frac{\sqrt{V_{rms}^2 - V_{dc}^2}}{V_{dc}} = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} = \sqrt{FF^2 - 1}$$

11. The *transformer utilization factor* is defined as

$$TUF = \frac{P_{dc}}{V_s I_s}$$

where $\mathbf{V}_s$ and $\mathbf{I}_s$ are the rms voltage and rms current of the transformer secondary respectively.

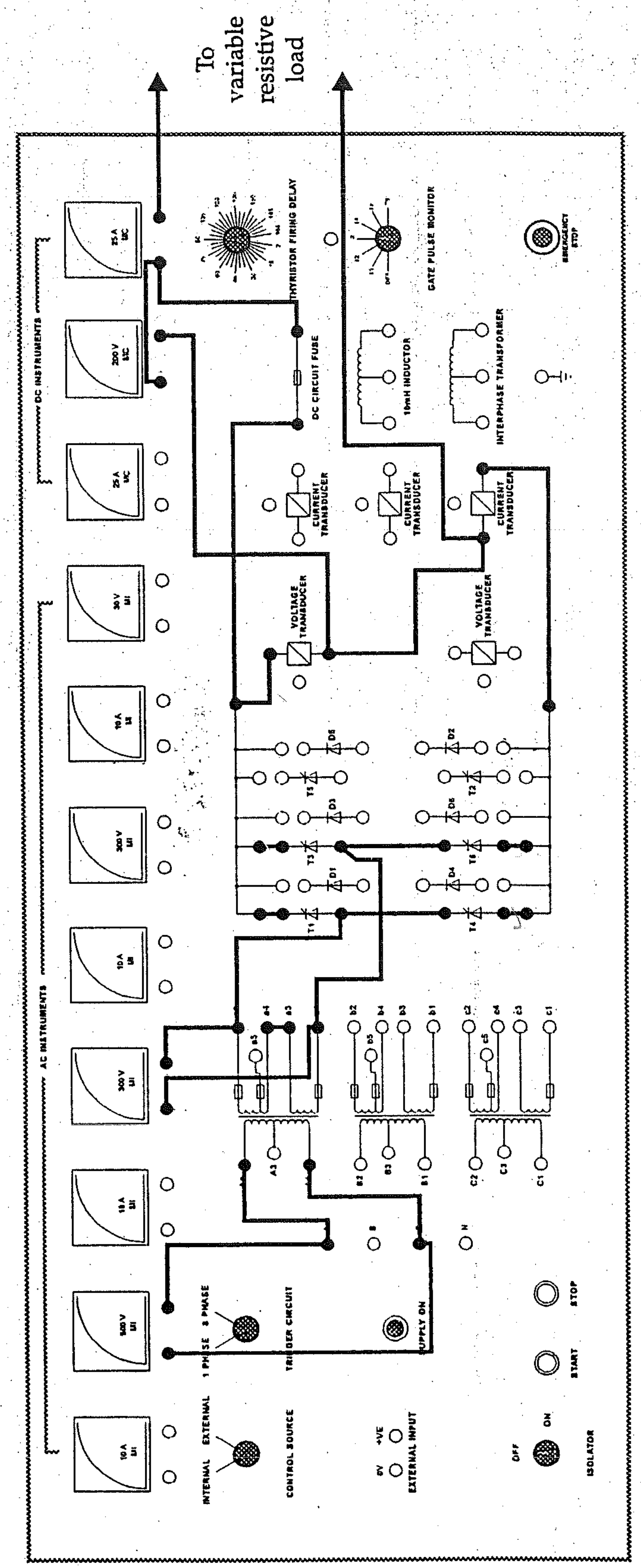


Figure 6.2 Single-phase, Fully controlled Rectifier Bridge Circuit

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EXPERIMENT 8

SINGLE-PHASE HALF-CONTROLLED BRIDGE RECTIFIER

Object:

To investigate the special characteristics of single-phase half-controlled bridge rectifier circuit and compare its characteristics with those of fully controlled bridges.

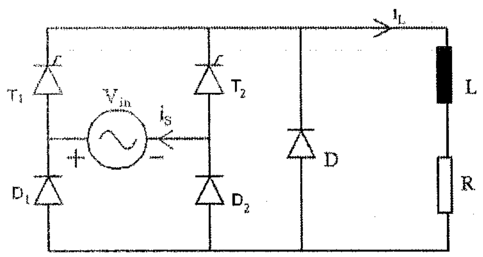
Equipment:

TecQuipment NE9023 thyristor and diode circuit teaching unit.
Resistive load bank, 9A max, variable R
CRO
Digital multimeter.

Preliminary Work:

1) Build the following circuit in Matlab/Simulink. Run the simulation for the firing angles of 30° 90° 150°.

a) Obtain the rectified and inductor voltages (V_{out}, V_{D1}, V_{T1}) and current waveforms (I_L, I_S) for $0 \le t \le 60$ms. Present these curves in your preliminary report.



Vs (rms) = 220 V at 50 Hz

R = 5Ω

L = 20 mH

b) Evaluate the dc average voltage (Vout) from the simulation and compare the same with the results obtained from the analytical expressions for the same.

2) Compare the performance parameters of this circuit with that of the single-phase fully-controlled bridge rectifier.

Experimental Procedure

1. Connect the single-phase half-controlled bridge rectifier circuit with RL load, including a current transducer on the transformer primary and secondary sides which will allow the supply current waveform to be observed on a CRO with earthed frame.
2. Adjust the value of R to give a 0.5A when firing angle of delay set to zero. Take the readings of ac and dc part of the output voltages. Observe the output voltage and the load current waveforms on the CRO.
3. While increasing the load current to about 5 A and α is increased from zero to 180°, make the readings. Sketch the waveforms of output voltage and load current, transformer primary current, thyristor currents and voltage for α=30° and α=135°.

Results and Discussion:

1. For each test, calculate the average and rms value of the output voltage from a knowledge of the waveforms and the value of supply voltage. Put these results in a table together with the measured values.
2. What is the effect of increasing firing angle on the waveforms?
3. Explain the function of free-wheeling diode considering the experimental result.

PERFORMANCE PARAMETERS OF ______________________ RECTIFIER

1. The average value of *output (load) voltage* given as $\mathbf{V}_{dc}$.

2. The average value of *output (load) current* given by $\mathbf{I}_{dc}$

3. The *output dc power* given by $\mathbf{P}_{dc} = \mathbf{V}_{dc}\mathbf{I}_{dc}$

4. The *rms value of output voltage* given as $\mathbf{V}_{rms}$

5. The *rms value of output current* given as $\mathbf{I}_{rms}$

6. The *output ac power* given by $\mathbf{P}_{ac} = \mathbf{V}_{rms}\mathbf{I}_{rms}$

7. The *efficiency* or *rectification ratio* of a rectifier given by $\eta = \frac{P_{dc}}{P_{ac}}$

8. The output voltage consists of two components an ac component and a dc component. The *effective* or (rms) value of the ac component of output voltage is given by

$$V_{ac} = \sqrt{V_{rms}^2 - V_{dc}^2}$$

9. The *form factor* which is a measure of the shape of the output voltage is given by

$$FF = \frac{V_{rms}}{V_{dc}}$$

10. The *ripple factor* which is a measure of the ripple content is given by

$$RF = \frac{V_{ac}}{V_{dc}} = \frac{\sqrt{V_{rms}^2 - V_{dc}^2}}{V_{dc}} = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} = \sqrt{FF^2 - 1}$$

11. The *transformer utilization factor* is defined as

$$TUF = \frac{P_{dc}}{V_S I_S}$$

where $\mathbf{V}_s$ and $\mathbf{I}_s$ are the rms voltage and rms current of the transformer secondary respectively.

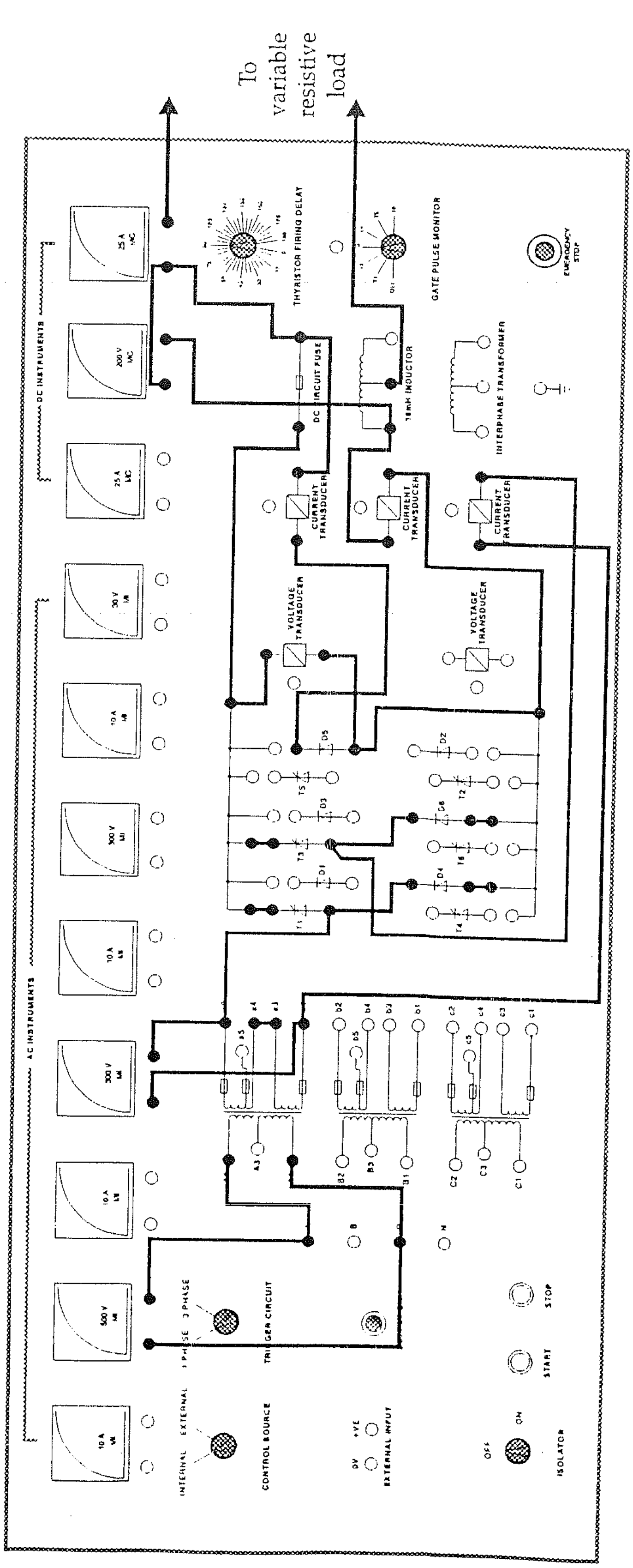


Figure 5.7.1 Single-phase, Half Controlled Bridge Circuit with Freewheeling Diode

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EXPERIMENT 9

SINGLE-PHASE AC CONTROL BY THYRISTORS

Object:

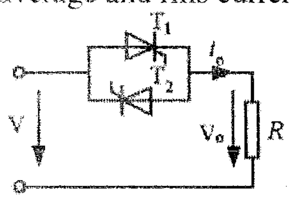
To investigate the control of single-phase AC control by thyristors with gate firing delay for resistive and inductive loads.

Equipment:

TecQuipment NE9023 thyristor and diode circuit teaching unit.
Resistive load bank, 9A max, variable R
CRO
Digital multimeter.

Preliminary Work:

1) Study the operation of the following circuit. Search for the instantaneous line current, average and rms current through each thyristor for α=30°



Experimental Procedure

1. Connect the required circuit with R load, including a current transducer on the transformer primary and secondary sides which will allow the supply current waveform to be observed on a CRO with earthed frame. Ensure that the thyristor trigger circuit selector switch is in the 1-Q position.
2. Adjust the value of R to give a 0.5A when firing angle of delay set to zero. Take the readings of ac and dc part of the output voltages. Observe the output voltage and the load current waveforms on the CRO.
3. While increasing the load current to about 5 A and α is increased from zero to 180°, take the readings. Sketch the waveforms of output voltage and load current, transformer primary current, thyristor currents and voltage for α=0°,60° and 120°.
4. Turn off the circuit and connect 10 mH inductive load in series with the resistive load. Repeat the procedures in step 3. Take the readings. Sketch the load voltage and current waveforms for α=45° and 90°

Results and Discussion:

1. Plot the readings of rms load voltage against firing delay α.
2. Comment on the range of firing angle required for full voltage control for the R and RL loads.
3. What are the advantages and disadvantages of this method of controlling AC compared with the more traditional methods of a tap-changing transformer or variac.

PERFORMANCE PARAMETERS OF ____________________________ RECTIFIER

1. The average value of *output (load) voltage* given as $\mathbf{V}_{dc}$

2. The average value of *output (load) current* given by $\mathbf{I}_{dc}$

3. The *output dc power* given by $\mathbf{P}_{dc} = \mathbf{V}_{dc}\mathbf{I}_{dc}$

4. The *rms value of output voltage* given as $\mathbf{V}_{rms}$

5. The *rms value of output current* given as $\mathbf{I}_{rms}$

6. The *output ac power* given by $\mathbf{P}_{ac} = \mathbf{V}_{rms}\mathbf{I}_{rms}$

7. The *efficiency* or *rectification ratio* of a rectifier given by $\eta = \frac{P_{dc}}{P_{ac}}$

8. The output voltage consists of two components an ac component and a dc component. The *effective* or (rms) value of the ac component of output voltage is given by

$$V_{ac} = \sqrt{V_{rms}^2 - V_{dc}^2}$$

9. The *form factor* which is a measure of the shape of the output voltage is given by

$$FF = \frac{V_{rms}}{V_{dc}}$$

10. The *ripple factor* which is a measure of the ripple content is given by

$$RF = \frac{V_{ac}}{V_{dc}} = \frac{\sqrt{V_{rms}^2 - V_{dc}^2}}{V_{dc}} = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1} = \sqrt{FF^2 - 1}$$

11. The *transformer utilization factor* is defined as

$$TUF = \frac{P_{dc}}{V_S I_S}$$

where $\mathbf{V}_s$ and $\mathbf{I}_s$ are the rms voltage and rms current of the transformer secondary respectively.