PSDE5027 Assignment 2

by Emyr Dyer

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HND Electrical & Electronic Engineering

Investigation into Single Quadrant DC Motor Drive

PSDE5027 – Power and Machines

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1 RESEARCH

1.1 THYRISTOR CONTROLLED RECTIFICATION

A Thyristor is a semiconductor device like a bipolar transistor, in that it has multiple semi-conductive layers, however, unlike a bipolar transistor which has three layers (PNP or NPN), a thyristor has four (PNPN) which in effect has three junctions as a result (Pelly, 1971).

While like a diode, a thyristor only operates in one direction (current flow), although unlike a diode the thyristor can operate as either as a rectifying diode or an open circuit switch.

The three terminals of the device are the Cathode, Anode, and Gate, which can be rapidly switched on or off (Subrahmanyam, 1987).

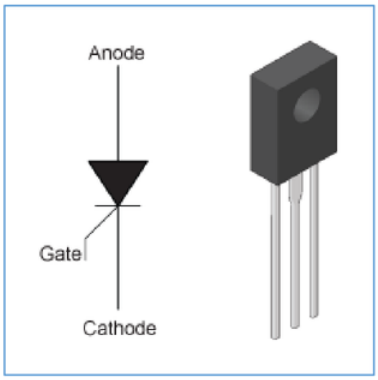


Figure 1.1: Thyristor

a good description

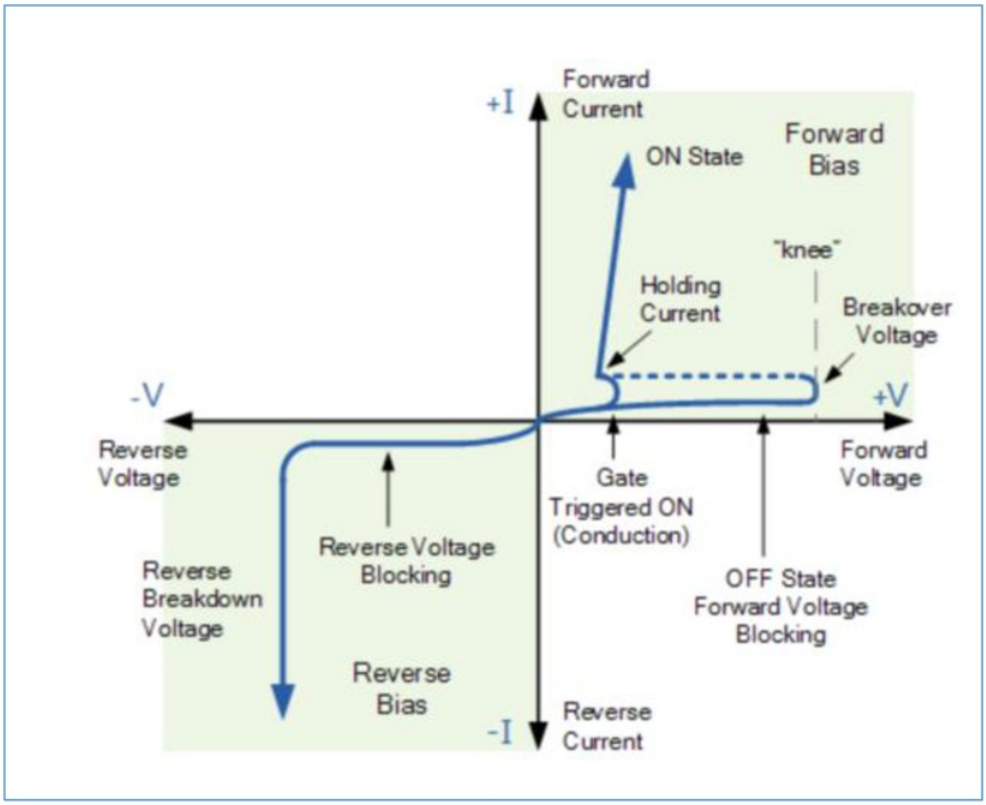


Figure 1.2: Thyristor Characteristics

A Forward Current and Voltage identify the Forward Characteristics. When the Forward Voltage increases, the Thyristor begins to conduct and turns On when appropriate current flows and the supply does not exceed the breakover voltage. It is important that with AC, that the reverse breakdown voltage is not exceeded during the negative half-cycle of the AC waveform. When turning off, the Current must reduce to the point of Holding Current and if the gate current is higher than what is required, the Thyristor closes at a lower supply voltage.

good explanation

1.2 Full-wave, Half Controlled Rectifier Circuit

Also called a Bridge Rectifier, due to the arrangement of the diodes which point towards the positive side of the Load.

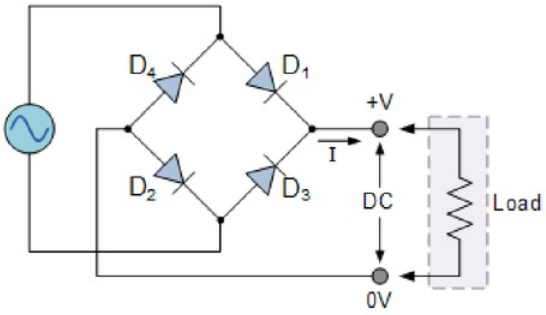


Figure 1.3: Bridge Rectifier

During the Positive half cycle, the D1 and D4 diodes conduct and during the Negative half cycle, the diodes D2 and D3 flip the negative half cycle to positive (Rashid, 2011).

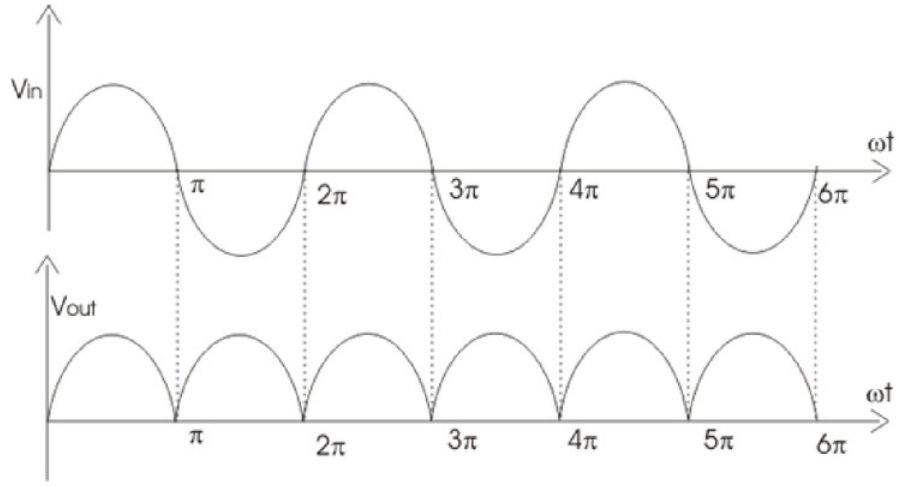


Figure 1.4: Rectified Waveform

The Vpk of the Vout waveform is calculated as;

$$V_{PK} = V_S \times \sqrt{2}$$

The average voltage can be found using;

$$V_{AV} = \frac{1}{\Pi}\int_0^{\Pi} V_{PK} \sin(\theta)\, d\theta$$

$$V_{AV} = \frac{2V_{PK}}{\Pi}$$

good work but this is not what the brief asked for, the circuit should contain 2 thyristors and the load should contain inductance and a back emf also in order to represent a dc motor armature. The equation to be researched or derived was the one used to calculate the average dc voltage for the simulation and practical exercises.

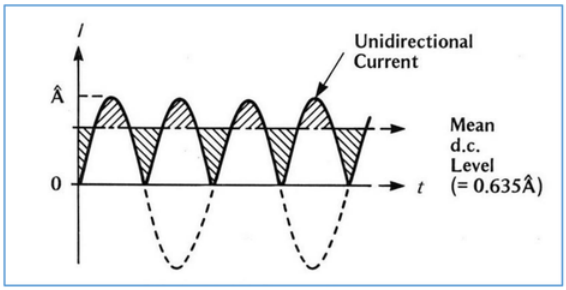


Figure 1.5: Full-wave Rectification

no thyristor switching and no delay angles

1.3 Industrial Applications of DC Drives

DC Drives had a distinct prevalence in industry due to the inherent benefits such as simple speed control, lower maintenance costs and service life in comparison to AC Drives. There is also the consideration that DC Drives can excel better in certain applications such as hoists. The type of DC Motors used with Thyristor control are Brush Motors, so while there will be some maintenance in replacing brushes, this is a simple enough task that is considered in the design of a brush motor. However, DC Drives also control brushless DC Motors.

DC Drives offer significant speed ranges, high accelerating and starting torques. Due to the characteristics of DC Drives, in that they are considered cheap and cost effective in comparison to AC Drives depending on the application (Austin Hughes, 2012).

2 SIMULATION OF A HALF-CONTROLLED RECTIFIER CIRCUIT

A circuit was built in Multisim to simulate a Half-Controlled Rectifier Circuit.

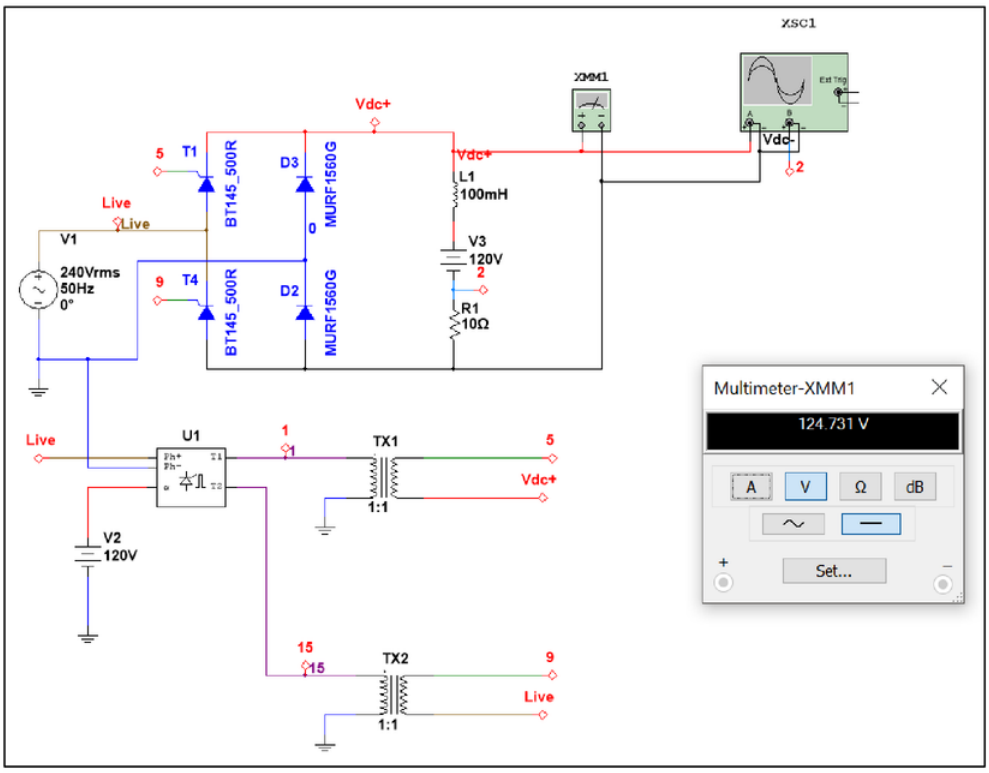


Figure 2.1: Multisim build of a Half-Controlled Rectifier Circuit

With the circuit completed, the circuit was run once to display the Back-EMF readings.

more marks were available for an explanation of this circuit.

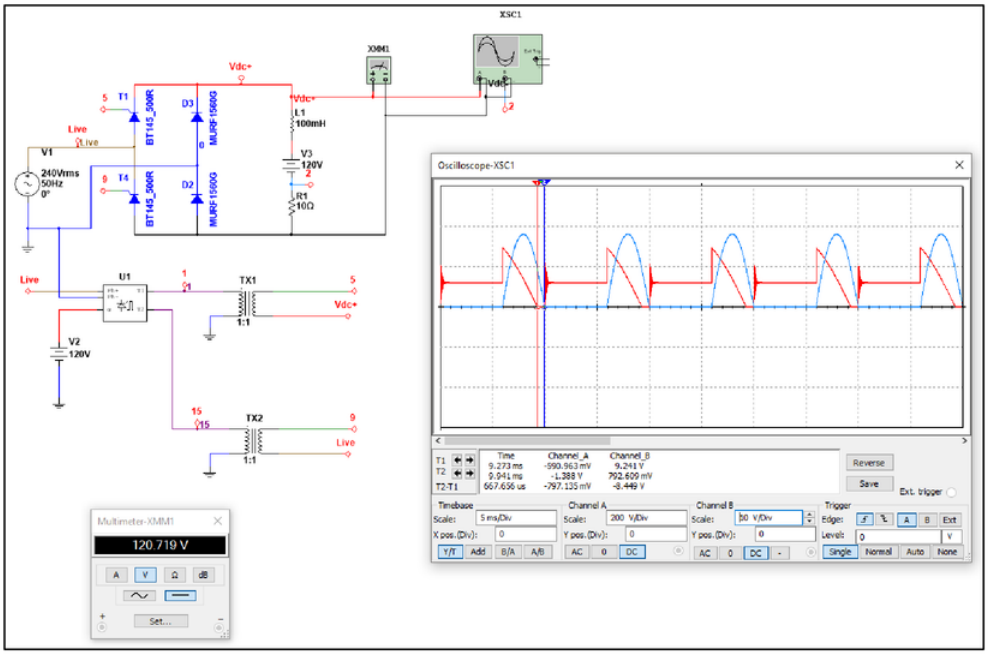


Figure 2.2: t1 with Firing Angle of 120V

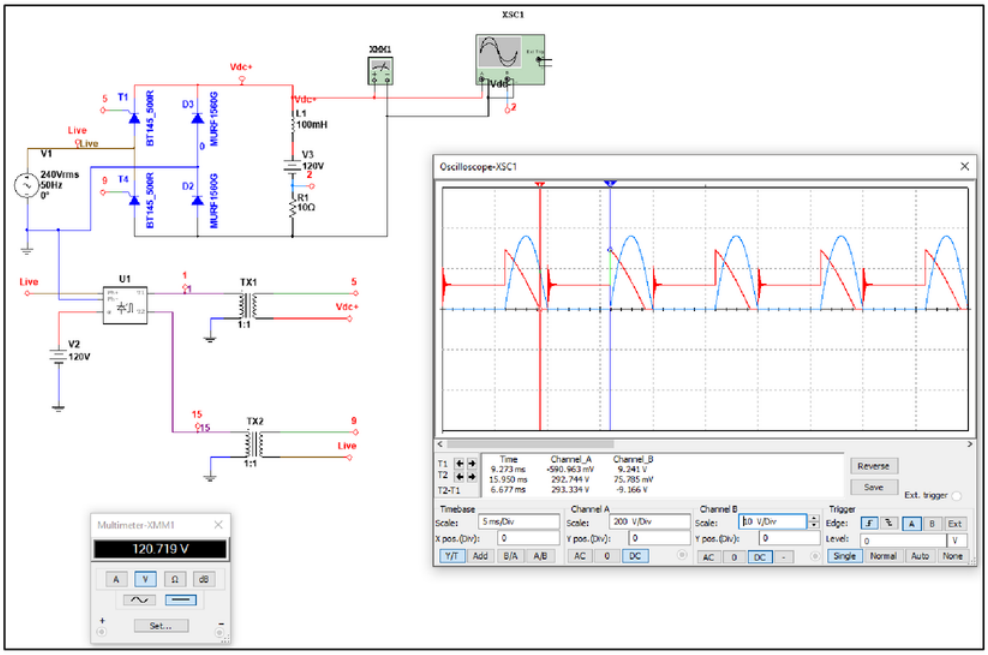


Figure 2.3: t2 with Firing Angle of 120V

With the readings taken, the following calculations were carried out.

$Vrms = 240V$

$$Vmax = \sqrt{2} \times Vrms = \sqrt{2} \times 240 = 339V$$

$$E = 120V$$

$$t_1 = 0.668ms$$

$$t_2 = 6.677ms$$

$$\beta = \frac{t_1}{10 \times 10^{-3}} \times \Pi = \frac{0.668 \times 10^{-3}}{10 \times 10^{-3}} \times \Pi = 0.21rad$$

$$\alpha = \frac{t_2}{10 \times 10^{-3}} \times \Pi = \frac{6.677 \times 10^{-3}}{10 \times 10^{-3}} \times \Pi = 2.098rad$$

$$Vav = \frac{E(\alpha - \beta) + Vmax[1 + \cos\alpha]}{\Pi} = \frac{120(2.098 - 0.21) + 339[1 + \cos 2.098]}{\Pi} = 125.73V$$

The result of the calculation is not so successful as there is a 5V discrepancy. Another attempt was made by changing the firing angle from 120V to 80V.

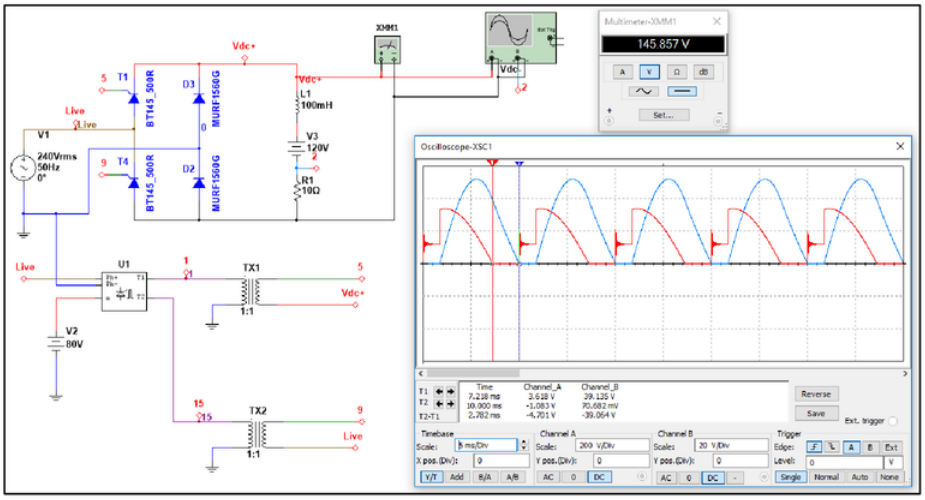


Figure 2.4: t1 with Firing Angle of 80V

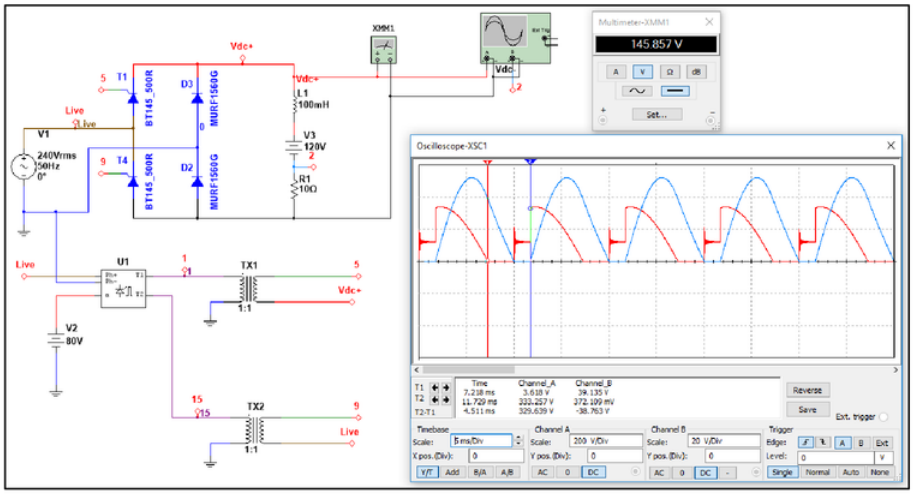


Figure 2.5: t2 with Firing Angle of 80V

With the two readings taken, the following calculations were carried out.

$Vrms = 240V$

$Vmax = \sqrt{2} \times Vrms = \sqrt{2} \times 240 = 339V$

$E = 120V$

$t_1 = 2.782ms$

$t_2 = 4.511ms$

$$\beta = \frac{t_1}{10 \times 10^{-3}} \times \Pi = \frac{2.782 \times 10^{-3}}{10 \times 10^{-3}} \times \Pi = 0.874rad$$

$$\alpha = \frac{t_2}{10 \times 10^{-3}} \times \Pi = \frac{4.511 \times 10^{-3}}{10 \times 10^{-3}} \times \Pi = 1.417rad$$

$$Vav = \frac{E(\alpha - \beta) + Vmax[1 + \cos\alpha]}{\Pi} = \frac{120(1.417 - 0.874) + 339[1 + \cos 1.417]}{\Pi} = 145.18V$$

This time the calculation was much closer to the measured value.

E	t_1	t_2	α	β	Measured	Calculated
120	$0.668ms$	$6.677ms$	$2.098rad$	$0.21rad$	$120.719V$	$125.73V$
120	$2.782ms$	$4.511ms$	$1.417rad$	$0.874rad$	$145.857V$	$145.18V$

very good presentation of results and calculations

A possible cause of discrepancy for the first attempt was human error as the values for either or both of the t values, could have been misidentified with poor indicator placement on the oscilloscope display.

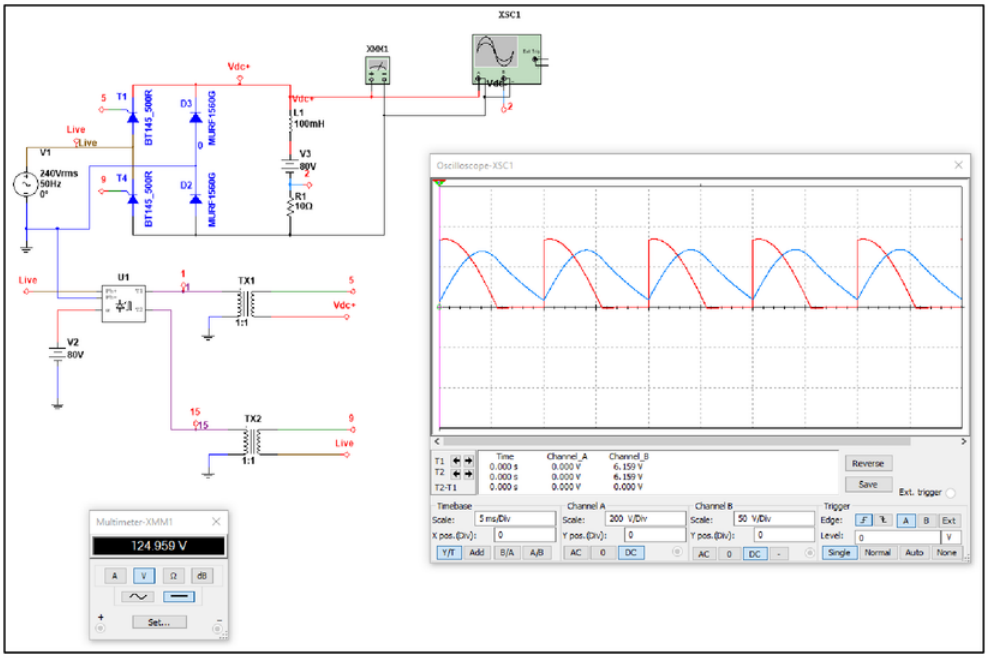


Figure 2.6: Back EMF Loading of 80V with Firing Angle of 80V

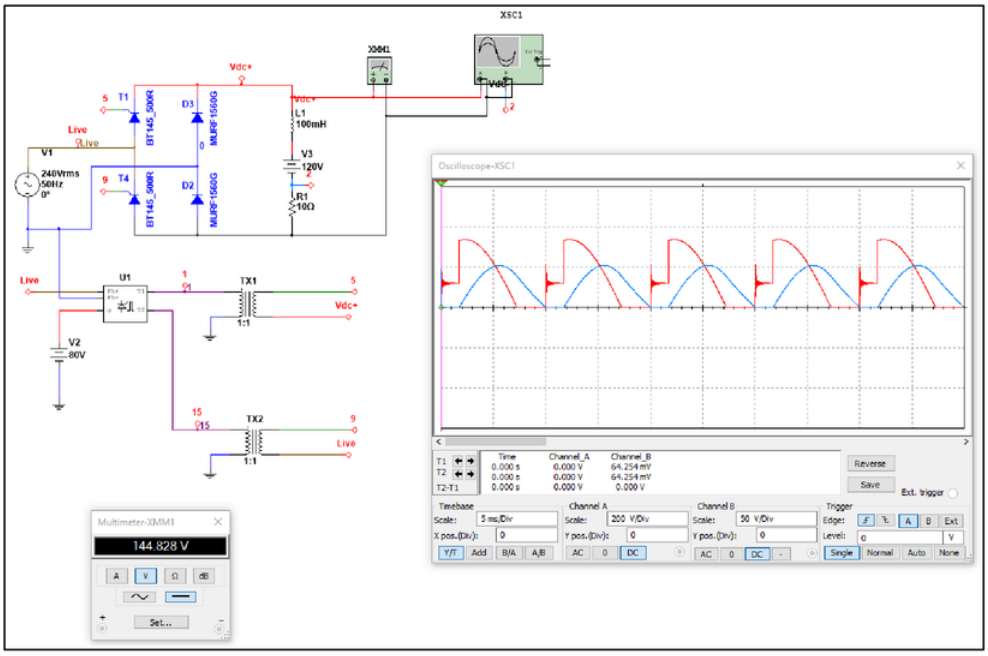


Figure 2.7: Back EMF Loading of 120V with Firing Angle of 80V

a discussion was needed here to explain these waveforms

3 Practical Investigation into a Single Quadrant DC Drive

As part of a team of three, an experiment was conducted to observe the characteristics found through research and simulation. To carry out this experiment, a DC motor with Prony Brake was used to effect a load onto the Motor. Measuring equipment used, comprised of a Digital Tachometer to measure speed, and a Laptop running a Picoscope and Picoscope software to measure the current waveforms. The Author's role in the experiment was to catalogue the screenshots taken by the Picoscope software, while two other colleagues took speed measurements and setting the load.

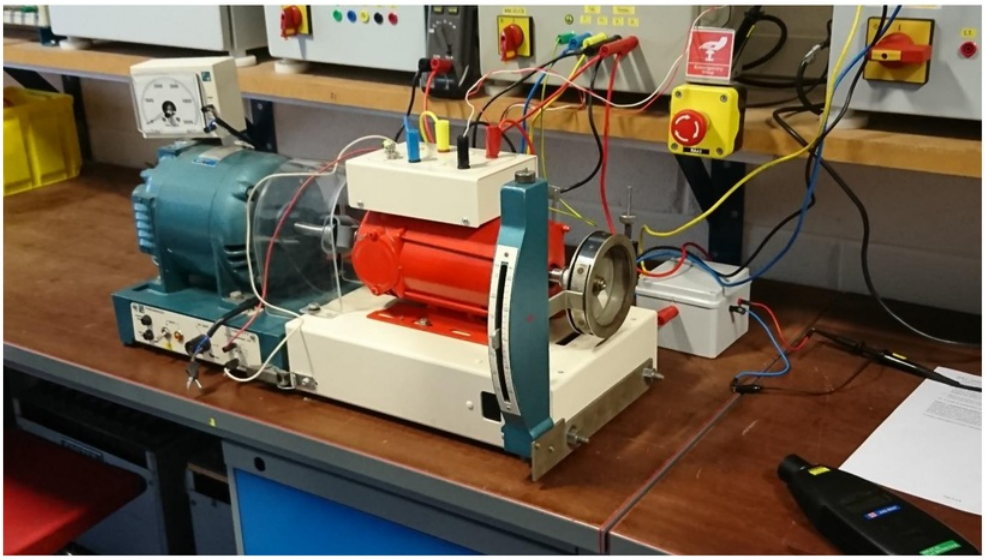


Figure 3.1: DC Motor with Prony Brake linked to Parker 512 C Drive (Tachometer in shot)

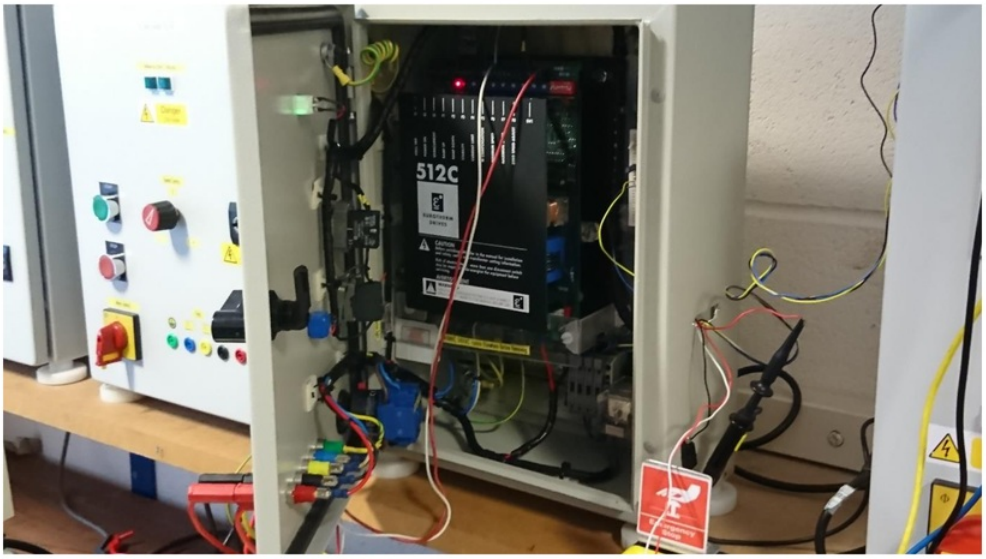


Figure 3.2: Close-up of Parker 512 C Drive with Picoscope probes linked

The first test carried out was without a loading on the motor. The speed at which the DC Motor ran was 567rpm as read by the Tachometer.

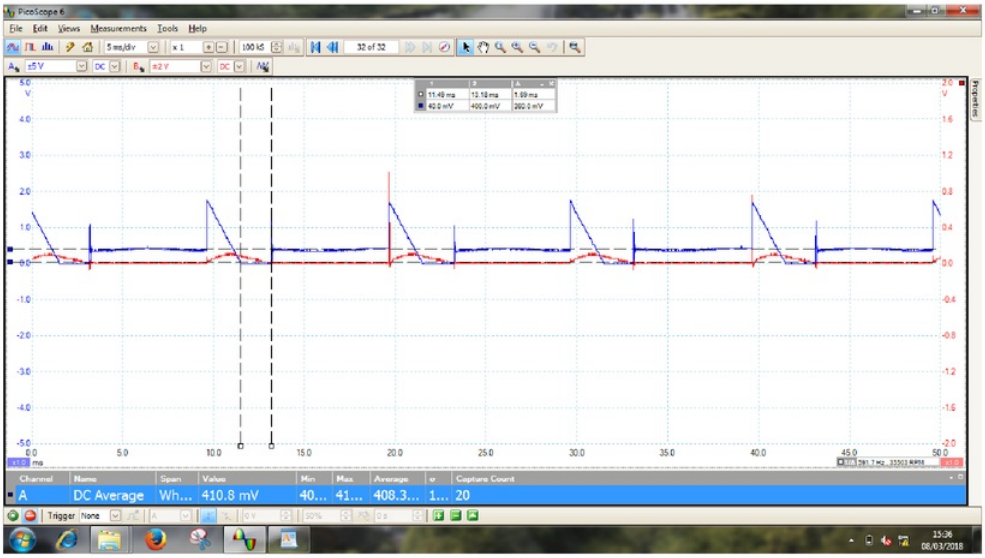


Figure 3.3: t1 reading at 567rpm

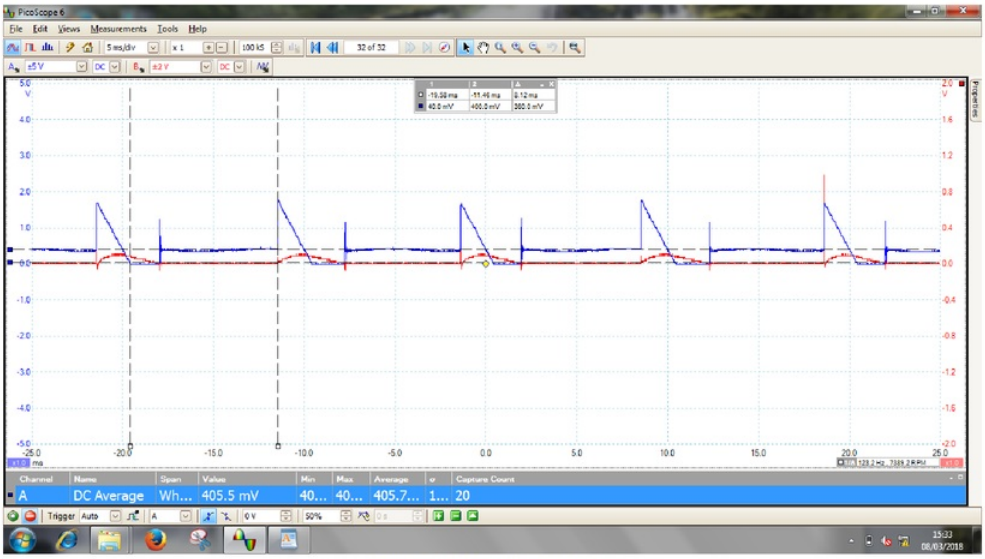


Figure 3.4: t2 reading at 567rpm

With readings taken, the following calculations were performed;

$Vmean = 41V$

$Vmax = 337V$

$$E = 40V$$

$$t_1 = 1.69ms$$

$$t_2 = 8.12ms$$

$$\beta = \frac{t_1}{10 \times 10^{-3}} \times \Pi = \frac{1.69}{10 \times 10^{-3}} \times \Pi = 0.531rad$$

$$\alpha = \frac{t_2}{10 \times 10^{-3}} \times \Pi = \frac{8.12}{10 \times 10^{-3}} \times \Pi = 2.551rad$$

$$Vmean = \frac{E(\alpha - \beta) + Vmax[1 + \cos\alpha]}{\Pi} = \frac{40(2.551 - 0.531) + 337[1 + \cos 2.551]}{\Pi} = 43.89V$$

The experiment was run again, this time at a speed of 1179rpm.

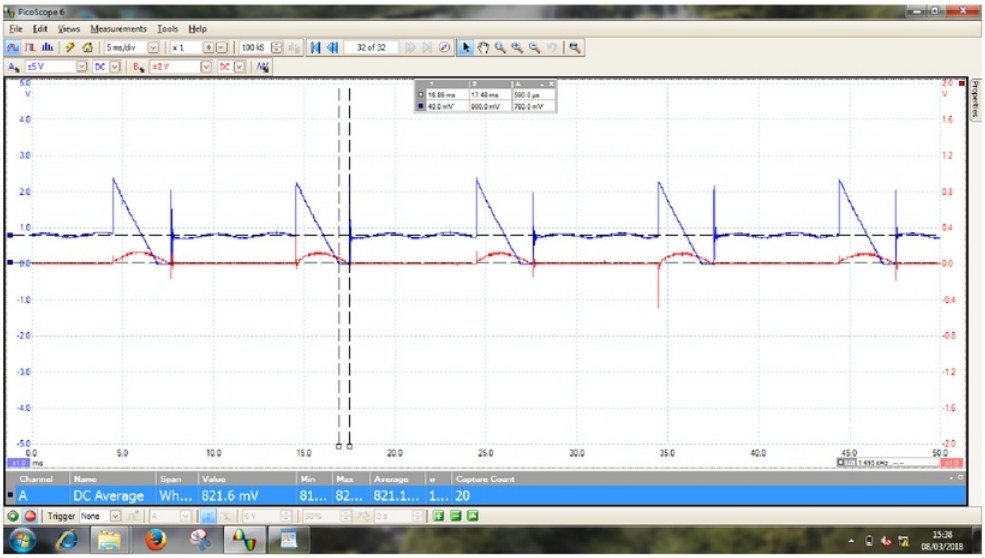


Figure 3.5: t1 reading taken at 1179rpm

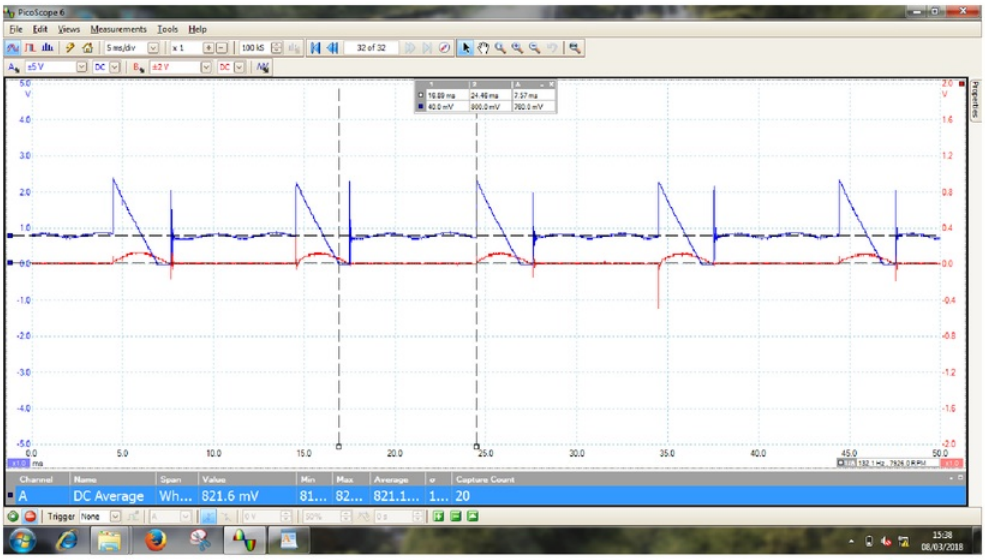


Figure 3.6: t2 reading taken at 1179rpm

$Vmean = 82V$

$Vmax = 337V$

$E = 80V$

$t_1 = 0.59ms$

$t_2 = 4.57ms$

$$\beta = \frac{t_1}{10 \times 10^{-3}} \times \Pi = \frac{1.69}{10 \times 10^{-3}} \times \Pi = 0.185rad$$

$$\alpha = \frac{t_2}{10 \times 10^{-3}} \times \Pi = \frac{8.12}{10 \times 10^{-3}} \times \Pi = 2.378rad$$

$$Vmean = \frac{E(\alpha - \beta) + Vmax[1 + \cos\alpha]}{\Pi} = \frac{80(2.378 - 0.185) + 337[1 + \cos 2.378]}{\Pi} = 85.6V$$

Then a final set of No Load readings were taken. It should be noted that there was no measurable t_1 reading to be measured, so value is assumed to be 0.

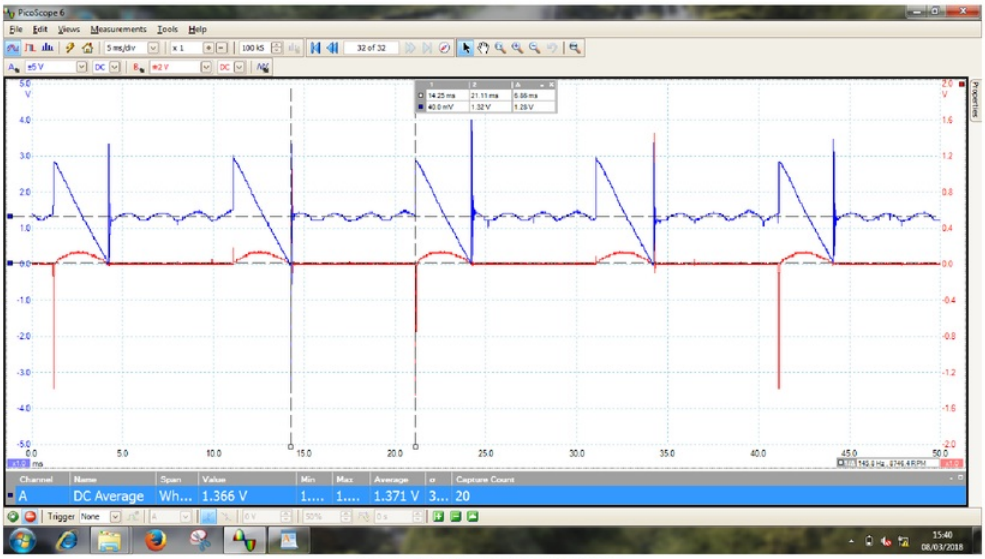


Figure 3.7: t2 reading at 1977rpm

$Vmean = 132V$ *137*

$Vmax = 337V$

$E = 137V$ *132*

$t_1 = 0ms$

$t_2 = 6.86ms$

$$\beta = \frac{t_1}{10 \times 10^{-3}} \times \Pi = \frac{0}{10 \times 10^{-3}} \times \Pi = 0rad$$

$$\alpha = \frac{t_2}{10 \times 10^{-3}} \times \Pi = \frac{6.86}{10 \times 10^{-3}} \times \Pi = 2.155rad$$

132

$$Vmean = \frac{E(\alpha - \beta) + Vmax[1 + \cos\alpha]}{\Pi} = \frac{137(2.155 - 0) + 337[1 + \cos 2.155]}{\Pi} = 142.083V$$

What can be observed is that with No Load, the Back EMF increases with speed. Between the Measured and Calculated Back EMF, there is a slight difference in value, but less than observed in the simulations.

error in use of data, result would be much

With those *closer is correct values were used.*

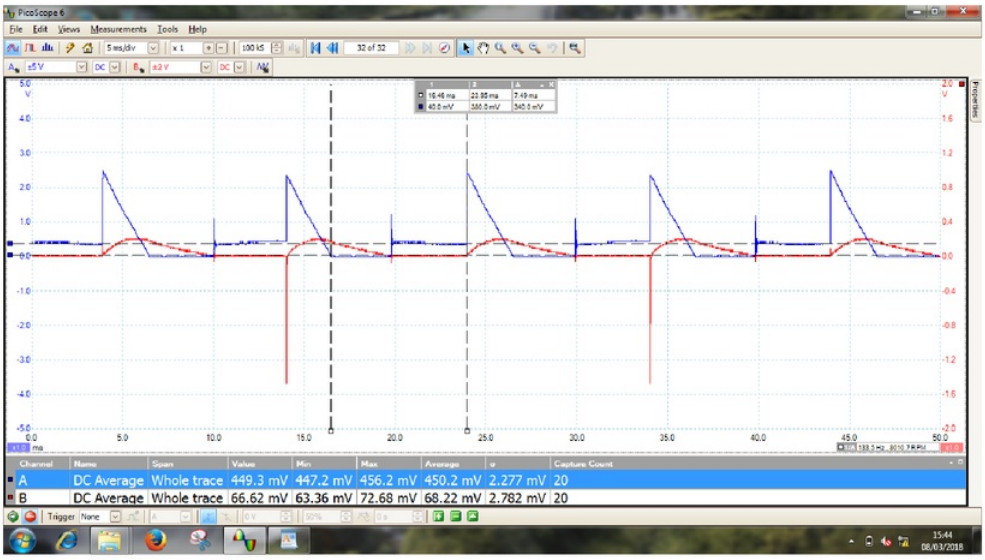


Figure 3.8: 0.2NM at 577rpm

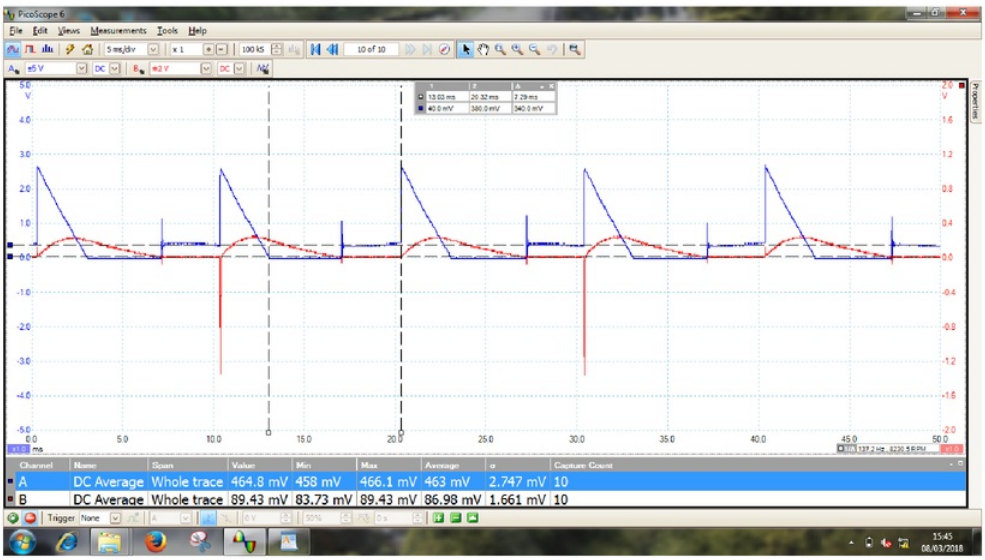


Figure 3.9: 0.4NM at 577rpm

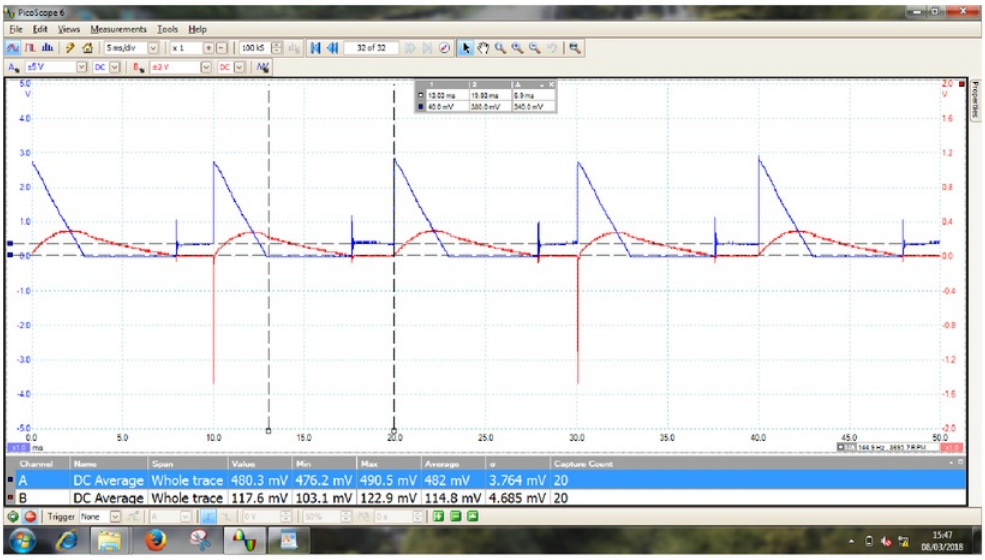


Figure 3.10: 0.6NM at 577rpm

4 CONCLUSIONS AND RECOMMENDATIONS

Through research and Investigation, both simulated and practical, it is observed that DC Drive control is an excellent means of controlling the speed of a DC motor when there is a varying load placed on the motor, which is ideal in the application for a lift (elevator) which over time will have a different load and inertia that must be overcome during operation.

5 WORKS CITED

Austin Hughes, W. D., 2012. *Electric Motors and Drives: Fundamentals, Types and Applications.* Oxford: Newnes.

Pelly, B. R., 1971. *Thyristor phase-controlled converters and cycloconverters: operation, control, and performance.* Michigan: Wiley-Interscience.

Rashid, M. H., 2011. *Power Electronics Handbook.* New York City: Elsevier.

Subrahmanyam, V., 1987. *Thyristor Control of Electric Drives.* New York City: Tata McGraw-Hill Education.

Citations

6 IMAGE SOURCES

Figure 1.1 http://www.bbc.co.uk/staticarchive/e5e943bdad1b3c9baabaf62c2db8c90c8d613d84.gif

Figure 1.2 https://electronicspost.com/wp-content/uploads/2015/07/V-I-Characteristics-of-SCR.png

Figure 1.3 https://www.electronics-tutorials.ws/diode/diode20.gif

Figure 1.4 https://www.electrical4u.com/electrical/wp-content/uploads/2013/05/full-rectified-wave.gif

PSDE5027 Assignment 2

GRADEMARK REPORT

FINAL GRADE

40/100

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

Text Comment. a good description

PAGE 5

Text Comment. good explanation

PAGE 6

Text Comment. good work but this is not what the brief asked for, the circuit should contain 2 thyristors and the load should contain inductance and a back emf also in order to represent a dc motor armature. The equation to be researched or derived was the one used to calculate the average dc voltage for the simulation and practical exercises.

PAGE 7

Text Comment. no thyristor switching and no delay angles

PAGE 8

Text Comment. more marks were available for an explanation of this circuit.

PAGE 9

PAGE 10

PAGE 11

Text Comment. very good presentation of results and calculations

PAGE 12

Text Comment. a discussion was needed here to explain these waveforms

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

Text Comment. 137

Text Comment. 132

Text Comment. 132

Text Comment. error in use of data, result would be much closer is correct values were used.

PAGE 18

PAGE 19

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PAGE 23

GRADING FORM: CSG-RUBIC

EMYR DYER	**45**

RESEARCH-INFORMED LITERATURE

Section 1: Your research - good evidence of

reading. However, not all research relates to the assignment task. (6/15) Section 5: Your use of Harvard for citing and listing - small range of sources listed and cited correctly. (2/5)

8

KNOWLEDGE AND UNDERSTANDING

Section 2: Explanation of simulation circuit - Briefly outlined with a good diagram. (4/10) Section 3: Explanation of practical circuit. Briefly stated with good supporting photos. (4/10)

8

ANALYSIS

Section 2: Analysis of results from simulation – A good set of results and calculations and a brief analysis for the first part but little said for the last part.(5/10) Section 3: Analysis of results from practical experiment – Good results, calculations would be closer if correct values had been used for last calculation. No comments made on part 2 of the experiment. (5/10) Section 4: Overall conclusions and recommendations – brief comments made. (2/10)

12

PRACTICAL APPLICATION AND DEP.

Section 2: Simulation – Good use of software and presentation of results. (6/10) Section 3: Practical experiment – Good use of equipment and Picoscope software. (6/10)

12

SKILLS FOR PROFESSIONAL PRAC.

All sections – Good presentation, well structured.

(3/5) Section 4: Team role – briefly stated in section 3. (2/5) MARK CAPPED TO 40% DUE TO LATE SUBMISSION.

5