

Ass 2 Scott Dedoncker Power and Machines FINAL

by Scott Dedoncker

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HND Electrical & Electronic Engineering

PSDE 5027: Power & Machines



Assignment 2

Investigation into Single Quadrant DC Motor Drives

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1. Research

1.1. Thyristors

A thyristor is an electrical component that works as a controlled rectifier for a circuit. The component has three connection legs consisting of a gate, a positive leg called the anode, and a negative leg called the cathode. The gate is used to regulate the current between the other two legs. They are similar in design and operation to transistors in that a small current is detected at the gate of the thyristor, and this in turn acts as a switch and allows for a larger current to flow between the anode and cathode. The difference from a transistor is that if this small current is removed from the gate of the thyristor, the current will continue to flow between the anode and cathode as the thyristor latches upon the initial detection of current at the gate. This remains until another external forced is imposed on the circuit causing the circuit to restart/reset.

The build of a thyristor can be visualised as a collection of diodes. Diodes are constructed using p-type and n-type semiconductor materials to create a current junction allowing current to either flow through it one way, or block current from flowing through it depending on whether it is forward or reversed biased. A thyristor is built up using four pieces of this material, layered side-by-side alternating between p and n-type material. This creates three junctions between the four layers with the cathode connecting to n-type material, and the anode connecting to p-type material. This is how the current flow is regulated through the thyristor. This is showcased in figure 1 below.

(Woodford, 2018)

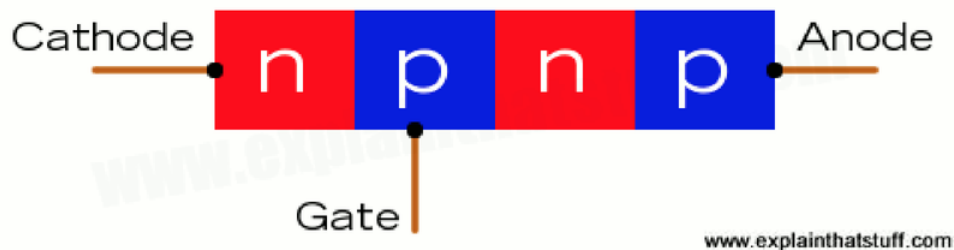


Figure 1 - Thyristor Diode comparison (Woodford, 2018)

A thyristor has three operational states of forward conducting, forward blocking and reverse blocking. Forward blocking is the state where both the upper and lower legs of the diode are forward bias, and no current is flowing through the thyristor. Reverse blocking is similar to forward blocking in that no current flows through the thyristor, but both legs are reverse diode. Forward conducting is the state in which the anode becomes positively charged and the cathode becomes negatively charged. Once the gate detects a current flow, the lower half of the thyristor (gate) is switched which in turn switches the upper half of the thyristor. This continues to switch between the two half's continuously. This is known as positive feedback and allows for current to then flow between the anode and cathode. Once the gate activates the flow of current between the anode and cathode, the gate current becomes irrelevant to controlling the flow of current between the thyristor.

(Woodford, 2018)

*a good
explanatio
n*

1.2. Low Power DC Drive Parker 512C

A DC drive, or variable speed drive is effectively a DC motor used to control speed. This is done by applying and controlling a DC voltage to the drive to either drive or generate. One type of drive that is widely used in industry, and will specifically be used in the practical task of this assignment is the Parker 512C DC Drive.



Figure 2 - Parker 512C (Axis Controls, 2018)

This specific drive is designed for controlling the speed of either permanent magnet or shunt wound DC motors, specifically controlling the torque or speed of the motor. The model ranges in specification from 4 amp to 32 amp, depending on its application. It is designed to be installed within an enclosure in an industrial scenario and should always have a permanent earth connected to the site earth. It can utilise voltages ranging from 110V to 415/420V AC, and can be used at either 50 or 60Hz. The armature voltage is used as the loop for the closed systems feedback when controlling voltage. It includes programmable switches for this purpose. It also has a safety cut out feature which removes current from the motor after 1 minute. This drive is what is connected to the AC 3 phase motor and analysed in task 3 of this assignment.

(Parker)

good

1.3. DC Rectifier Circuits

Semiconductor built power devices have a wide range of applications throughout industry, from simple tasks such as charging batteries, to controlling motor speeds in the form of DC drives, electric controlled traction and high voltage DC transmission. These applications use phase-controlled (thyristor) rectifiers, which gives them an advantage of controlling voltage output over typical diode rectifiers. This is done by varying what is called the firing angle of the phase-controlled rectifier to suit a desired output voltage. This is applied mainly in DC drive control.

1.3.1. Single Phase Half Wave Controlled Rectifier (Resistive Load)

The circuit as well as waveforms for this type of rectifier can be seen in figure 3. The circuit consists of a voltage supply, the resistive load and a thyristor. The thyristor begins as forward bias and awaits a gate voltage to be applied to it so that it can begin to conduct. Upon the application of a gate voltage, the thyristor begins to conduct and applies a voltage to the resistive load. This is the first (positive) half cycle of the thyristor. During the second (negative) half cycle the diode becomes reverse bias and deactivates. The load voltage is controlled by only being utilised in the positive half cycle of the thyristor and varying the firing angle (α). The waveforms show from top to bottom the input voltage waveform, current across the gate of the thyristor, output voltage waveform, and the voltage across the thyristor.

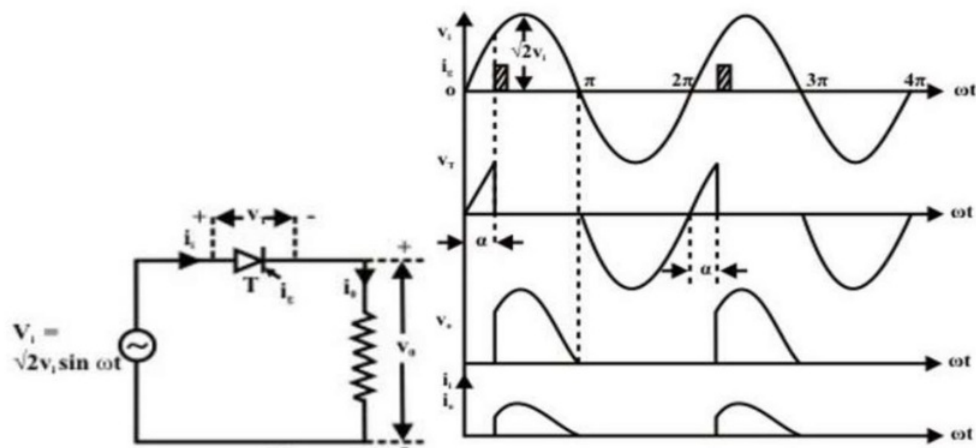
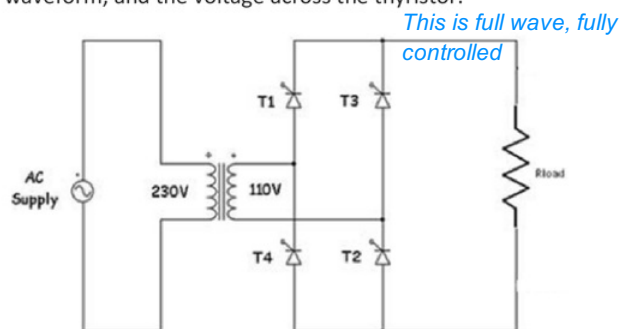


Figure 3 - Single Phase Half Wave Controlled Rectifier (Ahmed, 2017)

This is the wrong circuit, it should be full-wave, half controlled. Where is your derivation of the formula for average voltage or your quotation from a source as required by the brief?

1.3.2. Single Phase Full Wave Controlled Rectifier (Resistive Load)

The circuit as well as waveforms for this type of rectifier can be seen in figure 4. This circuit contains 4 thyristor, a resistive load, and a voltage source of 230v 3-phase stepped down to 110v. This circuit works similarly to the first circuit in that it utilises the two half cycles, positive and negative of the input voltage. For the first half cycle (positive), thyristor T1 and T2 are set at forward bias awaiting a signal from the gate current. A gate pulse is then activated and detected through thyristor T1 and T2 when $\omega t = \alpha$. Once this happens the two thyristor begin to conduct and apply voltage to the load. During the second half cycle (negative) thyristor T3 and T4 are forward bias and T1 and T2 are set to reverse bias. When these two thyristor receive a gate current at $\omega t = \pi + \alpha$ they begin to conduct and apply a voltage to the resistive load. This means the load is receiving a voltage over both half cycles. The waveforms show from top to bottom the input voltage waveform, output voltage waveform, and the voltage across the thyristor.



This is the wrong circuit, it should be full-wave, half controlled. Where is your derivation of the formula for average voltage or your quotation from a source as required by the brief? The load should contain inductance and a back EMF also.

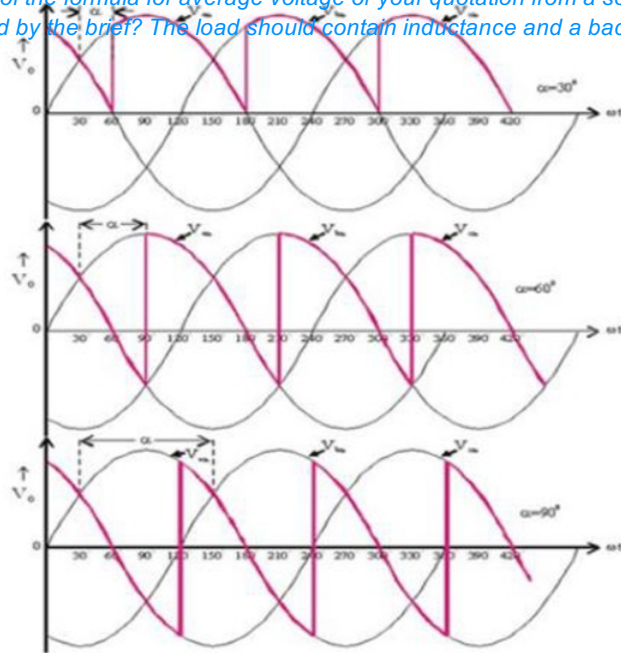


Figure 4 - Single Phase Full Wave Controlled Rectifier (Electronics Tutorial, 2015)

These are 3 phase waveforms from a 3 phase rectifier but the brief asks for a single phase rectifier. Again, you have not read the brief carefully enough.

2. Simulation of a Half-Controlled Rectifier Circuit

For the simulation task of this assignment, a half controlled rectifier circuit needed to be simulated and monitored in Multisim. The performance of the circuit needed to be analysed for a single phase, full wave D.C motor. The armature needed to be modelled as a load containing a source of inductance (fig.5 L1), a resistor (fig. 5 R1) and a voltage source of back E.M.F (fig.5 V3).

From the example of the circuit in figure 5 it is clear to see that the circuit uses a full wave controlled rectifier with a resistive inductive load. The source of voltage for the circuit is set to 240 Vrms at 50 Hz. Two types of thyristors were used and a multi meter as well as an oscilloscope was connected to the circuit to take measurements.

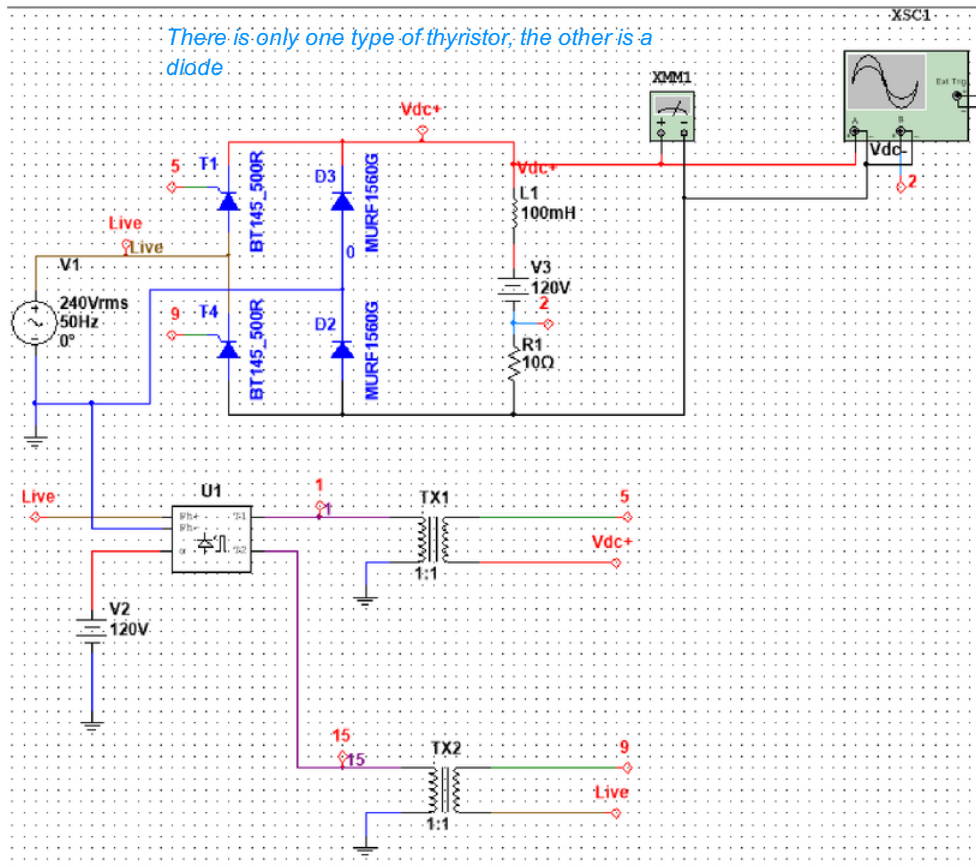
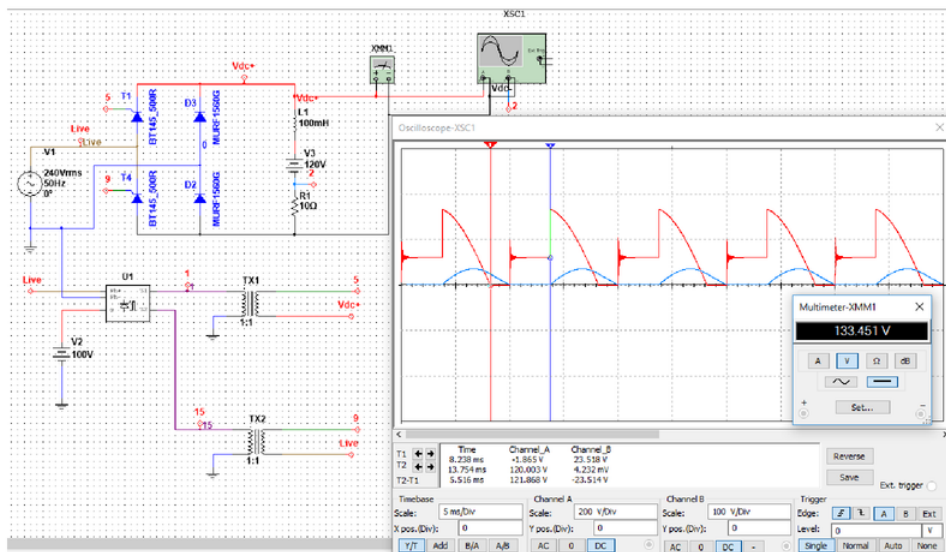


Figure 5 - Simulation Circuit

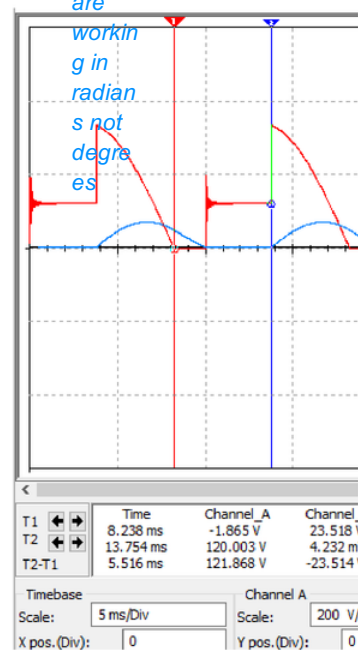
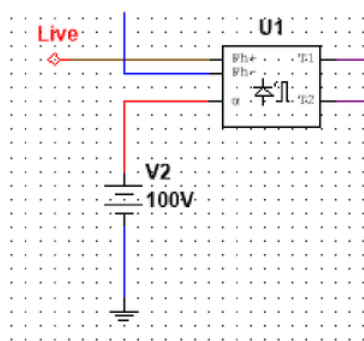
2.1. Firing Angle Results 1

The firing angle was first set to 100° . This gave an armature voltage of 133.451V. E (Back E.M.F) was set to 120v in this circuit. Measuring t_2 gives a value of 5.516ms.

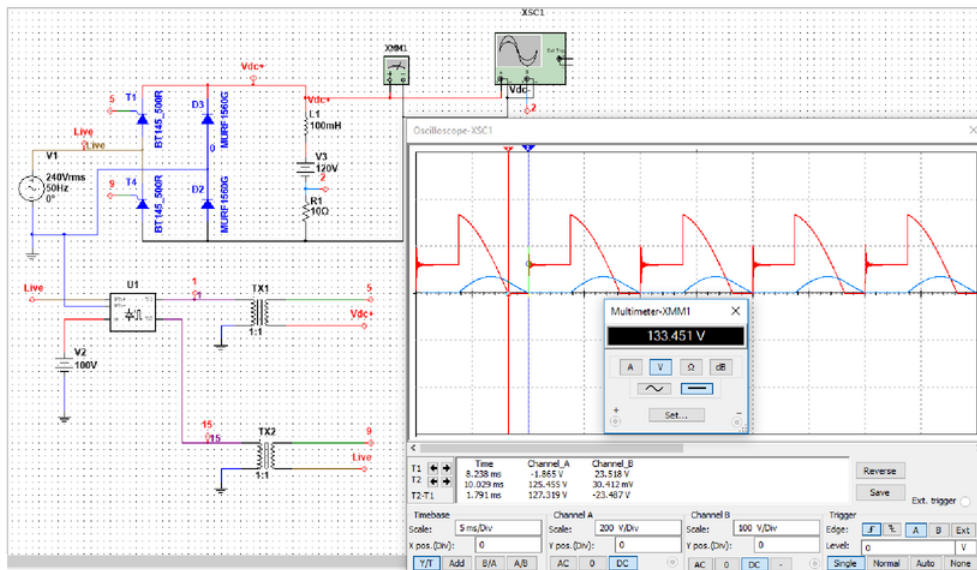


As this time is a fraction of 10 ms, the distance between the two points for t_2 can be verified using the equation; $t_2 = 5.516\text{ms}/10\text{ms} \times 180^\circ = 99.288^\circ$. This proves the results as the firing angle was set to 100° , so taking into account minor discrepancies the equation gives the same result. Alpha can then be derived using the equation; $\alpha = 5.516\text{ms}/10\text{ms} \times \text{Pie} = 1.73^\circ$. This can be used to calculate the armature voltage.

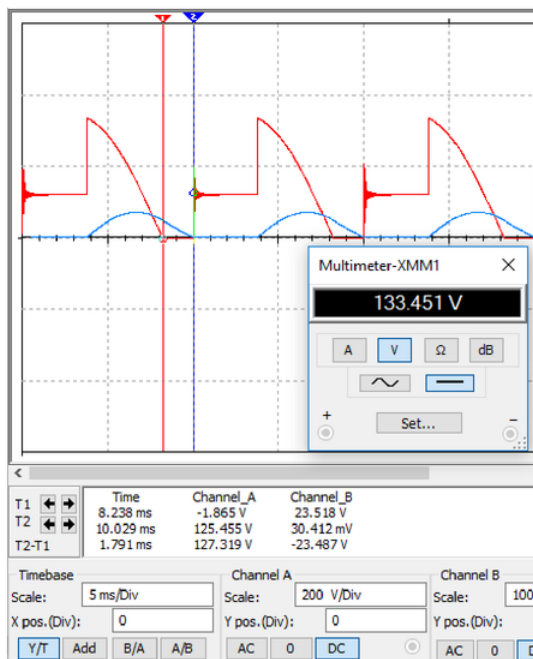
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Measuring t1 with the same firing angle gives a value of 1.791ms.



The distance between these two points for t1 is not shown in the circuit and therefore cannot be confirmed. Therefore, we can only work out beta with the equation; $\beta = 1.791\text{ms}/10\text{ms} \times \pi = 0.562^\circ$. This value will also be used to work out the armature voltage.



The average armature voltage is shown for this firing angle of 133.451V. As E was also measured at 120v, Vrms was set to 240v, we can confirm this armature voltage by using the following equations:

$$V_{max} = \sqrt{2} \times V_{rms}$$

$$V_{max} = \sqrt{2} \times 240 = 339V$$

$$V_{av} = \frac{E(\alpha - \beta) + V_{max} (1 + \cos \alpha)}{\pi}$$

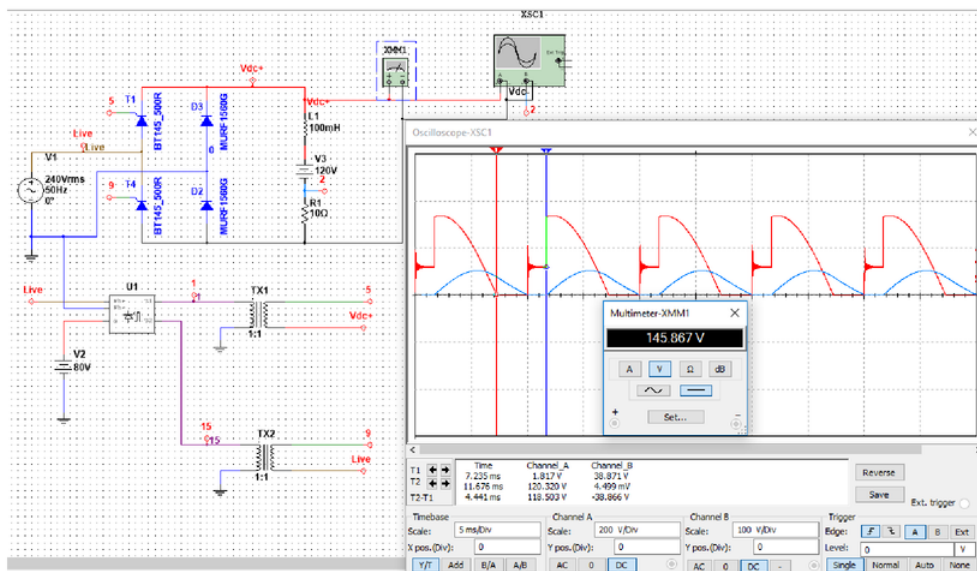
$$V_{av} = \frac{120(1.73 - 0.562) + 339 (1 + \cos(1.73))}{\pi} = 135.41V$$

correct equation but where did it come from?

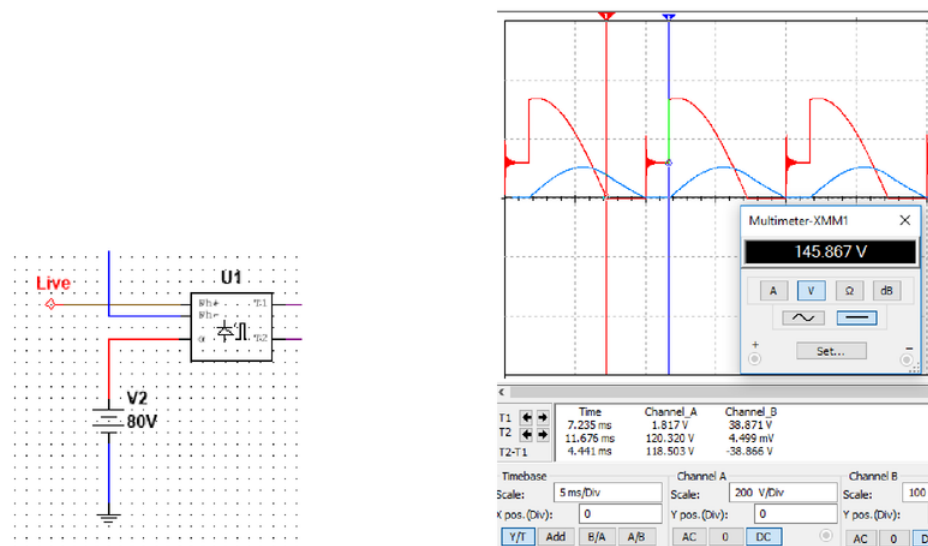
2.2. Second Firing Angle results

The firing angle was altered again to give two new simulated results for alpha and beta. This time the firing angle was set to 80° (v). E still remained at 120v and was proved on channel A of the oscilloscope to be such, and the armature voltage was measured at 145.867V for this firing angle.

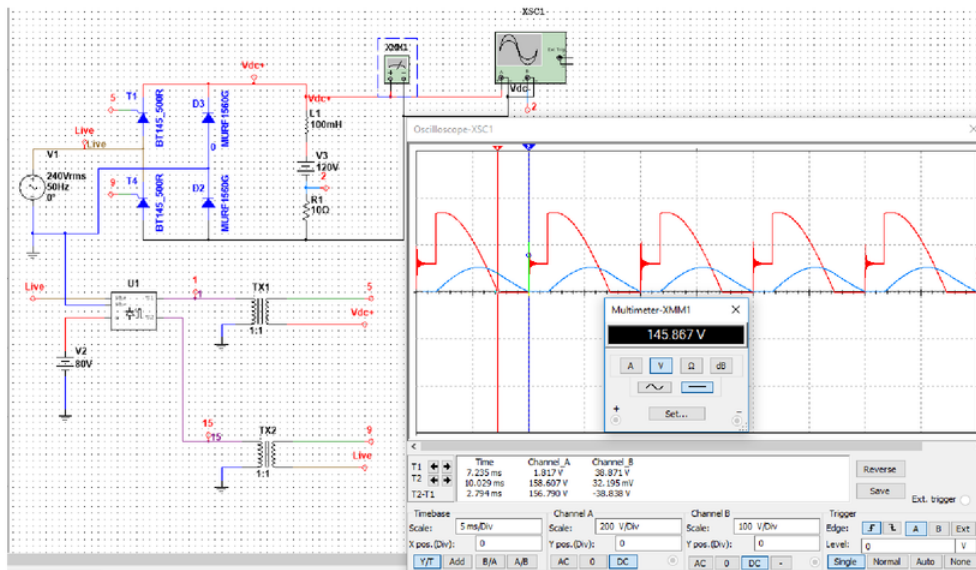
Measuring the distance between the two points for t2 on the oscillator response gave a value of 4.441ms. Using the equation again to confirm the firing angle gave a value of; $t_2 = 4.441\text{ms} / 10\text{ms} \times 180 = 79.938^\circ$. Alpha was then derived for the armature voltage calculation using the equation; $4.441\text{ms} / 10\text{ms} \times \pi = 1.39^\circ$.



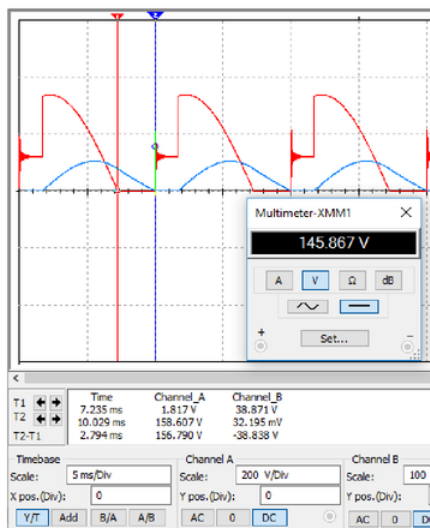
Comparing this value of 79.938V to the inputted value of 80V proves that the measured distance for t2 is correct, and the value of t2 for the firing angle is accurate.



Measuring t_1 with the same firing angle gave a value of 2.794ms. However, as t_1 could not be compared to any value of the circuit, only beta needed to be derived for the armature voltage equation. The equation for this was; $\beta = 2.794\text{ms} / 10\text{ms} \times \pi = 0.878^\circ$.



The measure value for E on this test is slightly higher than the inputted value of 120V as the cursor was not put on accurately and instead measured the initial voltage spike of 158.607V. This is a minor discrepancy.



The armature voltage needed to be confirmed using calculations similar to the first sets of results. The average armature voltage is shown for this firing angle of 145.867V. As E was also measured at 120v, Vrms was set to 240v, and using the two derived values for alpha and beta, we can confirm this armature voltage by using the following equations:

$$V_{av} = \frac{E(\text{Alpha} - \text{Beta}) + V_{max} (1 + \cos \text{Alpha})}{\pi}$$

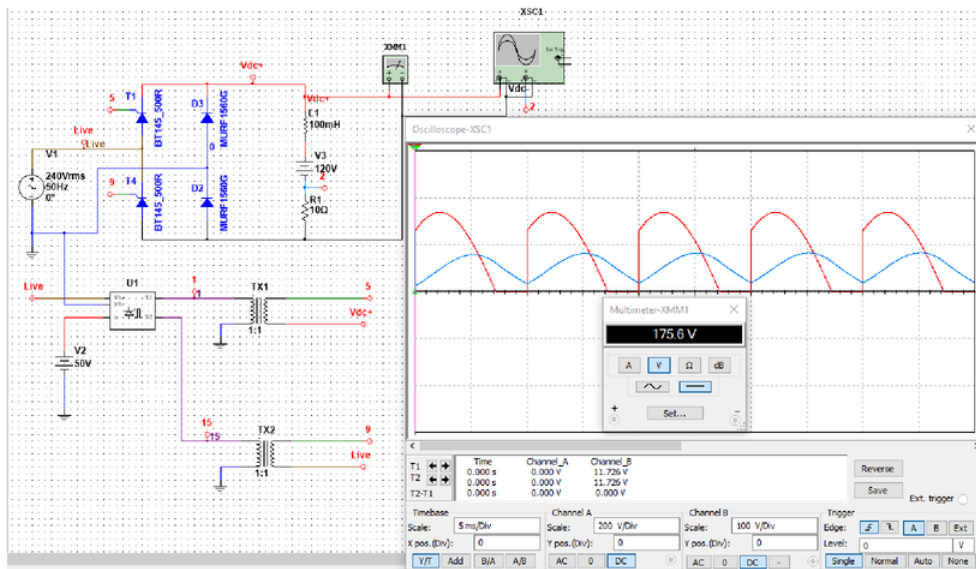
$$V_{av} = \frac{120(1.395 - 0.878) + 339 (1 + \cos(1.395))}{\pi} = 146.52V$$

where is your comparison table and reasoning?

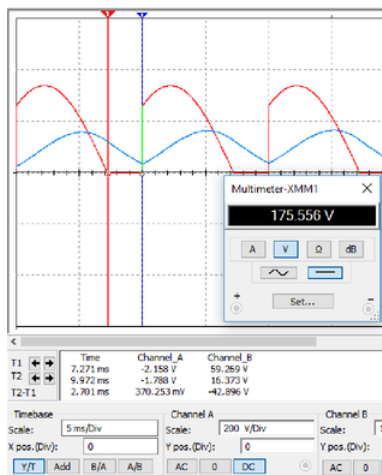
2.3. Mechanical Loads

The second part of this task involved simulating and observing the effects of mechanical loads on the armature inductance for one firing angle. In order to do this the Back E.M.F needed to be changed for two values simulating continuous and discontinuous current.

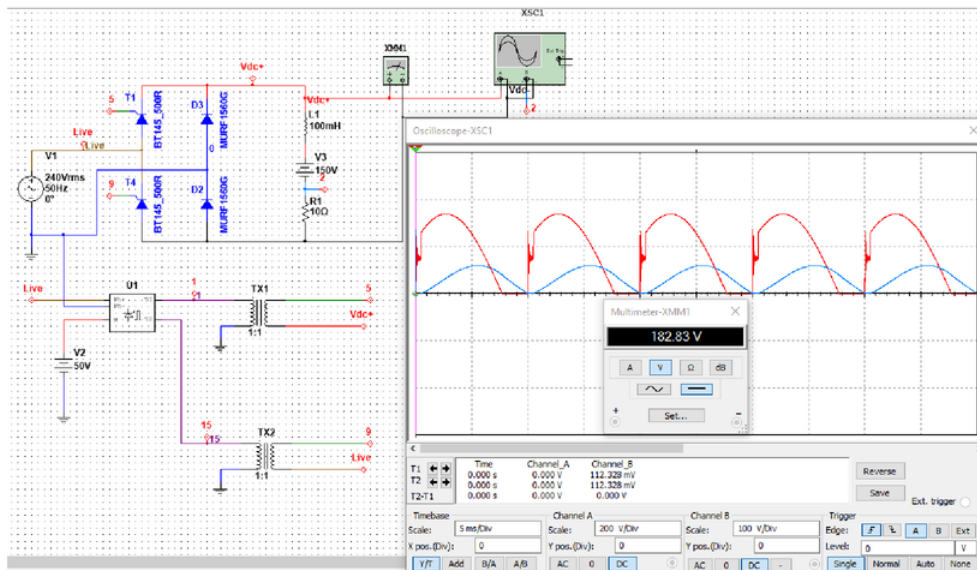
The first simulation was for continuous current and used a firing angle of 150° and a back E.M.F of 120V. As there was continuous current between the diodes, there is no visible back E.M.F in the simulated results given by the oscilloscope. The blue waveform indicates continuous current as it never dips below 0.



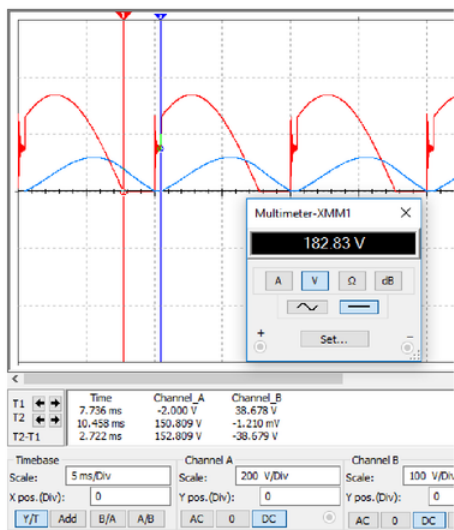
T2 was measured at 2.701ms.



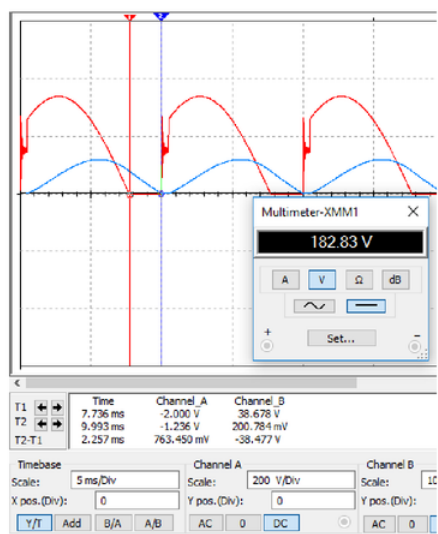
The second simulation used the same firing angle of 50° , with a back E.M.F value of 150V set on V3. This gave a simulated response that indicated discontinuous current as the blue waveform dipped below 0 for a certain period of time. While the current was discontinued, it also resulted in a back E.M.F being displayed by the red waveform.



T2 was measured at 2.722ms.



T1 was measured at 2.257ms.



3. Practical Investigation into a Single Quadrant DC Drive

The final task for this assignment involved working in a small team performing a practical analysis of a single quadrant dc drive. The drive being investigated was the Parker 512C as researched earlier on in the assignment. A DC motor including the use of a prony brake, and a multi meter and laser sensor were used to measure certain variables including the voltage and RPM of the motor.

Two experiments were conducted, one looking into the drive and motors performance under no load conditions where the motor would be analysed under 3 different speeds. The second experiment restricted the motor to one speed setting and the prony brake would be used to apply three different (mechanical) load settings to the motor shaft.



Figure 6 - Test Motor and Drive

For the first experiment two values were to be measured from each waveform. The first would be the $\pi\theta$ value for t_1 . This is known as the firing angle and records the current degradation period once the phase response reaches 0. The second value measured was t_2 , also known as the phase response time. The conducting period of the waveform while visible on the results would not be recorded.

this is a dc motor! The second test would involve applying the prony brake to the motor shaft to simulate a load on the 3-phase motor. The drive would then be activated and the current waveform would be recorded again. Values of t_1 and t_2 would once again be measured, with t_1 expecting to increase as the load increases, and t_2 decrease.

these paragraphs contain misconceptions

3.1. Speed Setting: 651 RPM

Picoscope is not a simulation
The first speed setting of 651RPM gave us the following response when the data was inputted into the simulation software. The waveform shows a general no load response. The two cursors were used to locate t1 on the response, which was measured at 1.58ms.

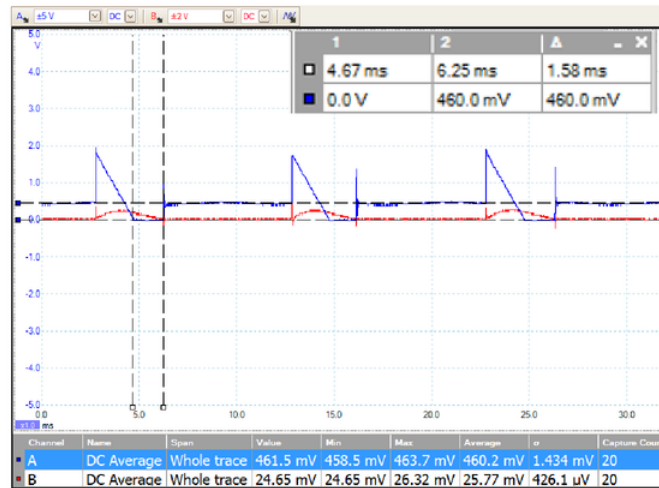


Figure 7 - Speed Response 1.1

T2 was also measured to be 8.16ms by moving the cursors so that they would record the response time of one phase of the drive. *alpha (the firing angle)*

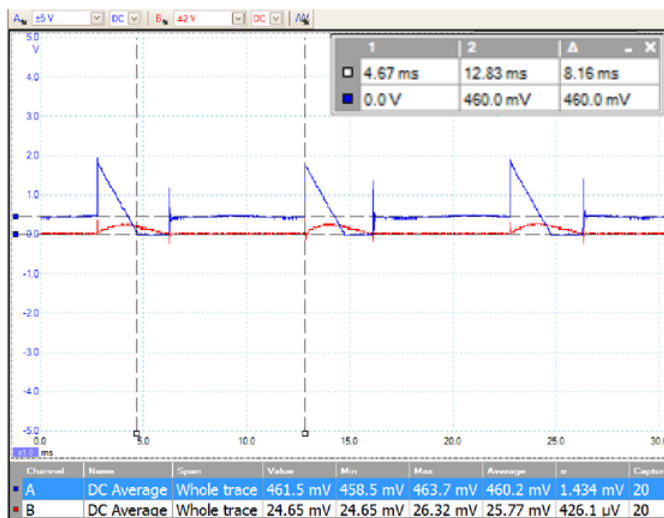


Figure 8 - Speed Response 1.2

where are your calculated values?

3.2. Speed Setting: 1319 RPM

The second speed test performed had the motor Spelling span up to 1319 RPM. This decreased the down time it took for current depletion from this phase and therefore gave a smaller t1 reading. The t1 value was measured as 59 us.

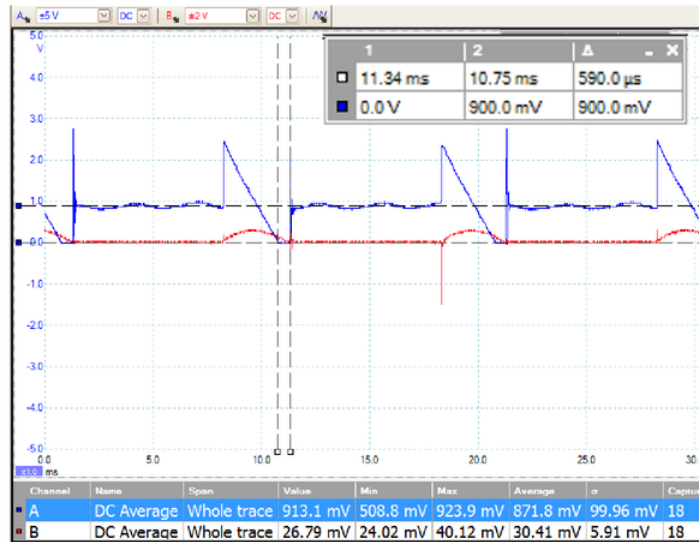


Figure 9 - Speed Response 2.1

The phase response period also slightly shortened due to the increased rpm. The t2 value was measured over the response time period at being 7.53ms

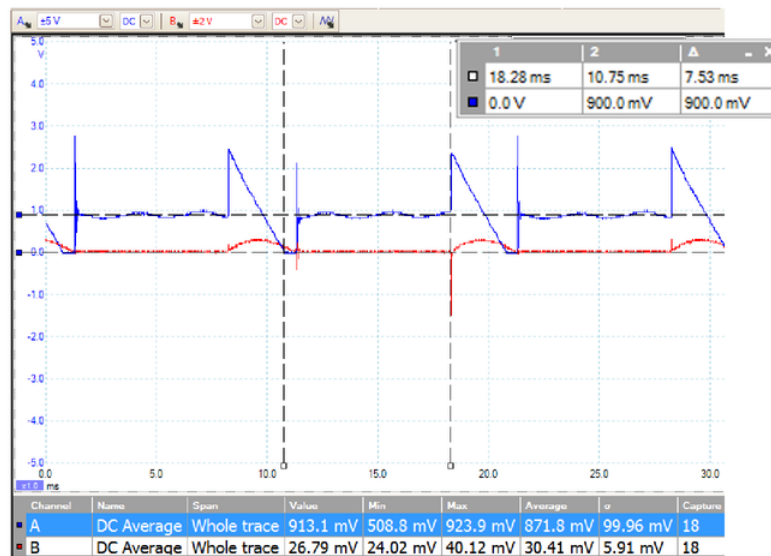


Figure 10 - Speed Response 2.2

3.3. Speed Setting: 2597 RPM

The third speed of 2597 RPM did not have a t1 value to record as can be seen in figure 11. This is because the time frame for π_0 had become so small it was negligent. T2 was still measured for the response time however it had once again decreased due to the increased rpm. T2 was recorded as 6.63ms.

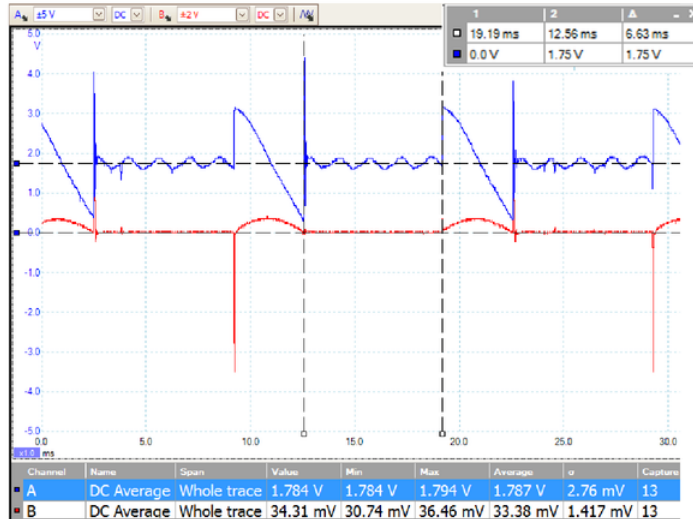


Figure 11 - Speed Response 3.1

calculations? table of results for comparison?

3.4. Braking Test 1

The first test for braking test recorded a speed of 1067 RPM. T1 was then recorded giving a value of 1.31ms.

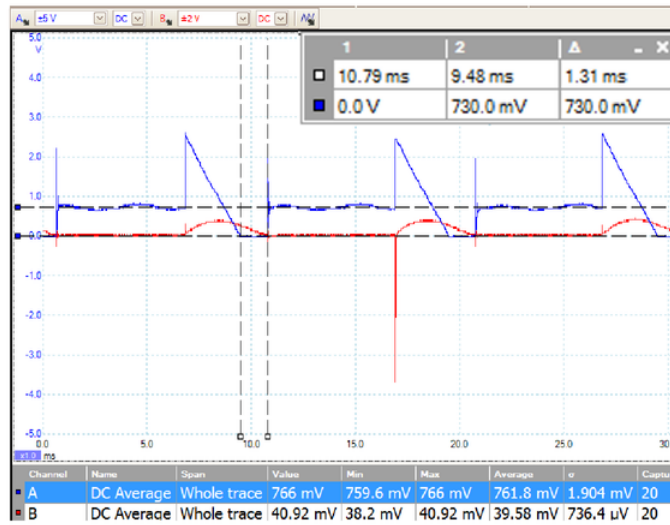


Figure 12 - Braking Test 1.1

alpha

The phase response time value for t2 for this test gave a value of 7.42ms

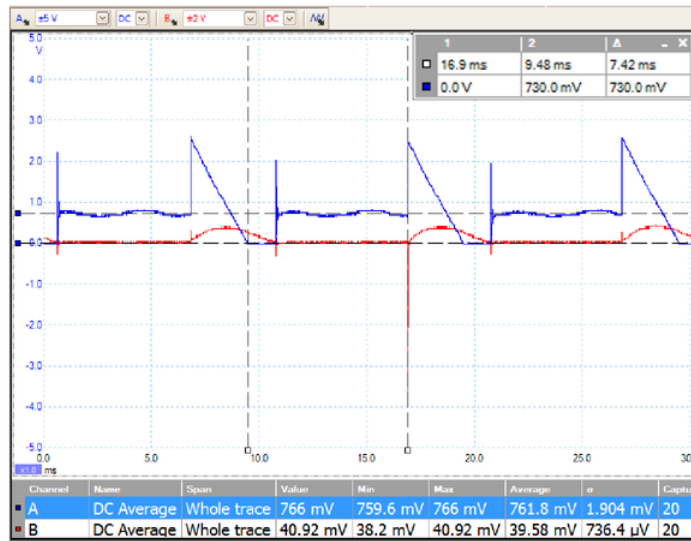


Figure 13 - Braking Test 1.2

3.5. Braking Test 2

The second braking test had the prony brake apply more pressure to the motor shaft, causing for a heavier load to be applied to it while working. This caused the RPM of the motor to decrease down to 1051 RPM. It also caused T1 to increase due to the larger working load. T1 was now measured as being 3.24.

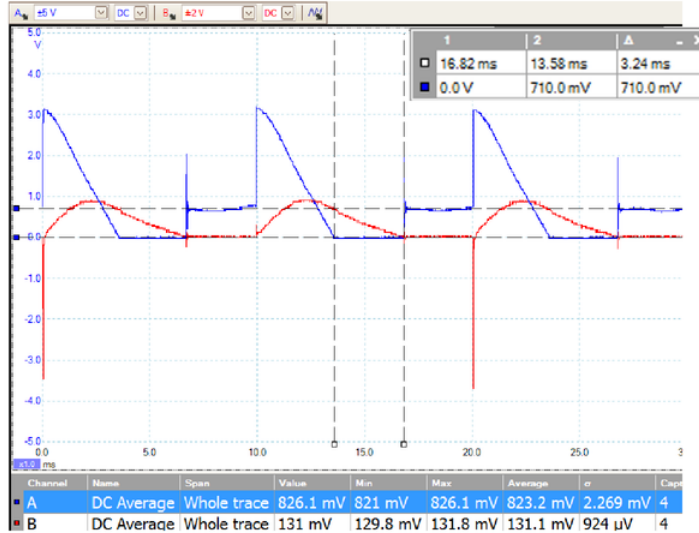


Figure 14 - Braking Test 2.1

Due to the increased load on the motor it caused for a shorter response time between phases. This lead to t2 decreasing to 6.47ms.

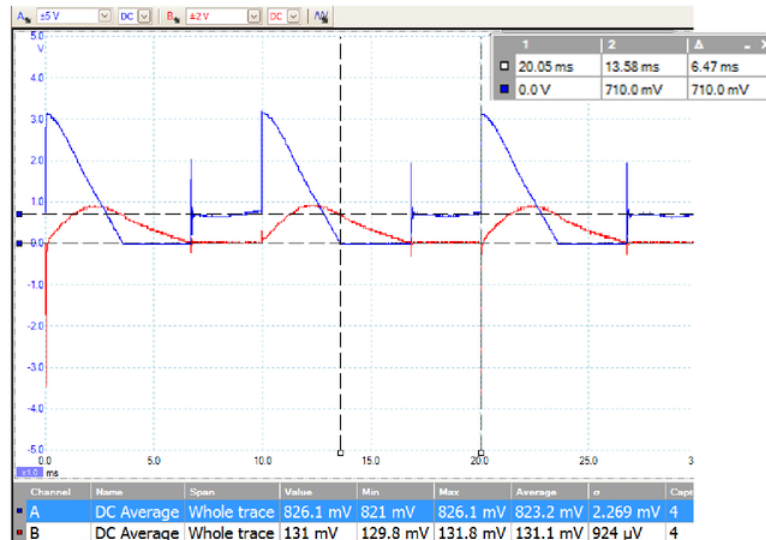


Figure 15 - Braking Test 2.2

3.6. Braking Test 3

The third braking test had the load increased further to apply more force on the working motor shaft. This caused the current degradation period to increase further again. T1 was measured as 3.99ms

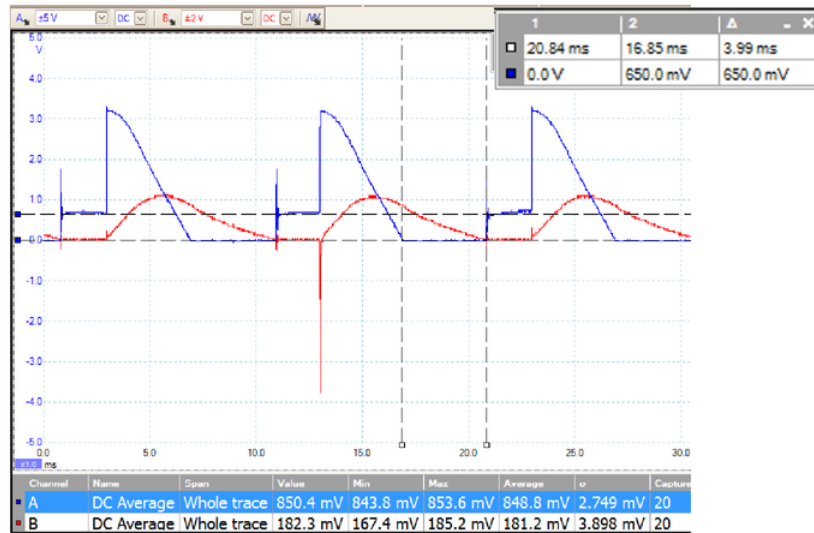


Figure 16 - Braking Test 3.1

The value for t2 also decreased due to the quicker phase response time as the motor was working harder. The value for t2 was measured at 6.12ms.

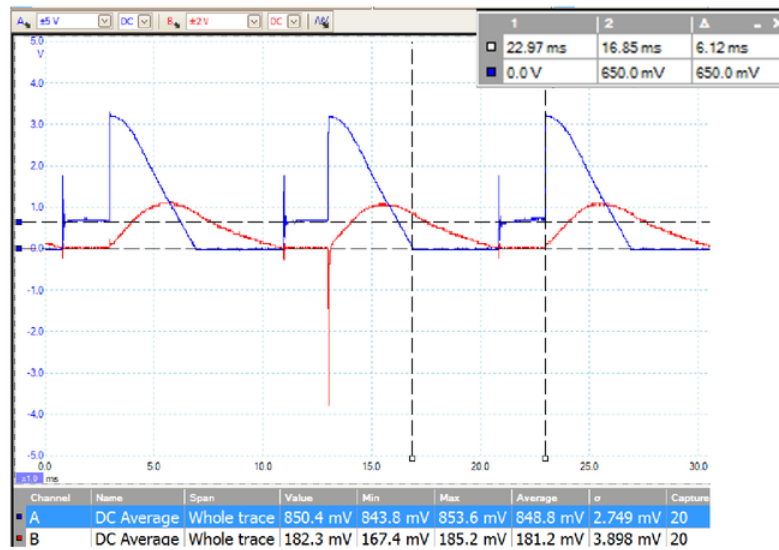


Figure 17 - Braking Test 3.2

4. Conclusions & Recommendations

4.1. Research

The first part of this assignment was to investigate various aspects of this topic. This would be used to give grounding on the knowledge needed to carry out the simulated and practical experiments in task 2 and 3. The first section that was researched was Thyristors. The thyristor was shown to be broken down into 3 parts, the anode, cathode and gate. It is explained how the gate is used to control the bias nature of the cathode and anode over two half cycles by using current flow. The second part of the research involved looking into the specific drive that would be used in the practical experiment. This was the Parker 512c DC drive and its design specifications were listed out in full in this section. The third part of the research investigated rectifier circuits including full and half wave circuits. This would relate to the simulated and practical experiments, as these would be used for both tasks. *half wave was not asked for* *No formula research yet it is included in section 2*

4.2. Simulated Experiment

The simulated experiment used a MultiSim circuit of a full wave controlled rectifier with a resistive inductive load. The first firing angle of 100° was simulated and gave an average voltage of 133.451v. various values were then derived using equations for t1, t2 alpha and beta and it gave the final equation which proved the average voltage measured on MultiSim. This proved that the simulation gave accurate results for the inputted firing angle value.

$$V_{av} = \frac{120(1.73 - 0.562) + 339 (1 + \cos(1.73))}{\pi} = 135.41V$$

The second firing angle value simulated was 80° and gave an average voltage value of 145.867v. the same equation was derived again using values given from this simulation and it proved that the simulated values were accurate as the equation gave a very similar average voltage value.

$$V_{av} = \frac{120(1.395 - 0.878) + 339 (1 + \cos(1.395))}{\pi} = 146.52V$$

Mechanical loads were then simulated in the forms of continuous current using the firing angle of 150°, and discontinuous current using the firing angle of 50°

4.3. Practical Experiment

the title of the assignment clearly shows this is a dc motor not a 3 phase ac motor.
The third task in this assignment involved using a practical rig with a 3-phase motor and parker 512c DC drive to simulate a motor being driven both off and under load. A laptop was then used to monitor the voltage and current waveforms from the motor while the experiment was being carried out. The motor was first run off load under three various speeds, and then under load for 3 different speeds, then for braking.

where is your section on collaboration?

5. Citation List

Works Cited

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6. Appendices

Ass 2 Scott Dedoncker Power and Machines FINAL

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

53/100

PAGE 1

PAGE 2

PAGE 3

Text Comment. a good explanation

PAGE 4

Text Comment. good

PAGE 5

QM

Spelling

Spelling error

Text Comment. This is the wrong circuit, it should be full-wave, half controlled. Where is your derivation of the formula for average voltage or your quotation from a source as required by the brief?

PAGE 6

Text Comment. This is full wave, fully controlled

Text Comment. This is the wrong circuit, it should be full-wave, half controlled. Where is your derivation of the formula for average voltage or your quotation from a source as required by the brief? The load should contain inductance and a back EMF also.

Text Comment. These are 3 phase waveforms from a 3 phase rectifier but the brief asks for a single phase rectifier. Again, you have not read the brief carefully enough.

PAGE 7

Text Comment. There is only one type of thyristor, the other is a diode

Text Comment. you are working in radians not degrees

Text Comment. correct equation but where did it come from?

Text Comment. where is your comparison table and reasoning?

Text Comment. 50 degrees

Text Comment. this is a dc motor!

Text Comment. these paragraphs contain misconceptions

Text Comment. Picoscope is not a simulation

Text Comment. alpha (the firing angle)

Text Comment. where are your calculated values?



Spelling

Spelling error

Text Comment. what is this?

Text Comment. alpha

Text Comment. calculations? table of results for comparison?

PAGE 21

Text Comment. alpha

PAGE 22

PAGE 23

PAGE 24

Text Comment. half wave was not asked for

Text Comment. No formula research yet it is included in section 2

Text Comment. the title of the assignment clearly shows this is a dc motor not a 3 phase ac motor.

Text Comment. where is your section on collaboration?

PAGE 25

PAGE 26

GRADING FORM: CSG-RUBIC

SCOTT DEDONCKER

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RESEARCH-INFORMED LITERATURE



Section 1: Your research - A good section on thyristors and the dc drive and apps. However, not all parts have been answered correctly and some information is not relevant to the task. (8/15)
Section 5: Your use of Harvard for citing and listing

9

- Small range of sources cited correctly but not listed according to Harvard. (1/5)

KNOWLEDGE AND UNDERSTANDING



Section 2: Explanation of simulation circuit - Some good parts but there are some misconceptions. (5/10) Section 3: Explanation of practical circuit. Some good parts but again, there are some misconceptions (5/10)

10

ANALYSIS



Section 2: Analysis of results from simulation – Some good analysis but no table of results for comparison and no account of differences. (6/10) Section 3: Analysis of results from practical experiment – Good measurements taken but no calculations performed and wrong terms used in explanation. (4/10) Section 4: Overall conclusions and recommendations – Generally good but again there are misconceptions e.g. you are referring to a 3 phase motor but the assignment is about a dc motor. (6/10)

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PRACTICAL APPLICATION AND DEP.



Section 2: Simulation – Good evidence of the use of Multisim software and presentation of results. (7/10) Section 3: Practical experiment – Good use of Picoscope and measuring equipment and good presentation of results. (7/10)

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SKILLS FOR PROFESSIONAL PRAC.



All sections – Well structured and presented. (4/5)
Section 4: Team role – non mention given. (0/5)

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