

PSDE 5027 Assn 2, NS

by Nathan Smith

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HND ELECTRICAL & ELECTRONIC ENGINEERING

PSDE 5027 POWER & MACHINES

ASSIGNMENT 2 INVESTIGATION INTO SINGLE QUADRANT DC MOTOR DRIVE

Nathan Smith, Word Count = 6101

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1. Research

Thyristors and their usage as controlled rectifiers

A thyristor or a silicon controlled rectifier as they are known to some companies as a brand name, is an electrical component which contains three parts which are the cathode (negative side), anode (positive side) and the gate. The gate part of the thyristor will control how the current will flow through the cathode and anode, this gate current will cause the thyristor to act as a latch as when a trigger current enters the gate it will produce a larger current to stay on latch from the anode to the cathode until that current is reset. So, a thyristor is basically a bistable switch once the gate has been triggered as explained above. A thyristor is basically a device that has reverse and forwards blocking capabilities and is activated to conduct by a gate.

A Thyristor can handle high voltage systems and usually deal with hundreds of volts and between 5 to 10 Amps, these make them ideal for industrial applications and are used in equipment like motor speed controlling, thermostats and switched on vehicle ignitions. Thyristors are a very reliable product and due to lack of complex and moving parts make them popular as solid-state relays. (Woodford, 2012). The thyristor or control rectifier is contrasted of four layers of semiconductors, these semiconductors create structures called the pnpn or npnp. There are three terminals and three PN sections are set up as j1-j3. The anode part is connected to the P part of the pnpn with the cathode joining to the n type of the structure. The gate part of the thyristor will connect to the p type part of the structure located closest to the cathode. (Woodford, 2012).

Figure 1 below shows an equivalent circuit of a thyristor.

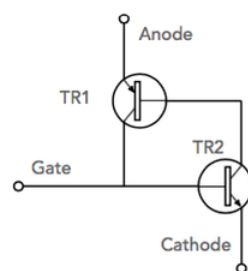


Figure 1: Equivalent circuit of Thyristor (Electronic notes, 2018)

A thyristor has three basic operations or states as a controlled rectifier, they are 'Forward conducting', 'Forward blocking' and 'Reverse blocking'. 'Forward blocking' is the state when the thyristor is blocking or stopping the conduction of forward current, these forward currents are usually brought forward by a diode which is forward biased. This stage of the thyristor makes it not in turn on stage and the gate part of the thyristor has not be activated. The second stage the thyristor can be in is the 'Reverse blocking' state, this is the stage when the thyristor will stop any current which is flowing in the same direction as the diode which is reverse biased, this stage of operation makes the thyristor conduct in 1 direction and stops it in the opposite direction. The last stage or mode of operation is the 'Forward conducting' mode and this is the stage when the trigger current has latched the gate part of the thyristor, this current does not need to be continuous on the gate as the gate will latch and remain conducting until the gate is reset by falling below a threshold called the holding current. (Electronic notes, 2018). Below in figure 2 shows the basic structure of a thyristor.

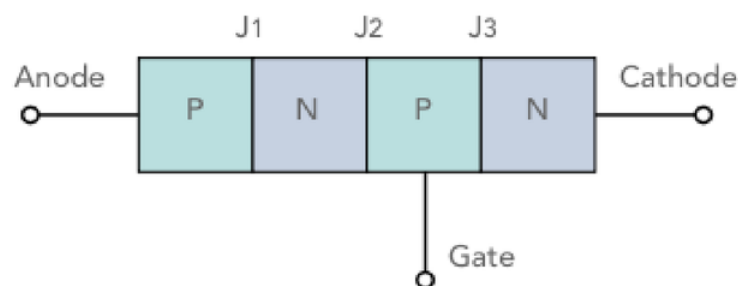


Figure 2: Structure of a Thyristor

The Thyristor are generally a good piece of equipment to use, they can handle large voltages, currents and powers and with the addition of a fuse they become protected. As shown in the above research they are very easy to operate and simple to turn on and off, the cost is low as shown in figure 3 below from RS components and a variety of sources online giving the same regions of pricing for these thyristors.



Figure 3: Pricing of thyristors for analysis

There are also some disadvantages to the thyristors as they can only control power in DC during a positive half cycle of an AC supply which means only DC power can be controlled with a thyristor. If a thyristor is used the gate current cannot go negative and the thyristor cannot be used in frequencies that are high. Oversell they are a good piece of equipment which are very versatile and commonly used in industrial applications.

There is four main types of thyristors which are commonly used and are as follows, the Silicon controlled rectifier as explained above, the GTO (gate turn off thyristor), the MCT (MOSFET Controlled Thyristor) and the Triac thyristor. The SCR thyristor is explained above and is basically a thyristor which has the ability to block in both directions and is triggered to conduct by a pulse received from the gate. This gate as stated above cannot switch off the thyristor and is slower that a transistor. This type of thyristor has the overall highest rating of the four devices to be talked about.

The GTO thyristor has the working operation similar to a SCR thyristor with the blocking in both directions and the gate activating the conducting, The GTO will need to include a snubber circuit which reduces the DV/DT and the GTO has a high on state voltage drop which is 3V. These thyristors are sensitive to fast volt changes between the cathode and anode when the thyristor is at the stage of turn off. Figure 4 below shows GTO symbol used to identify as a GTO thyristor.

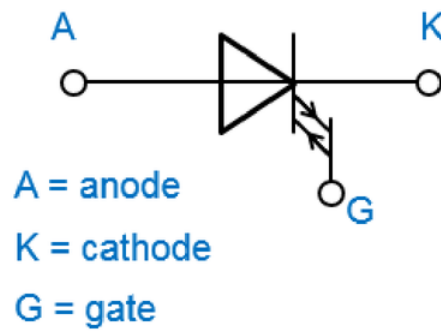


Figure 4: GTO symbols

The GTO thyristor will have a larger latch current than the SCR type thyristor along with the gate pulses which are positive will need a longer time period to be activated on at with a higher gate current than the silicon controlled rectifier. To reduce the cathode – anode voltage drops a small gate current can be maintained when its conducting.

The MCT or MOSFET controlled thyristor will be a combination of the low current control and quick speeds of switching from the MOSFET with the ability to handle high currents and maintain low on state losses from the SCR type thyristor. Figure 5 below shows the equivalent circuit of the MCT.

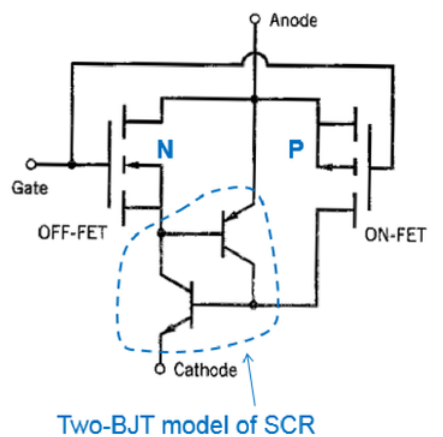


Figure 5: Equivalent circuit of MCT

From figure 5 above the channel labelled 'P' is for the switch on part of the circuit, the 'N' Label is for the MOSFET switching off, which gives the thyristor control by these two built in MOSFETs. A high impedance is produced by these MOSFET controlling gates which will then produce the low currents to drive the gates.

The final thyristor is the Triac thyristor which is basically two SCR type thyristors arranged back to back as shown below in figure 6.

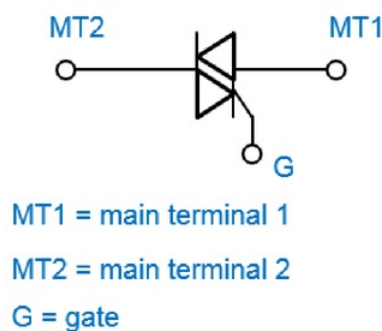


Figure 6: Triac

A Comparison chart is shown below to compare the four devices along with some other types of thyristor. As shown there is a wide range of differences between the thyristors and with advancements in technology and the same principles of 'Moore's' law the thyristors capabilities can expect to change in coming years.

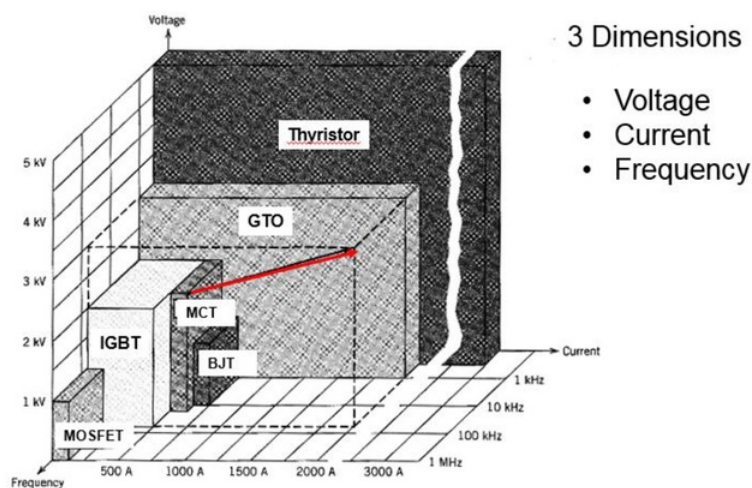


Figure 7: Comparison of thyristors

Full Wave and half controlled rectifier circuit and waveforms produced when connected to a DC motor with suitable formula to calculate average armature voltage.

Full wave full controlled bridge convertors are a commonly used convertor used in industry today, they supply a current with a unidirectional supply positively and negatively in terms of polarity. These bridge convertors can then act as an inverter or as a rectifier which is controlled, but most of their use does not include the inverter part so they are used as rectifiers. These single phase full controlled convertors as a rectifier then become a very complicated and expensive option and produce a poor voltage and current output form factor and input factor power.

To improve upon the output currents and voltage a diode is connected across the output shown below is figure 8, this prevents the negative excursion of the voltage output. (Kharagpur, 2018)

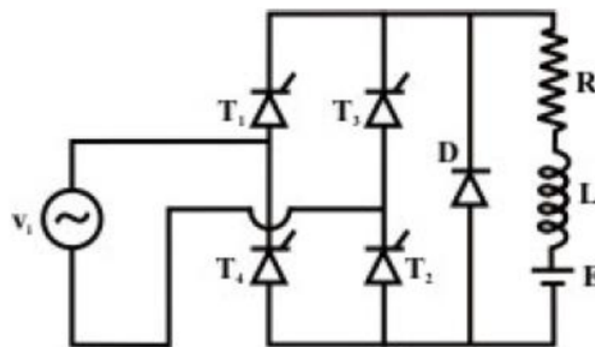


Figure 8: Full wave rectifier (Kharagpur, 2018)

This introduction of the diode becomes forward bias which will clamp the voltage load to zero as the voltage attempts to go negative. To reduce the complexity of the circuit the two thyristors of a fully controlled circuit have to be replaced by two diodes and become a single phase half controlled rectifier convertor as shown below in figure 9. (Kharagpur, 2018).

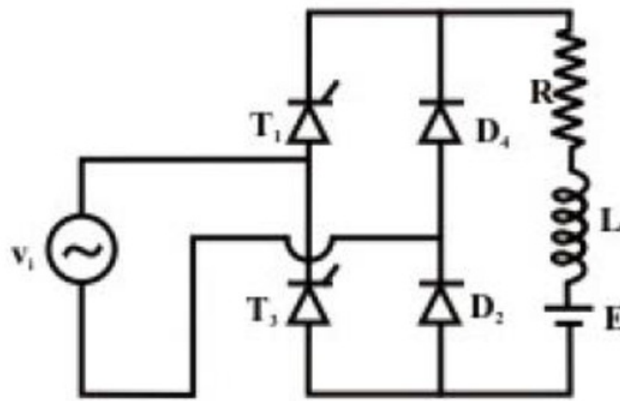


Figure 9: Full wave, half controlled rectifier circuit (Kharagpur, 2018)

So to summarise the half controlled receiver they are obtained by replacing two thyristors with two diodes in the circuit, a half controlled converter will not have a negative voltage and will not operate as an inverter. The half controlled converter will give higher output voltages than a fully controlled converter at the same firing angle and voltage and it will also produce better current and voltage form factors. These half controlled converters are most commonly used where output currents and voltages are required unidirectional. (Kharagpur, 2018)

The formulae to calculate the average armature voltage is shown below and used in task 2.

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

Citation Needed

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

$$\text{So } V_{max} = \sqrt{2} \times 240 = 339v$$

The continuous conduction mode of the half wave convertor waveforms are shown below in figure 10. And for the discontinuous conduction mode in figure 11.

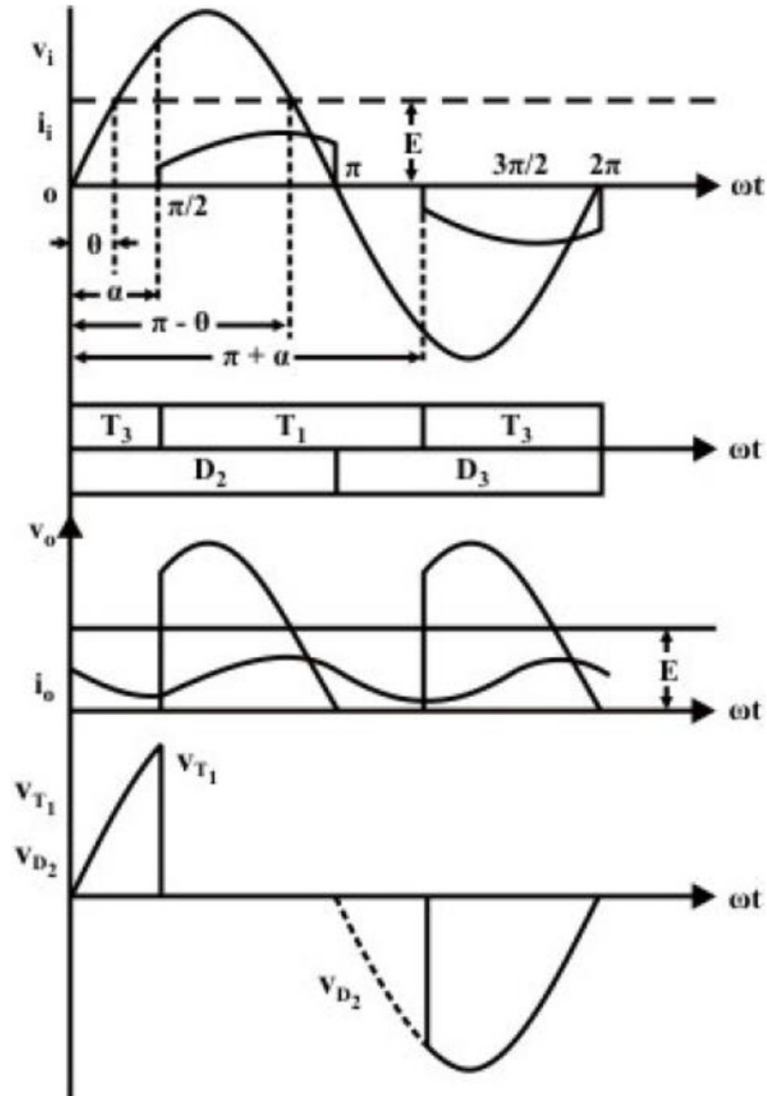


Figure 10: Continuous conduction waveforms (Kharagpur, 2018)

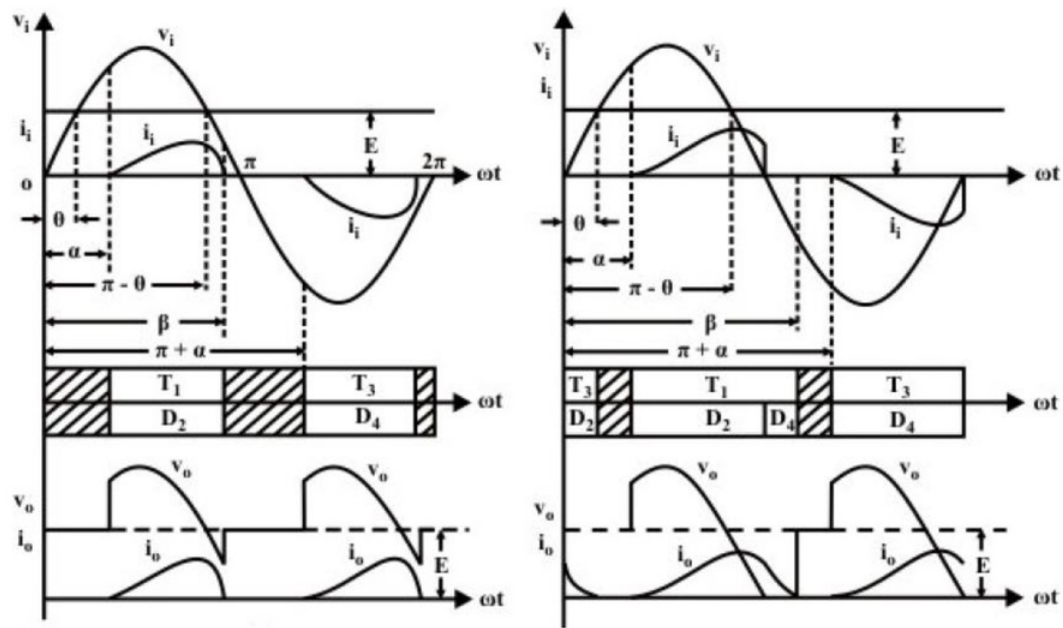


Figure 11: Discontinuous conduction mode (Kharagpur, 2018)

Figure 12 below also shows the input current waveform for a half controlled converter.

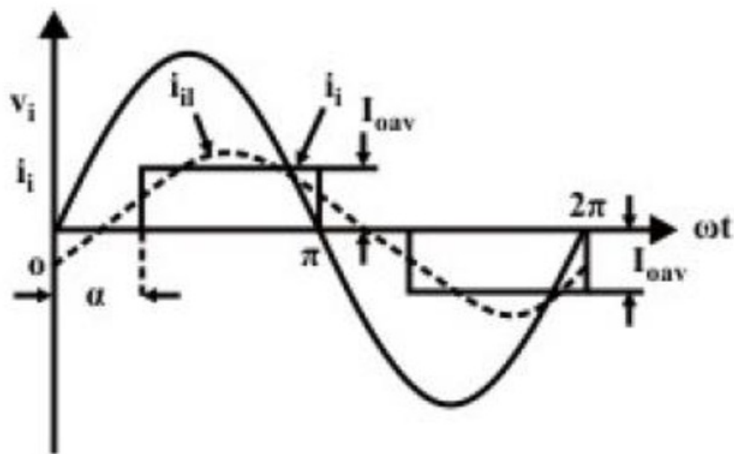


Figure 12: Input current for half controlled converter (Kharagpur, 2018)

Low power DC drive such as the Parker 512C

The Parker 512C is a type of low power DC drive converter which is mainly used for the control of shunt wound and permanent magnet DC motors. The DC drive is operated from a supply coming from a single-phase mains supply which will be an AC supply ranging from 110V to 415V at the usual 50Hz or 60Hz. (Parker, 2016).

(Parker, 2016) states that "A simple transformer tap arrangement allows the converter to be programmed to suit the applied voltage. The speed of the dc motor is controlled using linear closed loop system with a feedback signal from either tach generator or armature voltage, the feedback source being switch selectable."

(Parker, 2016, pp. 1-1)

The drive will contain a current loop which will provide a level of current to the motor which is always controlled, the switches are programmable and are used to scale the levels of current. After around one minute the drive has a stall detection circuit which will trip the circuit providing protection to the motor, and if a short circuit is present then an instant over current trip circuit will provide protection for the converter. Figure 13 below shows a component diagram for the Parker 512C DC drive. (Parker, 2016).

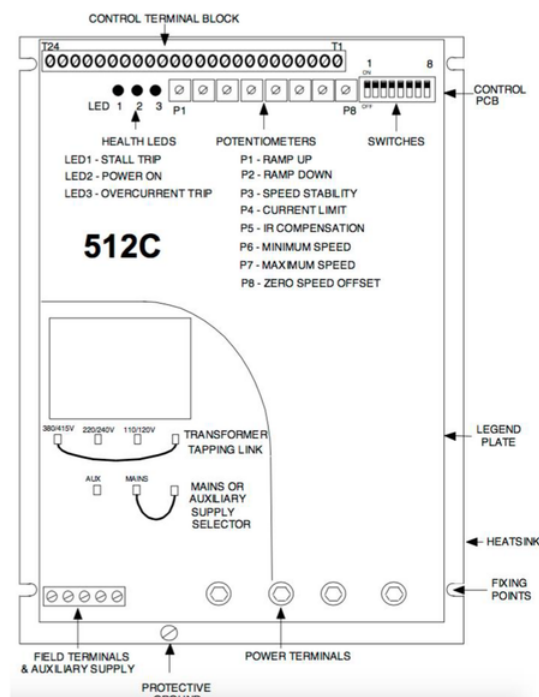


Figure 13: Component diagram for Parker 512C

Figure 14 below shows the block diagram of the parker 512c drive taken from the user manual for the motor drive.

Block Diagram

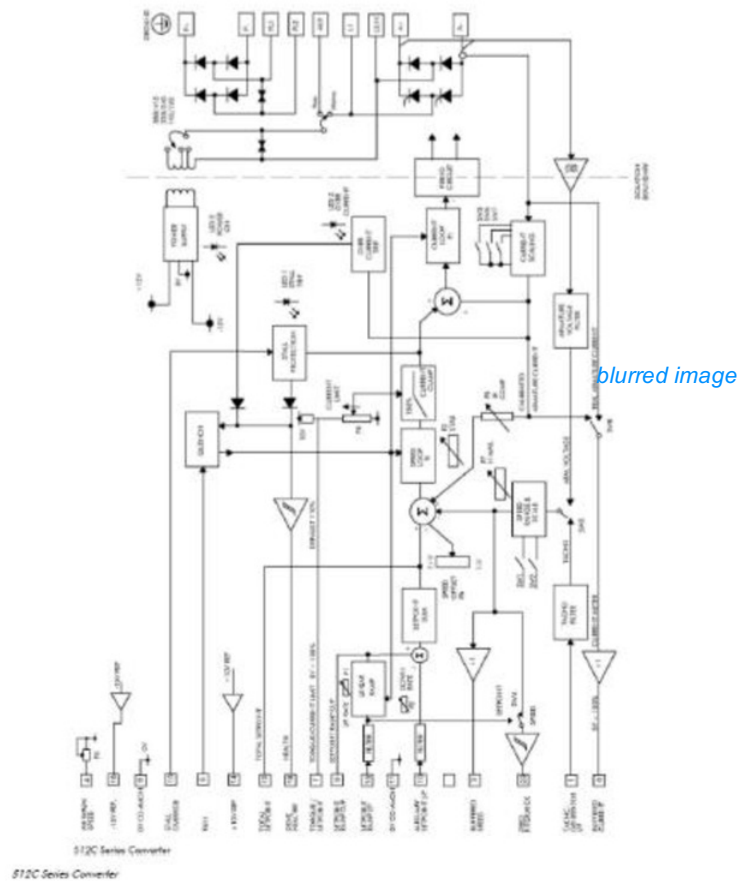


Figure 14: Block diagram for parker 512c

More data sheets and diagrams are attached below in the appendix of the assignment.

Applications of DC drives in industry

DC motor drives are used a lot in industry, modern DC drives commonly come under the control of a process controller or control computer. These computers usually control drives in an open loop mode and can be used to generate positions or speed references which is sent to the control loop. These computers controlling the dc drives do have some disadvantages which may include a single processor only having the ability to control a limited number of drives, and testing, commissioning maintenances and emergency start-ups are better suited for drives that work independently.

Some applications in industry are listed below.

Handling of materials or loads.

Hoists, cranes and unloading machines are machinery or plant which use the principle of lifting a load with a hook, straps, cages or claws. These machines use a wide range of control ranging the speeds, weight ratings, control applications and machine operations. A crane would use a dc motor drive with a range of around 10-500kw, and an unloader for aggregate or heavy metals would range to about 200kw. The drive will provide power for the machines to be operated from a safe distance and use the feature of automated control, the drives can also give control to the direction in which the machines are moving and also provide slowdown safety features to control the speed and function of the equipment as they come to the end of their travel.

Application in steel industry

Reversing primary mills are used to reduce ingots from a cross section to a small cross section in slabs or blooms. This is done by passing multiple times in each direction and is affected by the speed increase and decrease of the mill. The drives for these mills will be independent motors which will power the bottom rolls and top rolls of steel, the drives will be required to produce speed matching and sharing the load and will be controlled by a controller computer system which can regulate the roll speed and gaps of the rolling.

Hot continuous mills are also used in the steel industry which requires the material from the reverse primary mill to be reheated and sent through a set of stands which move in one way. One section of steel can be in multiple stands at one time so the load sharing feature is required by motors in these stands to an equal load share, the drives will produce this and this will help to prevent any damage or stresses to the steel.

To produce steel strips in a factory a lot higher power will be needed to carry out this procedure. A control computer which controls the process of the system and drives will alter the speeds and roll gaps along with the temperature of the system to produce different lengths and thicknesses of steel strips.

With the improvement of thyristors technology the use of ac drives is starting to look like a future alternative and a controlled ac drive may be as useful in coming years.

(J.McTaggart).

DC motor drives are commonly used in other applications like conveyor belts, elevators and mixers due to their ability to develop full torque from zero to the set speed and as the voltage sent to the armature of the motor is increased the speed of the motor will also increase, this gives good speed control. (Sprint Electric , 2018).

2. Simulation

Multisim was used to analyse the performance of a single phase, full wave, half controlled rectifier which will be connected to a DC motor armature and modelled as a load containing and inductance. The back EMF ^{misconception} produced by a resistance and a battery. Two firing angles will be produced to record the voltage and current waveforms by the use of the cursors on the graphs below, the timing will all be recorded and converted to radians as shown below. The average armature voltage will also be calculated as shown below taken from the research in task 1.

The first firing angle of 120v was used to produce the results shown below, the power source in the bottom left of the circuit was changed to 120v and this is how the firing angle is changed. The calculations below are used to work out the T1, T2, Beta, Alpha and radian values to be used to calculate the average voltage and complete the below table.

T1 = 741.80us. Beta = $741.80 (X10^{-6}) / 10ms(X10^{-3}) * 180 = 13.3524$, which is similar to the angle inputted below, only below is in V but they should match. Rad = $7.41(x10^{-6}/10(x10^{-3})*3.14 = 0.233$ units
nonsense

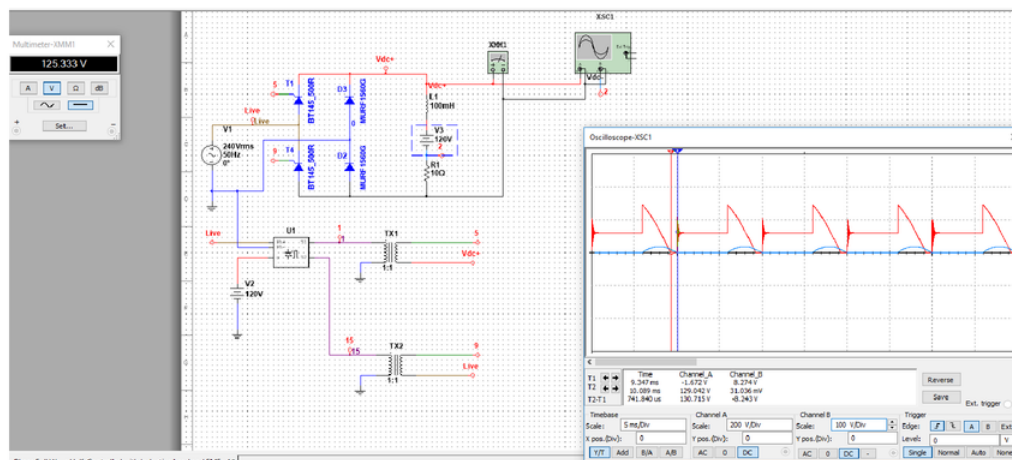


Figure 15: T1, Beta, angle of 120

$T_2 = 6.528$. $\alpha = 6.528\text{ms}/10\text{ms} \times 180 = 117.504$ degrees. In radians = $6.528/10 \times 3.14 = 2.05$

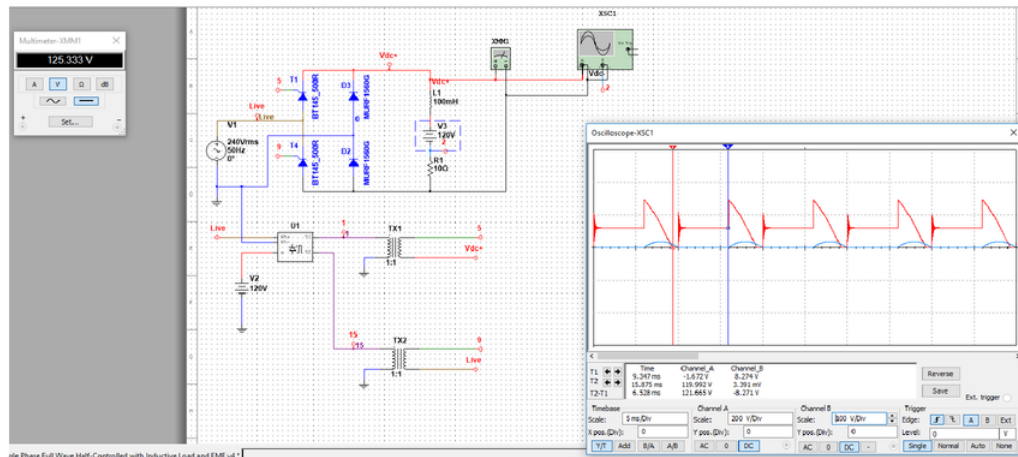


Figure 16: T_2 , α for 120

$E =$ back emf which = 120v

Equation for armature voltage taken from the research in task 1 = this will be compared to the armature voltage in the multimeter on the simulation above.

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

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

$$\text{So } V_{max} = \sqrt{2} \times 240 = 339v$$

$$V_{av} = \frac{120(2.05 - 0.233) + 339(1 + \cos 2.05)}{3.14} = 127.55$$

The calculated armature voltage and measured on the multimeter is off by a couple of volts due to the cursors calibration when measuring t_1 and t_2 and the back emf voltage.

The second firing angle of 80v as shown above by changing the value on the power source located in the bottom left of the circuit.

$$T1 = 2.819\text{ms}. \text{Beta} = 2.819/10 \times 180 = 50.742 \text{ or in rad} = 2.819/10 \times 3.14 = 0.8856$$

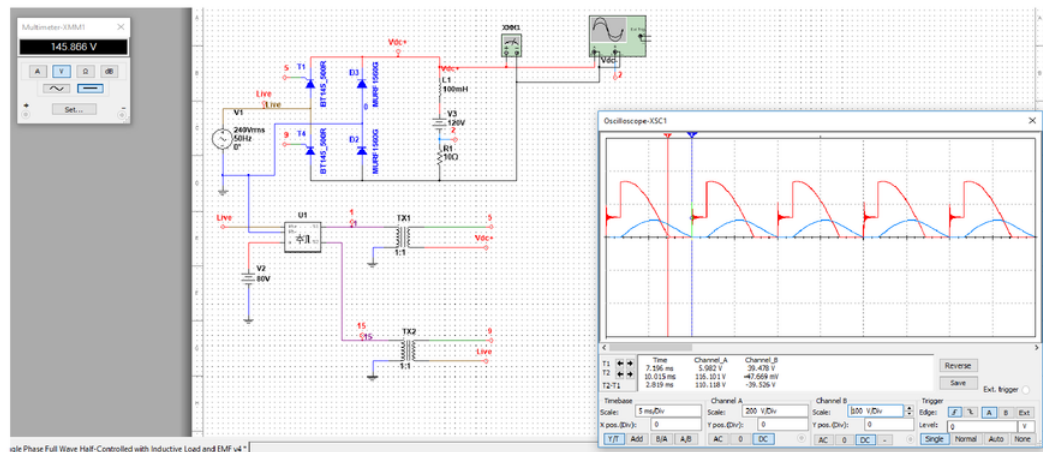


Figure 17: Firing angle 80, T1, Beta

$$T2 = 4.525. \text{Alpha} = 4.525\text{ms}/10\text{ms} \times 180 = 81.45 \text{ degrees, which is similar to the angle inputted below, only below is in V but they should match. Rad} = 4.525/10 \times 3.14 = 1.42$$

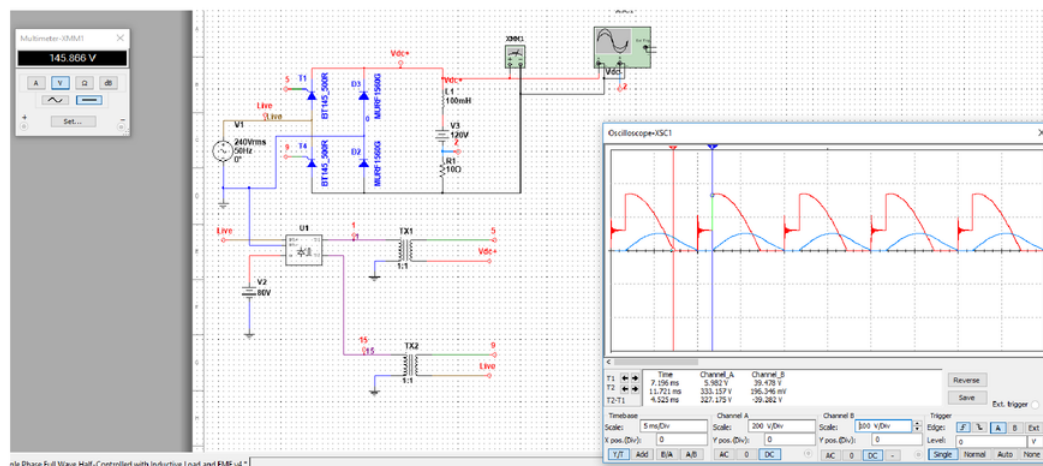


Figure 18: Firing angle 80, T2, Alpha

E = Back emf which is 120v

Equation for armature voltage = this will be compared to the armature voltage in the multimeter on the simulation above.

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

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

$$\text{So } V_{max} = \sqrt{2} \times 240 = 339v$$

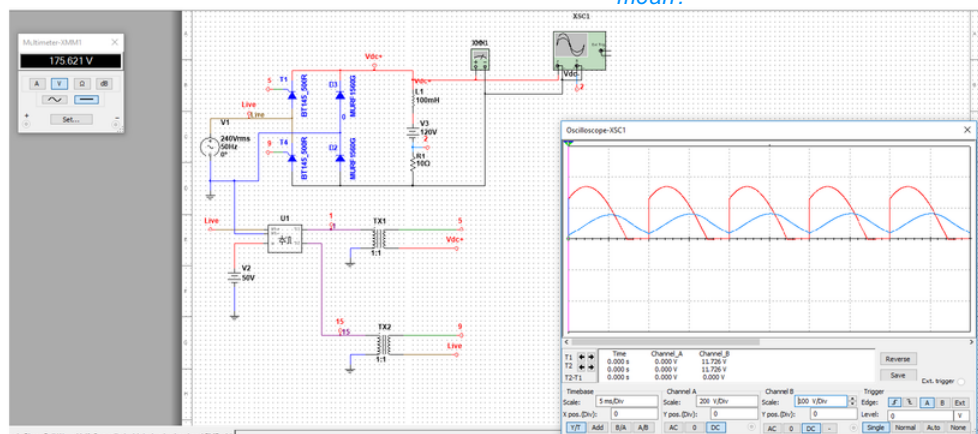
$$V_{av} = \frac{120(1.42 - 0.886) + 339(1 + \cos 1.42)}{3.14} = 144.51$$

The calculated armature voltage and measured on the multimeter is off by a couple of volts due to the cursors calibration when measuring t1 and t2 and the back emf voltage.

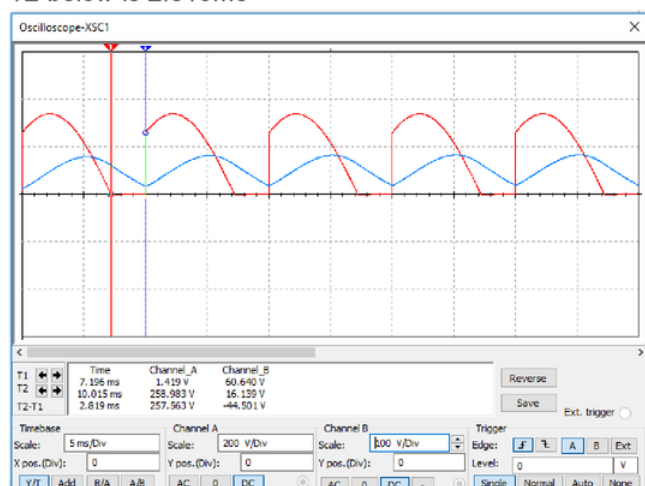
The table below shows the results from the two different firing angles.

E	T1	T2	α	β	Measure	Calculation
120	2.819	4.525	1.42	0.8856	145.86	144.51
120	741.80	6.528	2.05	0.233	125.33	127.55

B) Looking at current, two screenshots were taken showing continuous current and discontinuous current by changing the back emf in the above. A circuit explanation is included here and above the screenshots. With continuous current there is no t_1 due to no back EMF because of the current shorting out. When the current is flowing through the circuit there is no back emf from the mains supply, as the load drops off the current is still flowing in the circuit below then the load will kick back in and fire the thyristor again causing the angle.



T2 below is 2.819ms



Second screenshot showing discontinuous current. There is a small amount of emf as shown below. When the current drops off in the circuit an emf will be generated from the mains across the resistor and inductor which is showing the small back emf until the thyristor kicks back in and fires the angle again producing current which will have a value of '0' across the diodes.

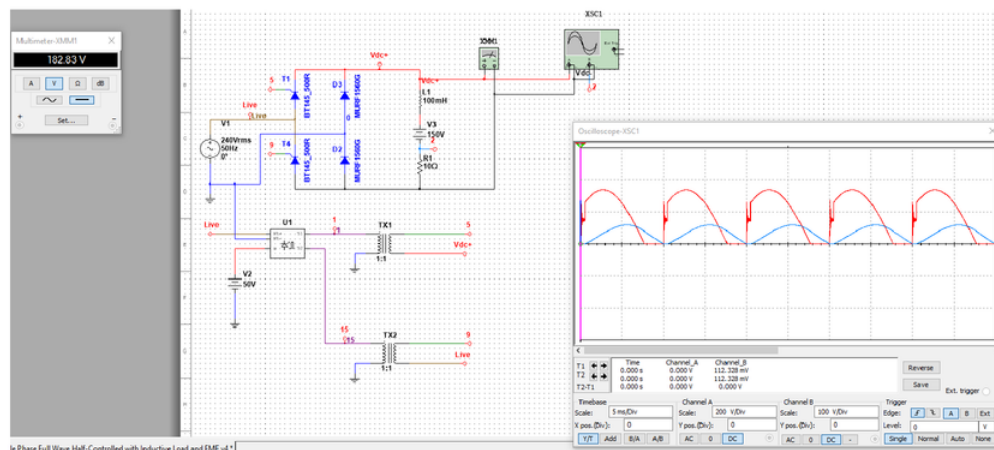


Figure 21: Discontinuous current

T2 below = 2.671ms

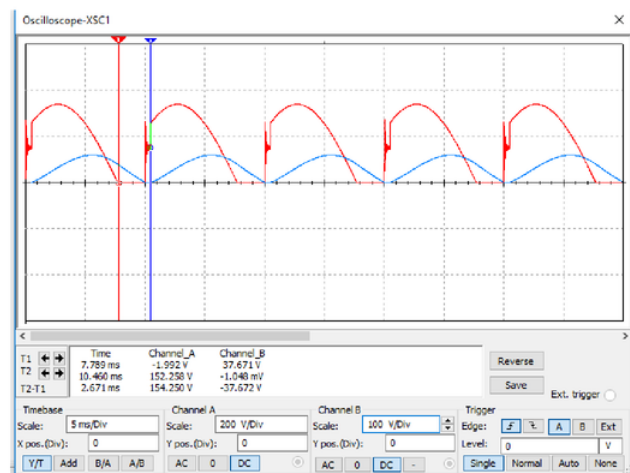


Figure 22: Discontinuous current T2

T1 below = 2.226ms

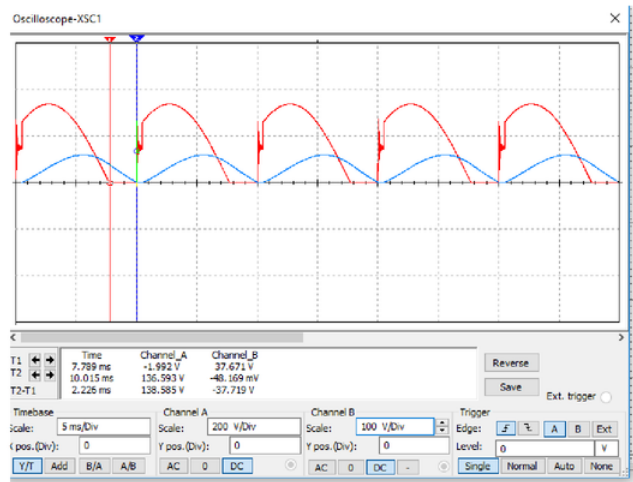


Figure 23: Discontinuous current T1

C) the circuit is explained above the screenshots and consists of a half controlled rectifier circuit with a resistive inductive load, which as discussed in the research uses two diodes with two thyristors to create this half controlled circuit thus not letting the voltage go negative. The voltage supply to the circuit is set at 240Vrms and has a frequency of 50 hertz. The firing angle is changed with the power source in the bottom left of the multisim circuit, this has two transformers connected which are useful application of inductance and are used to step up or step down a input primary voltage and connected to the ground as a common reference point. Measurements were taken with an oscilloscope and a multimeter incorporated into the circuit.

3. Practical Investigation

Task three looks at the practical deployment of a single quadrant DC drive, this involved using the practical apparatus set up in the lab at the college. The apparatus used was a Parker 512C drive with a DC motor, Prony brake and measuring equipment such as a multimeter to measure voltage and measuring equipment to measure the speed of the motor. Two experiments will take place which will include a no load condition of the motor where three different speed settings will be measured and the armature voltage and T1,T2 values also measured.

The second experiment will look at the motor for one speed set point under three different mechanical loads which are set at 0.2nm, 0.8nm and 1.2nm.

Figure 24 below shows the circuit diagram for the system being used in the practical experiment.

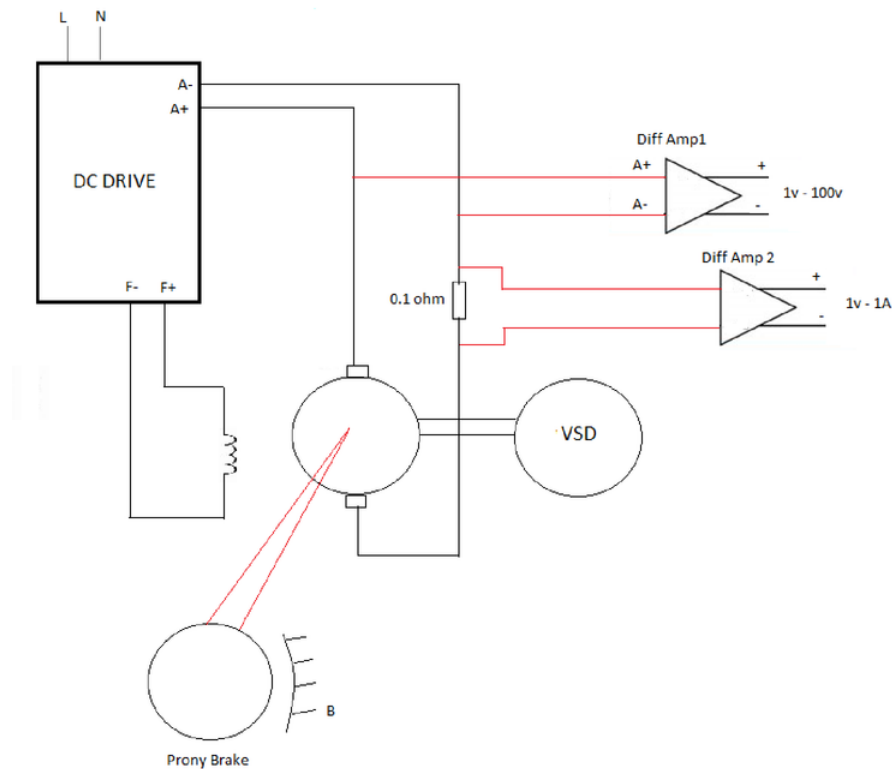


Figure 24: Circuit diagram for practical

Figure 25 below shows the setup of the apparatus used in the experiment with the motor and motor drive, along with measuring apparatus and the emergency stop.



Figure 25: Experiment setup

Figure 26 below shows the parker 512C motor drive.



Figure 26: Parker 512C motor drive

Experiment 1

As stated above this section is looking at the a no load on the motor with three different speed settings, the first speed setting was 651rpm, this was recorded with the speed recording instrumentation. Figure 27 below shows the T1 measured value with the experiment running.

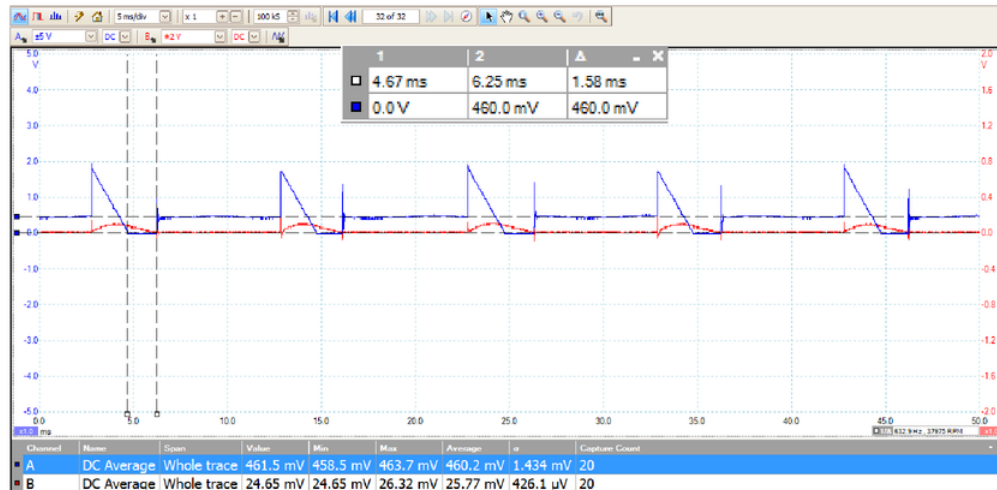


Figure 27: 1st experiment, T1 651rpm

The measured value for t1 was = 1.58ms. The T1 value is measured for the current from the end of the voltage firing angle to where the current value reaches zero (0). The equation from above and found in the research was used to find the value of β . The equation is;

$$1.51/10 \times 3.14 = 0.474 \text{ in radians.}$$

This will be added along with the alpha values to complete the table at the bottom of this section

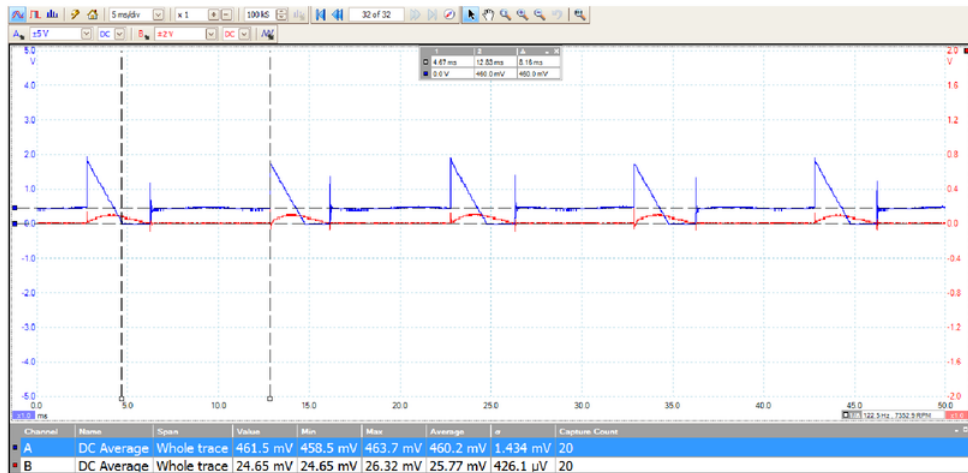


Figure 28: Experiment 1, T2 651rpm

Figure 28 above gives the value for T2 which is = 8.16ms – .This t2 value is the time between each voltage firing angle. The equation for alpha (α) is;

$$T2 = 8.16, \alpha = 8.16/10 \times 3.14 = 2.562. \text{ units?}$$

These values were added to the formulae used in the simulation and found in task 1 to find the average armature voltage, the equation is;

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

$$\text{So, } V_{max} = \sqrt{2} \times V_{rms}$$

$$\text{So } V_{max} = \sqrt{2} \times 240 = 339v$$

$$V_{av} = \frac{46(2.652 - 0.474) + 339(1 + \cos 2.652)}{3.14} = 44.53$$

units?

The table at the bottom of the task will shows these results clearly.

Figure 29 below is for the second speed setting of 1319rpm, the calculations follow.

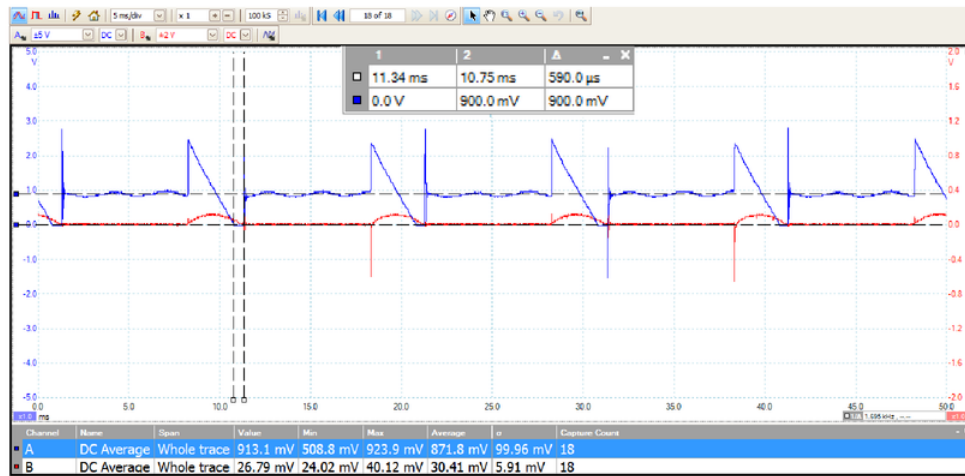


Figure 29: EX 1, T1, 1319rpm.

The measured value for t_1 was = 0.59ms. The T_1 value is measured for the current from the end of the voltage firing angle to where the current value reaches zero (0). The equation from above and found in the research was used to find the value of β . The equation is;

$$0.59/10 \times 3.14 = 0.185 \text{ in radians.}$$

This will be added along with the alpha values to complete the table at the bottom of this section

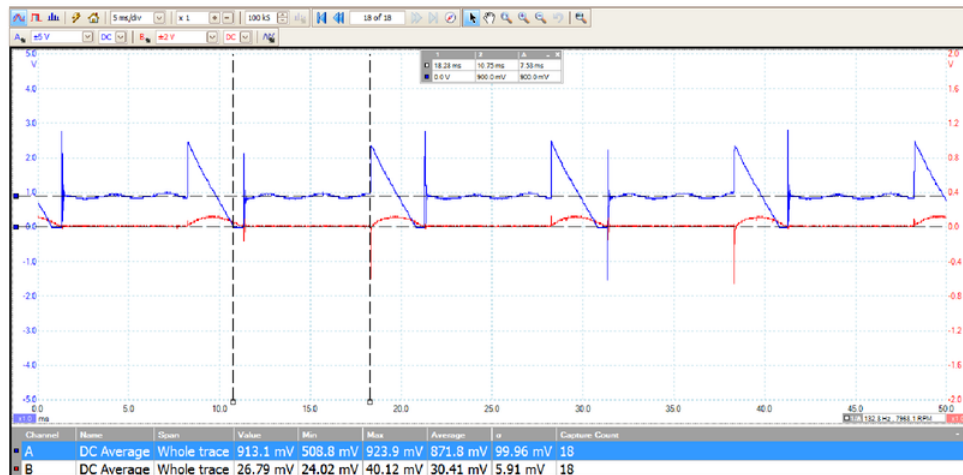


Figure 30: EX 1, T2, 1319rpm

Figure 30 above gives the value for T2 which is = 7.53ms – .This t2 value is the time between each voltage firing angle. The equation for alpha (α) is;

$$T2 = 7.53, \alpha = 7.53/10 \times 3.14 = 2.364.$$

These values were added to the formulae used in the simulation and found in task 1 to find the average armature voltage, the equation is;

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

$$\text{So, } V_{max} = \sqrt{2} \times V_{rms}$$

$$\text{So } V_{max} = \sqrt{2} \times 240 = 339v$$

$$V_{av} = \frac{90(2.364 - 0.185) + 339(1 + \cos 2.364)}{3.14} = 93v$$

The table at the bottom of the task will shows these results clearly.

Figure 31 below is for the second speed setting of 2597rpm, the calculations follow

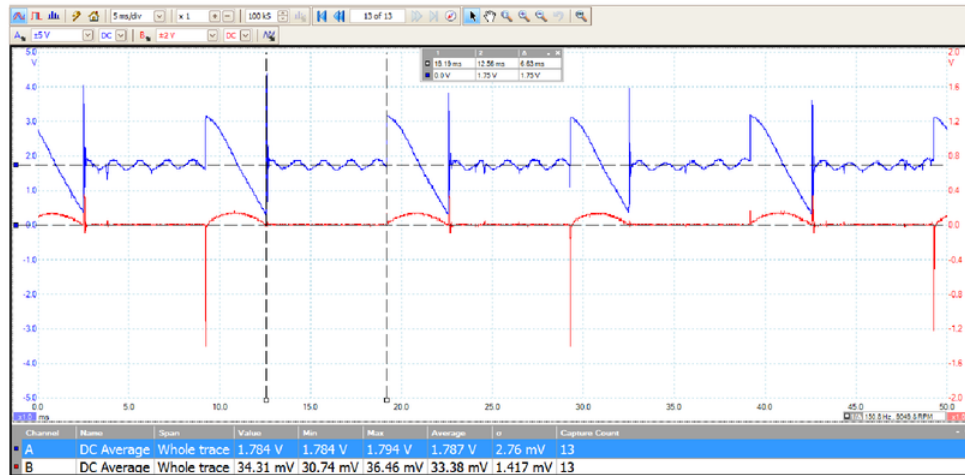


Figure 31: EX 1, T2, 2597rpm

Figure 31 above gives the value for T2 which is = 6.63ms – .This t2 value is the time between each voltage firing angle. The equation for alpha (α) is;

$$T2 = 6.63, \alpha = 6.63/10 \times 3.14 = 2.08$$

There was no value for T1 due to the current curve reaching zero at the same point as the voltage curve. The results and practical above have shown that as the speed increases the firing of the system becomes faster due to the motor working faster to produce the required speed. Each screen shot of the different speeds shows the t1 value reducing with the increasing speed, and the T2 value is decreasing as the speed increases. The results from the above will be inputted into a table form below the second experiment.

Experiment 2 (braking)

The below experiment is as described at the beginning of the task and will have different loads applied as a braking force. Figure 32 below is for a load of 0.2nm and a speed set at 1067rpm.

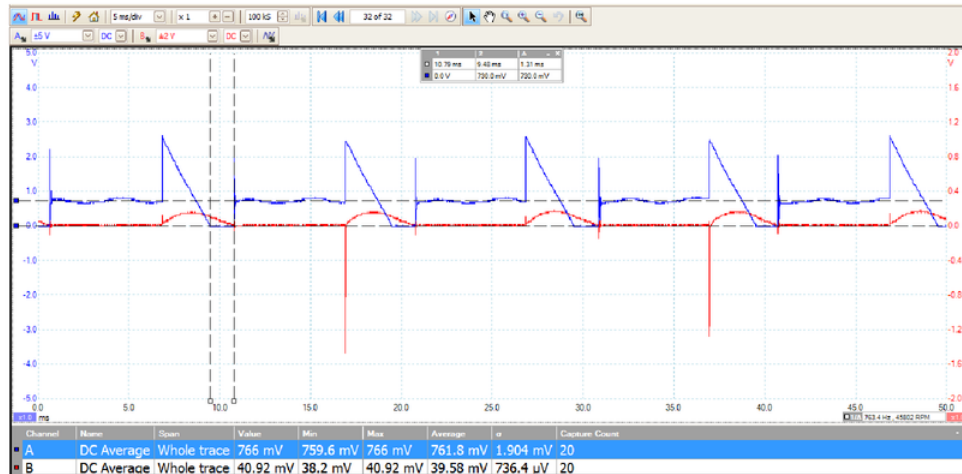


Figure 32: EX 2, T1, 0.2nm

As done above the values for Alpha and Beta will be calculated and compared to the measured values in the graph form at the bottom of the task.

$T_1 = 1.31\text{ms}$

The measured value for t_1 was = 1.31ms. The T_1 value is measured for the current from the end of the voltage firing angle to where the current value reaches zero (0).

The equation from above and found in the research was used to find the value of β . The equation is;

$$1.31/10 \times 3.14 = 0.411\text{v in radians.}$$

This will be added along with the alpha values to complete the table at the bottom of this section

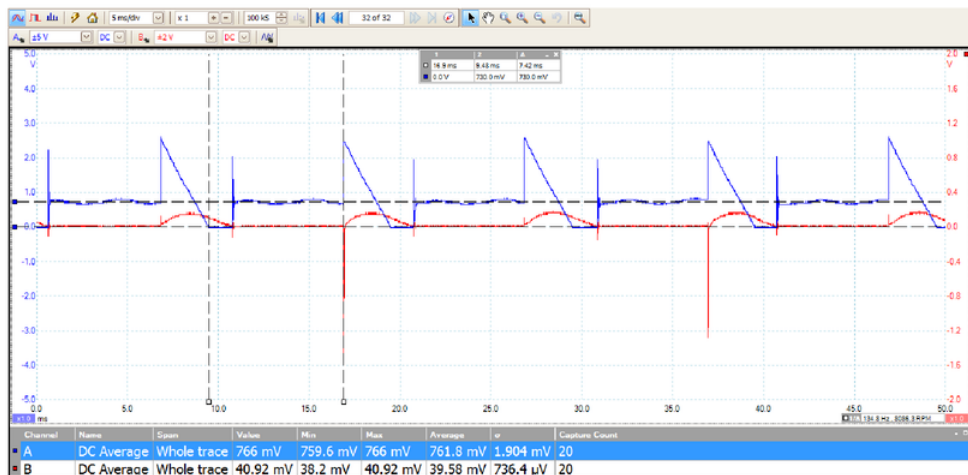


Figure 33: EX2, T2, 0.2nm

Figure 33 above gives the value for T2 which is = 7.42ms – .This t2 value is the time between each voltage firing angle. The equation for alpha (α) is;

$$T2 = 7.42, \alpha = 7.42/10 \times 3.14 = 2.33.$$

These values were added to the formulae used in the simulation and found in task 1 to find the average armature voltage, the equation is;

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

$$\text{So, } V_{max} = \sqrt{2} \times V_{rms}$$

$$\text{So } V_{max} = \sqrt{2} \times 240 = 339v$$

$$V_{av} = \frac{73(2.33 - 0.411) + 339(1 + \cos 2.33)}{3.14} = 78v$$

The table at the bottom of the task will shows these results clearly.

Figure 34 below is for the second load setting of 0.8nm, the calculations follow;

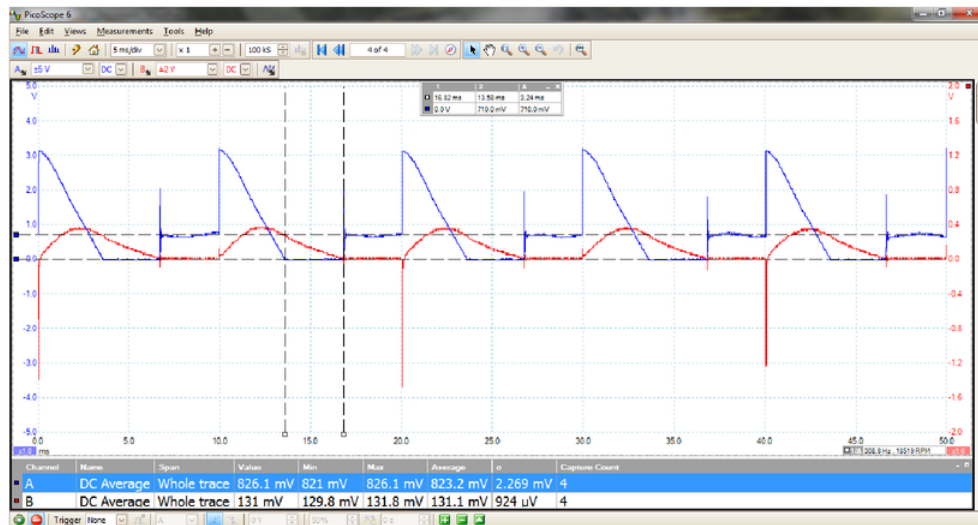


Figure 34: EX2, T1, 0.8nm

The measured value for t_1 was = 3.24ms. The T_1 value is measured for the current from the end of the voltage firing angle to where the current value reaches zero (0). The equation from above and found in the research was used to find the value of β . The equation is;

$$3.24/10 \times 3.14 = 1.02\text{v in radians.}$$

This will be added along with the alpha values to complete the table at the bottom of this section

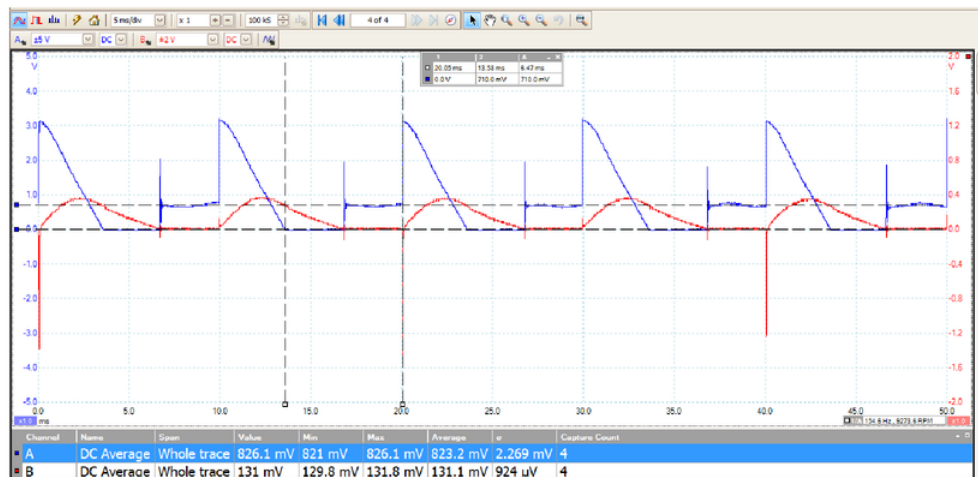


Figure 35: EX, T2, 0.8nm

Speed = 1051

T2 = 6.47

Figure 33 above gives the value for T2 which is = 6.47ms – .This t2 value is the time between each voltage firing angle. The equation for alpha (α) is;

T2 = 6.47, $\alpha = 6.47/10 \times 3.14 = 2.03$. back emf = 65v

These values were added to the formulae used in the simulation and found in task 1 to find the average armature voltage, the equation is;

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

$$\text{So, } V_{max} = \sqrt{2} \times V_{rms}$$

$$\text{So } V_{max} = \sqrt{2} \times 240 = 339v$$

$$V_{av} = \frac{65(2.03 - 1.02) + 339(1 + \cos 2.03)}{3.14} = 81.37v$$

The table at the bottom of the task will shows these results clearly.

Figure 36 below is for the second load setting of 1.2nm, the calculations follow

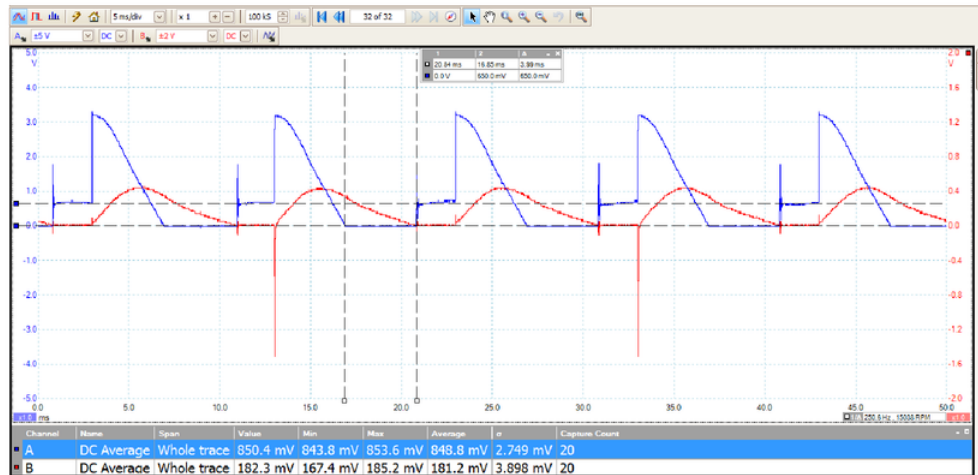


Figure 36: EX2, T1, 1.2nm

The measured value for t1 was = 3.99ms. The T1 value is measured for the current from the end of the voltage firing angle to where the current value reaches zero (0). The equation from above and found in the research was used to find the value of β . The equation is;

$$3.99/10 \times 3.14 = 1.25v \text{ in radians.}$$

This will be added along with the alpha values to complete the table at the bottom of this section

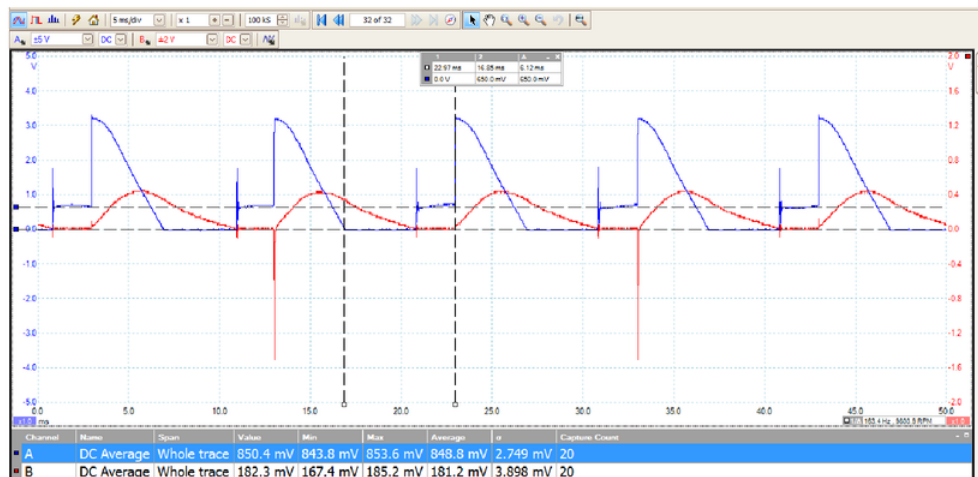


Figure 37; EX2, T2, 1.2nm

Figure 37 above gives the value for T2 which is = 6.12ms – .This t2 value is the time between each voltage firing angle. The equation for alpha (α) is;

$$T2 = 6.12, \alpha = 6.12/10 \times 3.14 = 1.92. \text{ back emf} = 65v$$

These values were added to the formulae used in the simulation and found in task 1 to find the average armature voltage, the equation is;

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

$$\text{So, } V_{max} = \sqrt{2} \times V_{rms}$$

$$\text{So } V_{max} = \sqrt{2} \times 240 = 339v$$

$$V_{av} = \frac{65(1.92 - 1.25) + 339(1 + \cos 1.92)}{3.14} = 85.2v$$

The table at the bottom of the task will shows these results clearly.

E	T1	T2	α	β	Measure	Calculation
46	1.58	8.16	2.562	0.474	46.15	44.53
90	0.59	7.53	2.364	0.185	91.5	93
175	N/A	6.63	2.08	N/A	1.79	N/A
73	1.31	7.42	2.33	0.411	78	78
65	3.24	6.47	2.03	1.02	82.61	81.37
65	3.99	6.12	1.92	1.25	85	85.2

The results for braking have had the opposite to the increase speed experiment, as the braking force is increase the firing angles become further apart in respect to time due to more force being applied to the motor and more strain being applied to the system. The results recorded and results calculated are very similar and have proved the experiment was successful and as expected. The results will have a slight difference due to calibration with the measuring tools.

4. Conclusions and Recommendations

Research conclusion & recommendations

The research asked to first look at thyristors and their use as controlled rectifiers, the assignment covered a wide range of thyristors and along with diagrams and symbols the thyristors were explained. Using a wide range of credited sources and with course notes a variety of thyristors were found and discussed, the research of thyristors was used with the practical and simulation as the understanding of how these components operated was used to explain and build the simulations and practical. A look into the use of transistors would be a recommendation but overall a good amount of knowledge was taken from this research and applied to other parts of the assignment. *not relevant* *not specific enough*

The full wave half controlled rectifier circuit was used to produce a calculation to be used in task 2 to produce an average armature voltage for the two different firing angles. A reputable source was used along with class notes and Moodle library resources to produce an explanation of the circuit, what differences it has to the fully controlled rectifier and waveforms produced. The circuit was also included with the modification taking it from a fully controlled rectifier to a half controlled rectifier. The research as explained above produced the equations needed to calculate the average armature voltage which would be used in task 2 in the simulation. This part of the research gave a good understanding of how the rectifiers worked and the putting the equation found, back into practice in task 2 worked out successful and gave as expected results as shown below in the assignment screen grab. A recommendation be to carry out research of a fully controlled rectifier as well as half controlled. *specifically what???*

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

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

$$\text{So } V_{max} = \sqrt{2} \times 240 = 339v$$

$$V_{av} = \frac{120(1.42 - 0.886) + 339(1 + \cos 1.42)}{3.14} = 144.51$$

The research of the Parker 512c was done via the use of the Parker official website and data sheets and manuals included. The online manual gave an introduction to what the drive is and what it does as well as all the data sheets and component diagrams needed which have been attached in the Appendix section of the assignment. This research was useful as it provided education for the type of drive used in task 3 and made the use of the machinery easier with the help of the data sheets and information. A recommendation would be for the assignment to ask for another make and model of drive to be researched to widen the knowledge on the subject.

The applications of DC drives in industry section was sourced from personal experience in industry along with knowledge gained from previous colleagues and research carried out online. This section gave a relatable experience with the assignment as knowledge read from books and findings is a good way of learning, but with the introduction of applying that knowledge to an industrial application open up the gates for learning and can help to grasp how the equipment works with real world scenarios.

Simulation conclusions & recommendations

This task was the main calculation and theory applied part of the assignment, the task asked to simulate a single phase full wave, half controlled rectifier and produce results to the simulation. The task made use of the research by understanding the equipment which was being used and using the calculations researched to produce results for the average armature voltage. The models were built on multisim and with the introduction of the oscilloscope to measure the time values all information needed to calculate the average voltage was obtained. The simulation proved successful in the table below and seen above in the assignment showing the calculated results and measured results were almost identical but due calibration issues and cursor accuracy were not exactly the same. These results however were what we expected and were correct meaning the formulae found in the research and applied back into the assignment was a success. See table below for task 2 average armature voltage results.

E	T1	T2	α	β	Measure	Calculation
120	2.819	4.525	1.42	0.8856	145.86	144.51
120	741.80	6.528	2.05	0.233	125.33	127.55

Practical Conclusions & Recommendations

This part of the assignment required the Parker 512c DC drive to be used with the apparatus in the electronic lab at Coleg Sir Gar. A small team was formed and the experiment would analyse the performance of the drive under a no load scenario with different speed set points and then again with different speed set point but with three different mechanical loads applied. This part of the assignment used the knowledge gained from the research and helped to understand the operation of the parker drive, the task proved successful with more loads requiring more current as expected to operate the motor. A recommendation would be to use again as explained above a different make and model of drive and use more accurate measuring equipment. The results above show that the T1 time will reduce when speeding up the system with no load and will decrease when braking the system, and vice versa for the T2 value. The table above at the end of section two can be referred to for a summary of the results recorded and calculated.

The assignment overall produced well as expected results and applying the research back into the simulation and practical gave a much better understanding of the

subject and tasks of the assignment. Any recommendations have been listed above in the task conclusions but overall the assignment was good in its application.

*what about team
working?*

5. Citation List

Works Cited

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Woodford, C. (2012, 01 11). *Thyristors*. (C. Woodford, Producer) Retrieved 03 14, 2018, from explainthatstuff.com: <http://www.explainthatstuff.com/how-thyristors-work.html>

6. Appendices

Parker 512c Data sheets;

Control Features

Speed Control	Control Action	Closed Loop with Proportional Integral Control and Adjustable Stability		
	Speed Feedback	Armature Voltage	Tachogenerator	
	100% Load Regulation	2 % Typical	0.1 % Typical	
	Maximum Torque/Speed Range	20:1	100:1	
	Overload	150% for 60 seconds.		
Torque Control	Control Action	Closed Loop with Proportional Integral Control		
	Accuracy	2 %		
	Overspeed	Inherent		
	Overload	None 100% Continuous (consideration must be given to motor when operating at low speed)		
Inputs/Outputs	Analogue Inputs	Setpoint Ramp	0 to +10V	100Kohm
		Auxiliary Speed Setpoint	0 to +10V	100Kohm
		Current Limit	0 to +7.5V	50Kohm
		Tachogenerator Input	0 to +350Vdc	110Kohm
	Analogue Outputs	Speed	0 to +10V	5mA
		Current (SW8 Off)	0 to +5V (0 to Idc)	5mA
		Current (SW8 On)	0 to +5V (0 to Ical)	5mA
		Setpoint Ramp	0 to +10V	5mA
		Total Setpoint	0 to +10V	5mA
		+10V Reference	+10V	5mA
		-10V Reference	- 10V	5mA
		Digital Inputs	Run	+10 to +24V
	Stall Override		+10	100Kohm
	Digital Outputs	Health	+24V	50mA Source
		Zero Speed or Setpoint	+24V	50mA Source

Understanding the Product Code

The unit is fully identified using a five block alphanumeric code which records how the Converter was calibrated, and its various settings when despatched from the factory.

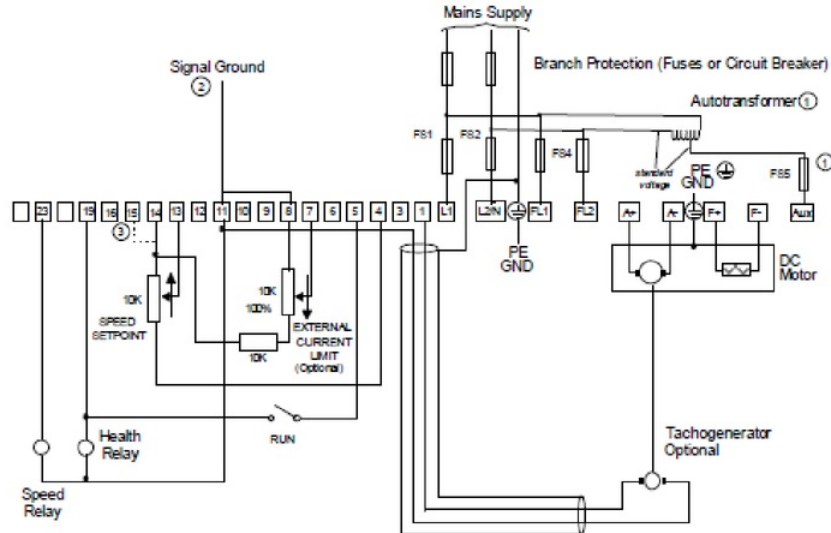
The Product Code appears as the "Model No.". Each block of the Product Code is identified as below:

Block No.	Variable	Description
1	512C	Generic product
2	XX	Two numbers specifying the current output, for example: 04 = 4Amp 08 = 8Amp 16 = 16Amp 32 = 32Amp
3	XX	Two numbers specifying mechanical package including livery and mechanical package style, and any option installed over and above the standard features of the product: Two numbers Livery 00 Standard Parker Hannifin Manufacturing Limited livery 01-99 Defined customer liveries
4	XX	Two numbers specifying the cover: IP00 Open Frame
5	XX	Two numbers specifying the special options: 00 = Standard 01 - 99 = Documented Special Options

Pre-Installation Planning

Basic Wiring Diagrams

Basic Connection



- ① When the mains voltage is non-standard, i.e. not selectable via the transformer tapping link (380/415V, 220/240V or 110/120V), connect a low power Autotransformer to generate a standard voltage. Connect the output of the Autotransformer to the AUX terminal. Move the Supply Selector from "MAINS" to "AUX". Select the appropriate voltage via the transformer tapping link. The Autotransformer must be connected to the same phase as the incoming power to provide correct coding to the controller.
- ② It is recommended that the "0V/common" be connected to protective earth/ground for safety reasons. In a system comprising of more than one controller, the "0V/common" signals should be connected together and joined to protective earth/ground at one point only.
- ③ Stall override link between terminals 14 and 15 required when using controller in current control.

FINAL GRADE

GENERAL COMMENTS

Instructor

62/100

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Citation Needed

Cite Source:

Please use the link below to find links to information regarding specific citation styles:

http://www.plagiarism.org/plag_article_citation_styles.html

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Text Comment. what about team working?

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GRADING FORM: CSG-RUBIC

NATHAN SMITH

62

RESEARCH-INFORMED LITERATURE



Section 1: Your research - Good evidence of background reading from a wide range of sources. However, you section on thyristors contains a lot of repetition. (9/15) Section 5: Your use of Harvard for citing and listing - Wide range of sources cited correctly but not listed properly according to the Harvard method. Try switching to Harvard in the reference section in MS Word. (3/5)

12

KNOWLEDGE AND UNDERSTANDING



Section 2: Explanation of simulation circuit - Some good explanations but there are some misconceptions also. (6/10) Section 3: Explanation of practical circuit - Good with helpful diagram, photos and description. (7/10)

13

ANALYSIS



Section 2: Analysis of results from simulation – Good results with comparison table and some attempt to account for differences. (6/10) Section 3: Analysis of results from practical experiment – Good results and calculations made and comparison table presented. (7/10) Section 4: Overall conclusions and recommendations – Generally good but could be more objective and specific about what has been learnt. Your recommendations appear to be aimed at the author of the assignment brief rather than would you could do better. It is clear however, that you do not understand what the drive is doing as the load is increased. (6/10)

19

PRACTICAL APPLICATION AND DEP.



Section 2: Simulation – Very good use of Multisim, clearly presented and tabulated results though some values have either no units or the wrong ones. (7/10) Section 3: Practical experiment – Very good use of equipment and presentation of results and tabulated results though some values have either no units or the wrong ones . (8/10)

15

SKILLS FOR PROFESSIONAL PRAC.



All sections – Well presented and structured. However, there are many spelling and grammatical

3

errors. (3/5) Section 4: Team role –Not mentioned.
(0/5)