

Investigation into Convertors

by Russell Maguire

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TIME SUBMITTED	17-JAN-2018 11:14 PM (UTC+0000)	WORD COUNT	4537
SUBMISSION ID	81971695	CHARACTER COUNT	28703



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BSc Electrical and Electronic Engineering

Power Electronics and Drives PSDE 6016

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2017 – 2018

Assignment 1 – Investigation into Convertors

Submission date:

17 – 01 - 2018

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1 Introduction

The following report will research, simulate and carry out a practical investigation into a single phase four-quadrant DC motor drive.

1.1 Aims

The aim of this assignment is to understand and demonstrate an investigation into DC drive and the technique that is employed for the control.

1.2 Objectives

- Using research demonstrate an understanding of single and three phase rectification of AC to DC conversion.
- Using research demonstrate the configuration of a DC drive and the control techniques used.
- Create a model of a single and three phase circuit with set component values. Analysis of the waveforms will be compared to theory.
- A practical experiment will be carried out in a team of a DC drive. An understanding of speed and load control will be shown, as well as four quadrant operation demonstrated and analysed.
- Practical experiment of speed control will be carried out and analysed against theory.

2. Research

did you
mean to
say
action?

There are many applications that require a DC supply either as a three phase supply or a single phase supply. There is also uncontrolled rectification that uses diodes to rectify the signal when the diode is saturated and controlled rectification that uses thyristors that are fired at differing angles to produce different shaped rectified signals. The selection of the components is determined by final application specification.

2.1 Single phase full wave controlled rectification

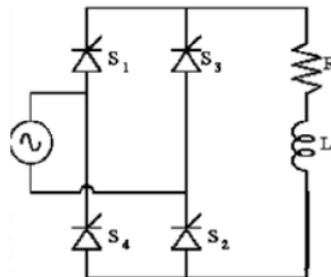


Figure 1 - single phase - (future electronics, 2016)

The above picture illustrates a single phase full wave controlled rectifier (SPFWCR). Utilising this method the armature voltage can be modified by adjusting the phase angle of the thyristors, it also has the ability to alter the power factor which will in-turn reduce the harmonics (Rashid, 2014).

2.1.1. Waveforms

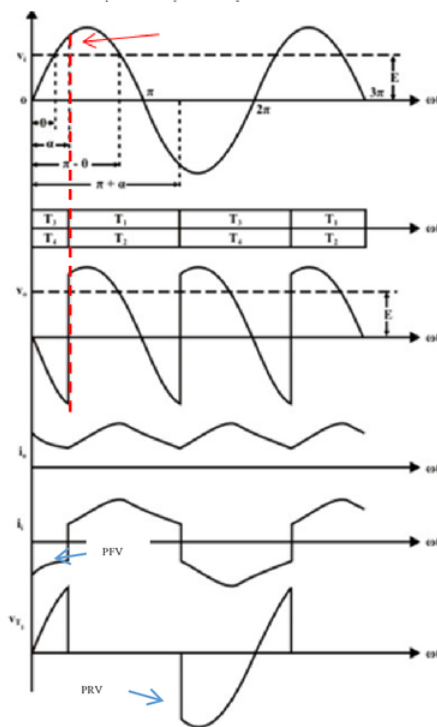


Figure 2 - Graph 1 - (Rashid, 2014)

It can be seen that when the Thyristor is fired at α , the resulting outputted waveform will look like the second graph down. The red dotted line highlights this.

When referring to figure 1, s_1 and s_3 are fired simultaneously at α , this creates 1 half of the wave, the other half is created when s_4 and s_2 are fired at $\pi + \alpha$.

At this point the current is continuous as even at its minimum it stays above 0. A larger inductance creates a smoother line.

It can be seen on the final graph that the thyristors are fired at PFV (Peak forward voltage and is signified as α) and at PRV (Peak reverse voltage is signified as $\pi + \alpha$).

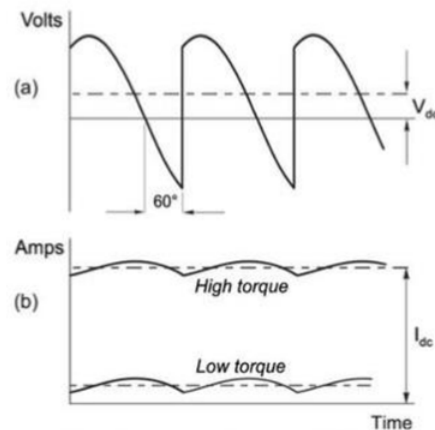


Figure 3 - current waveform - (Hughes, 2013)

On closer inspection it can be seen that in figure 3 graph (a) illustrates the rectified V_{ac} with the average voltage shown as V_{dc} . As it was shown before it can be seen that to vary the average V_{dc} the firing angle would be required to change. Graph (b) is the Armature current flow; it is noticeable that the ripple is far smaller than the voltage. This is due to the armature inductance smoothing the ripple much like a low-pass filter. However it must be made clear that due to the small ripple of 100 Hz for a 50 Hz supply there is a small deviation of torque every half cycle. Due to the small amplitude and frequency this is negligible. When observing figure # it can be seen that the beginning of the current pulse and end of the pulse are the same, therefore the voltage across the inductance is 0. This illustrates that the mean applied voltage equals the sum of the back emf and the mean voltage across the armature resistance. Thus the following expression is true.

$$V_{dc} = E + I_{dc} R$$

This expression shows the average voltage, speed can be changed by altering the firing angle (Hughes, 2013).

*Incorrect,
as this
equation
does not*

*contain
the firing
angle.*

2.1.2. Discontinuous & continuous current

It is also noticeable when referring to figure # graph (b) the current is continuous as at no point does the current not flow. However when observing the bottom line on the graph that represents reduced torque it can be seen that the current is nearing 0 and with a smaller amount of torque could become a discontinuous current. This could also happen sooner if the armature inductance is too small to smooth the current ripple and a larger ripple is present.

From this it can be assumed that discontinuous current is more prominent in smaller DC motors with small loads and small inductances. This can be observed in the lower graph below in figure #

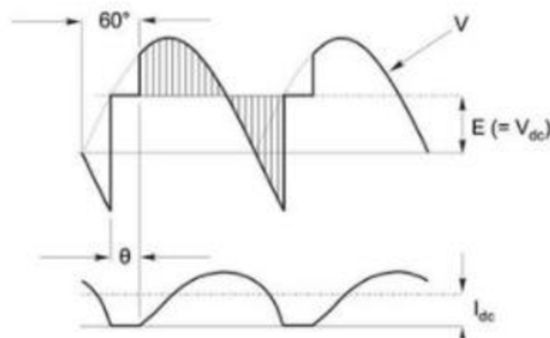


Figure 4 - Discontinuous current

An expression to better understand the waveform is to neglect the resistance and then the following is true.

$$\frac{di}{dt} = \frac{1}{L}(V - E)$$

2.1.3. Vmean and Back EMF

To enable a calculation on the mean voltage in regards to the firing angle the expression below will be integrated.

$$V_{av} = \frac{1}{\pi} \int_{\alpha}^{\pi + \alpha} V_{pk} \sin \theta \, d\theta$$

∴

$$V_{av} = \frac{V_{pk}}{\pi} (1 + \cos(\alpha))$$

It can be seen that as the field collapses there is zero current flowing (discontinuous current) when this occurs at θ then the following expression is true.

$$V_{mean} = \frac{1}{2\pi} \int_0^{\theta} V_{max} \sin \theta \, d\theta$$

It must be stated that the value of θ is reliant on the inductance.

this is only true for an inductive load
it would not be the same for a capacitive load
then back especially aske d for an inductive

For a full wave inductive load the parameters would be accounted for that being $\pi + \alpha$ to α .
 $\therefore$

$$V_{av} = \frac{1}{\pi} \int_{\alpha}^{\pi+\alpha} V_{pk} \sin \theta d\theta$$

This can be simplified to

$$2 \frac{V_{pk}}{\pi} \cos(\alpha)$$

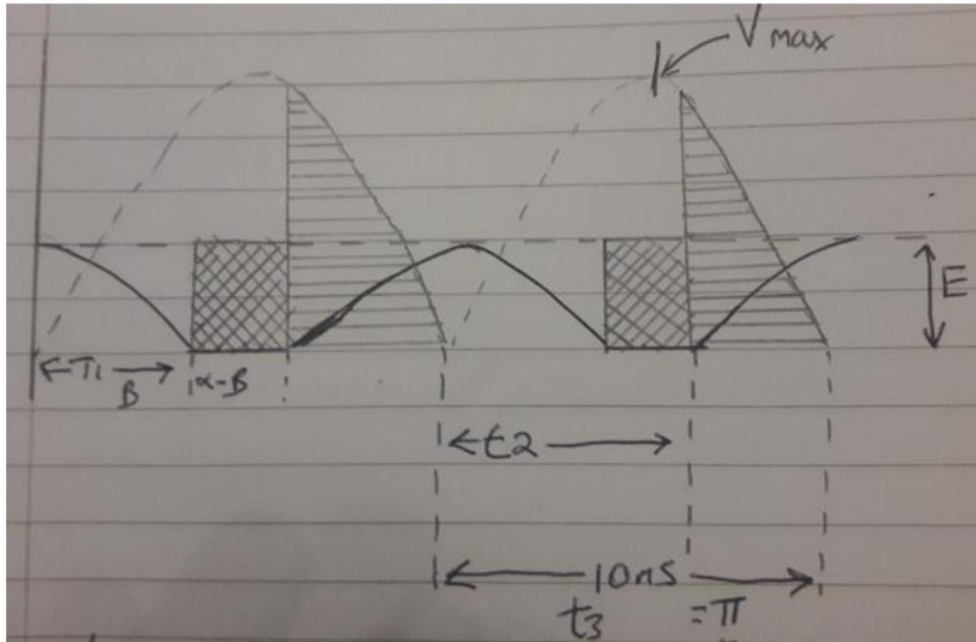


Figure 5 - DC graph including back emf

this is not an appropriate image for this level

It can be seen that from the equations so far and also by observing figure 4 the following equation can be derived to include E as the back EMF and α & β are the angles.

$$V_{mean} = \frac{1}{\pi} \left[E(\alpha - \beta) + \int_{\alpha}^{\pi} V_{max} \sin \theta d\theta \right]$$

The angles can be calculated as shown

$$\beta = \frac{t_1}{t_3} \pi$$

$$\alpha = \frac{t_2}{t_3} \pi$$

As before by integrating the formula the expression becomes the following.

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

2.2 Three phase full wave fully controlled rectifying circuits

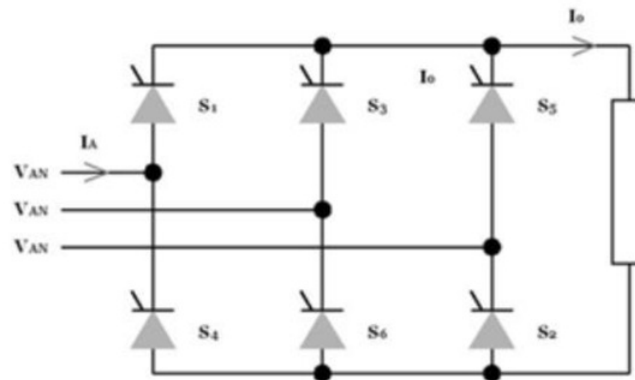


Figure 6 - 3 phase - (<http://www.electronics-tutorial.net>, 2016)

Figure 6 illustrate a three phase full wave fully controlled dc motor circuit. It can be see that each phase is connected to section of circuit with 2 thyristors, and each leg feeds a load which in this instance is inductive.

2.2.1. Waveforms

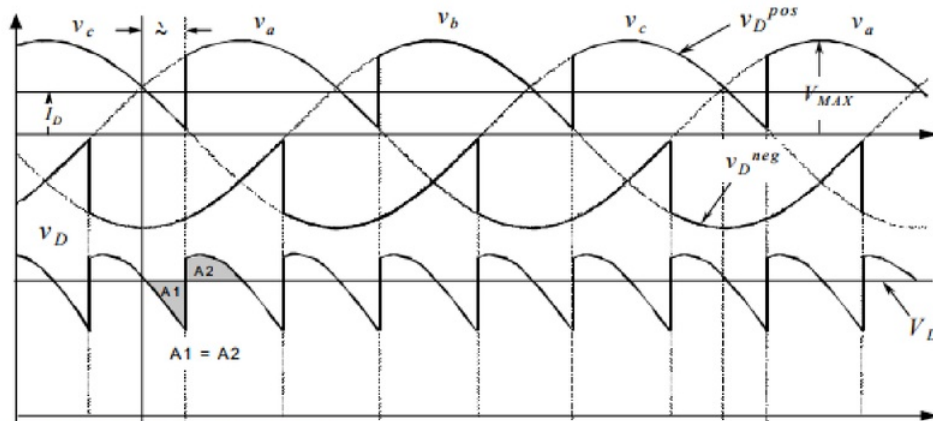
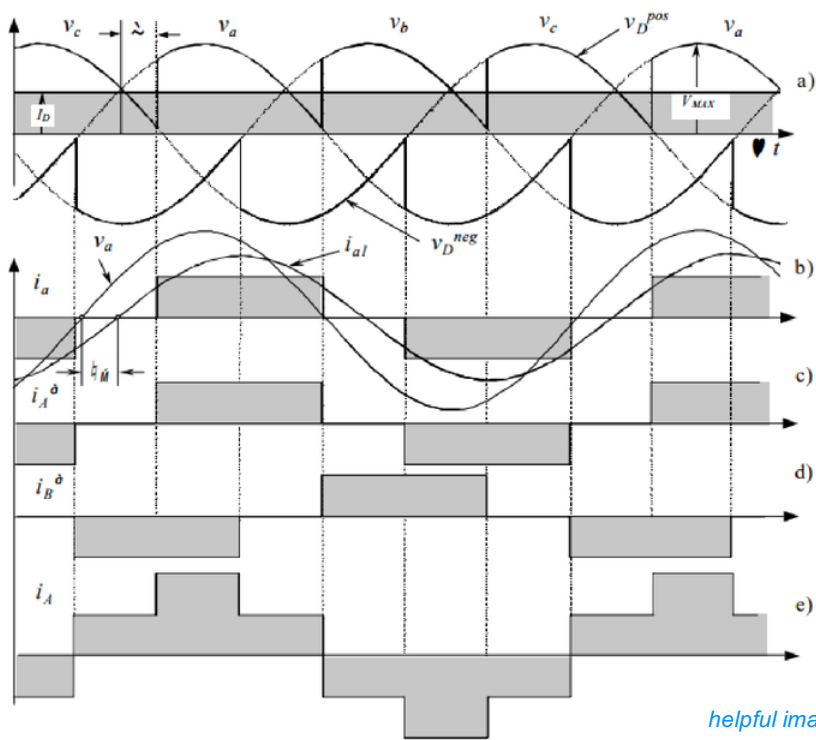


Figure 7 - Voltage Waveforms - (Dixon, 2001)

In the graph above it can be seen that a controllable sine wave has been developed by using Thyristors and firing them at angle α . And by combining the three sine waves pulses a six pulse load voltage waveform is developed, as shown on the bottom graph in figure 7 (Lander, 1993).

The average voltage is given as

$$V_{mean} = \frac{3}{\pi} V_{line}(Max) \cos \alpha \quad (\text{Lander, 1993})$$



[helpful image](#)

Figure 8 - Current waveform - (Dixon, 2001)

The current waveform that is developed is shown above, and it is noticeable that the supply current is of a quasi-square shape (Lander, 1993) as shown by graph e. This is noticeably a sine waveform when compared to the single phase circuit.

2.3 Investigation into dual bridge and 4 quadrant operation DC drives.

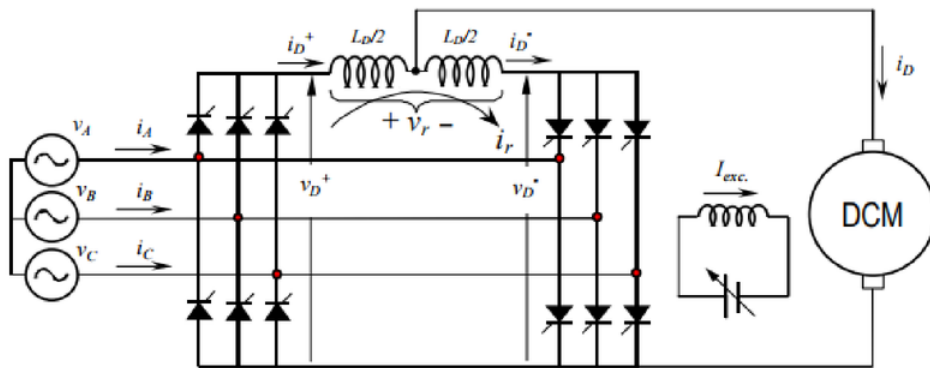


Figure 9 - Dual bridge - (Dixon, 2001)

The purpose of the dual bridge is to deliver positive or negative current to the load; this allows four quadrant operations as seen below in figure 10. It can be seen that the thyristors on the left are responsible for delivering positive and negative V_{dc} with a positive Current, this allows for the 1st and 4th quadrant operation. In contrast the rectifier on the right offers positive and negative V_{dc} and negative current which allows the motor to operate in 2nd and 3rd quadrant.

good observations

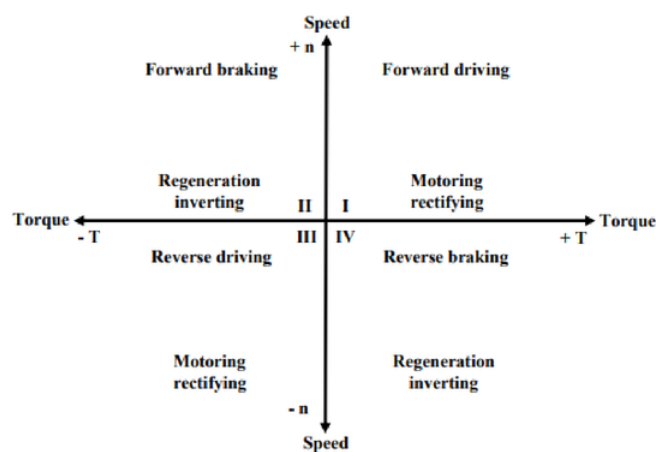


Figure 10 - Four Quadrant - (Dixon, 2001)

2.5 Configuration and control techniques of the Parker 514C

Below is a simplified schematic of the Parker 514C drive. The first notable point is the dual bridge convertor that is to the right of the schematic. F+ and F- will be connected to each end of one windings and A+ and A- will be connected to each end of the other winding. Ensuring the + for A and F are connected to the same side of the winding.

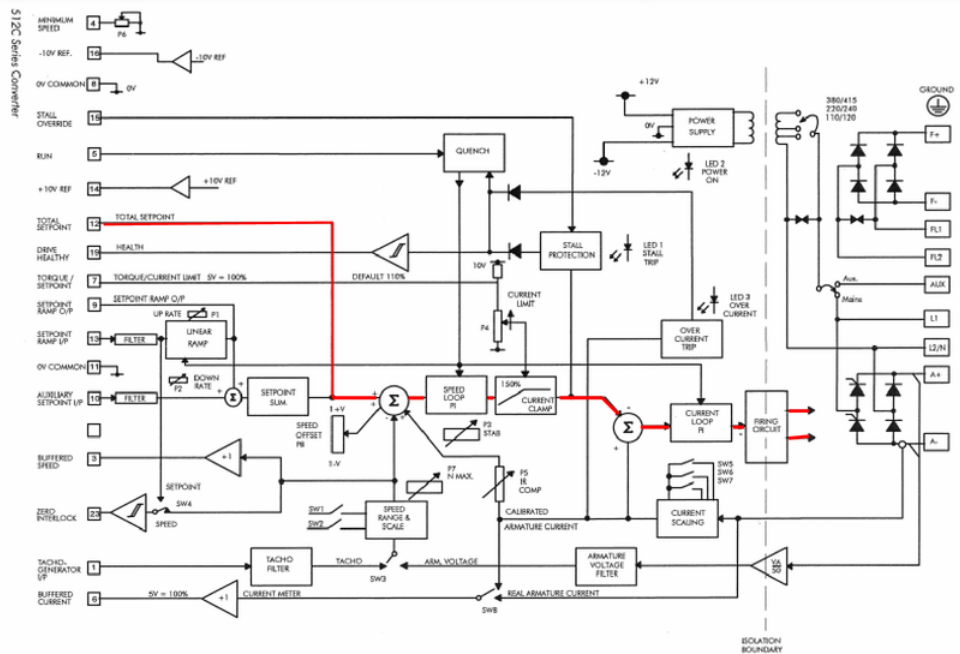


Figure 11 - Parker 514C

The control method to operate the drive requires a variety of analogue voltages and switches set depending on the required application. A simple method for speed control can be worked though as follows.

A voltage of -10V to +10v is applied to terminal 12 depending on forward or reverse application. This set point value is then applied to a summing point with the option of an auxiliary setpoint value and ramp up value added in line. Within the summing point the error value from the tacho generator is then subtracted whilst a calibrated armature current is applied. This combined value then passes to the speed control loop that applies the gain values of P and I to give a desired speed response. This value is then passed to the current clamp control. This then clamps the control value depending on the analogue value applied on terminal 7 to ensure motor protection from over load or fault. The next step is in to another summing point before reaching the current control that also applies PI control. This offers the user the ability to control the current demand for the motor if required. This final value is then passed to the firing circuit that gives a proportionate firing angle dependent on the value it is passed.

a good explanation offered.

3. Simulation of rectifying circuits (task 2)

For analysis simulations of a rectifying circuit will be carried out and analyzed. The simulation will be a model of a permanent magnet DC motor; this will be modelled as a load that contains inductance, resistance and a back emf. It will be fed by a single phase supply of 240V at a frequency of 60Hz.

3.1 Single phase, full wave fully controlled simulation

The inductance on this simulation is set at 100mh, and the resistor set at 10Ω and supply voltage at 100V.

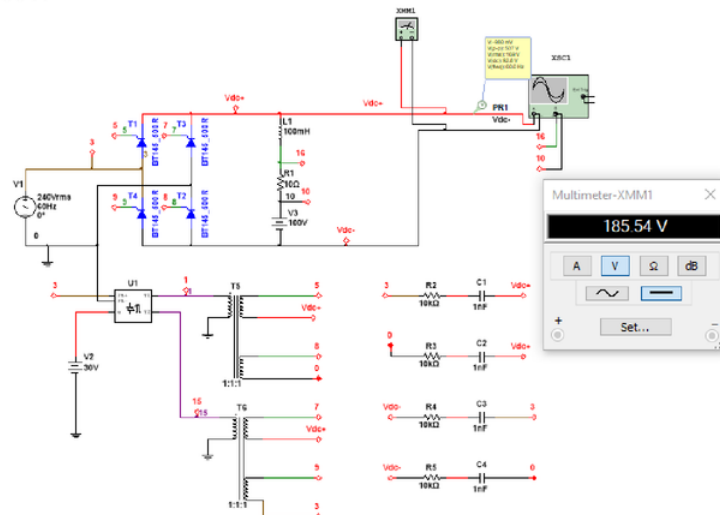
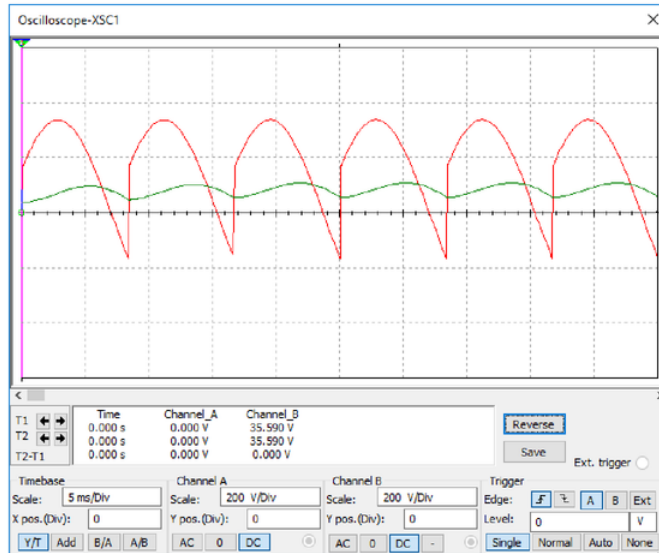


Figure 12 - Multisim 3

The expression to better understand the voltage compared to the outputted TD is $TD = \frac{\alpha}{f \times 360}$ where f = frequency parameter and α = voltage at pin α (National instruments, 2017). In the above image it can be seen that the firing angle has a voltage on the pin of 30V which gives a TD of 1.38ms.



It is

immediately

Figure 13 - Continuous current

notable when referring to figure 12 that there is continuous current and this ensures that there is no back emf present.

This is the same as what the research indicated and so the expression below can be used.

$$V_{mean} = \frac{2V_{max}}{\pi} (\cos \alpha)$$

As the frequency is 60 Hz which is 2π or $\frac{1}{60} = 0.016s$ or $16.6ms$.

π is then equal to $\frac{16.6ms}{2} = 8.33ms$

α is equal to $\frac{1.38ms}{8.33ms} \times \pi = 0.5204 \text{ rads}$

V_{max} was measured to be 337.2V

To compare the theory to the simulation the equation from the research will be used.

Therefore

$$V_{mean} = \frac{2 \times 337.2V}{\pi} (\cos 0.5204) = 186.25V$$

can you account for the small difference in the voltage reading to your calculations?

It can be proved that the expression used to determine V_{mean} is correct and the answer matched the simulated multi-meter reading in figure 11.

In the pictures below it can be seen that the firing angle has been set at 70V.

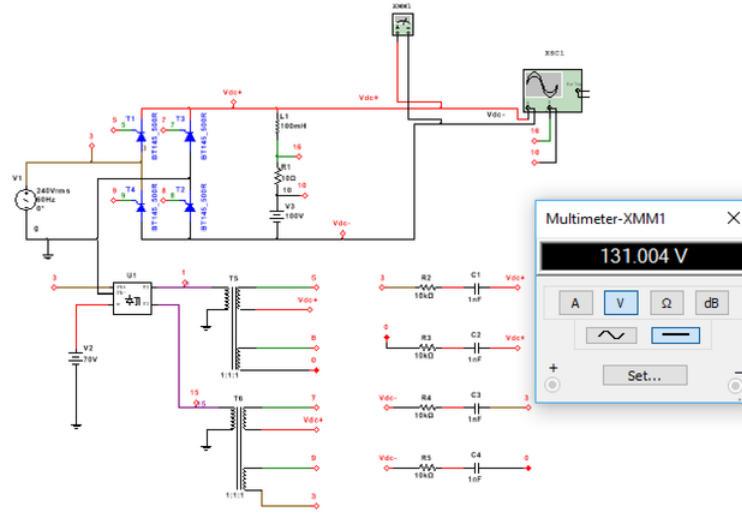


Figure 14 - MultiSim circuit 1

With α set at 70V which is 3.24ms it can be seen that the current has become discontinuous. It can also be seen that at the point of discontinuous current a back emf has been developed, this is signified by the arrow. This is to be expected as this was highlighted in the research.

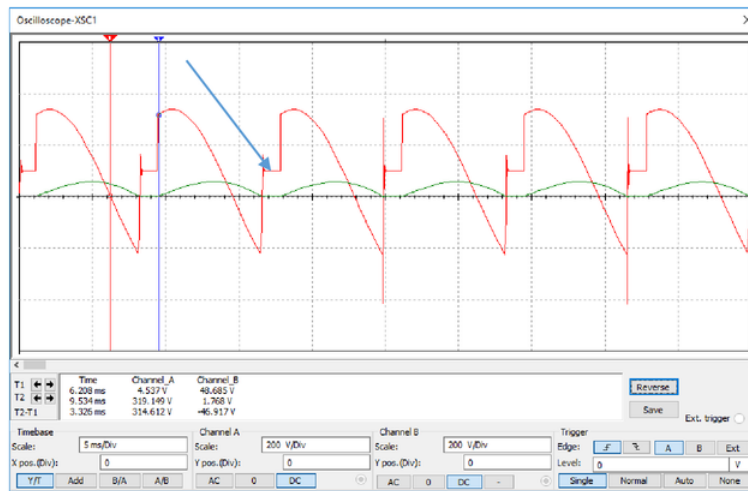


Figure 15 - Multisim circuit 2

It can be seen that the time delay t_1 is measured as 3.326ms, which confirms the national instruments equation as true.

As there is back EMF the following equation will need to be used to compensate for this.

This is also stipulated in the research.

$$V_{mean} = \frac{1}{\pi} (100(\alpha - \beta)) + \frac{V_{max}}{\pi} (\cos \alpha - \cos(\pi - \beta))$$

α is equal to $\frac{t_2}{t_3} \pi = \frac{3.326ms}{8.33ms} \times \pi = 1.254 \text{ rads}$

and β is equal to $\frac{t_1}{t_3} \pi$

It can be seen that T1 is illustrated in the oscilloscope below as being 2.016ms

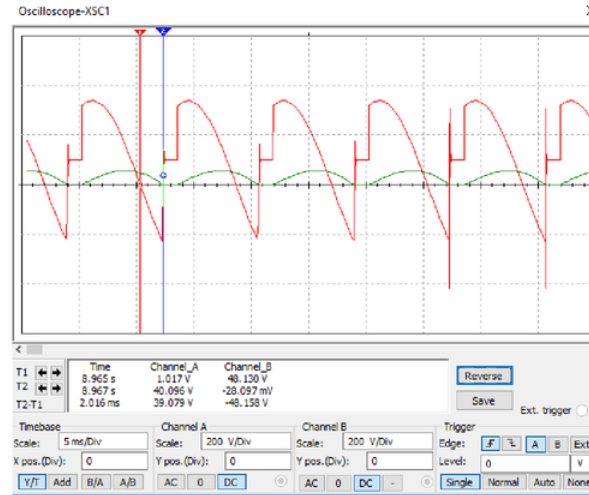


Figure 16 - t1 measurement

Therefore

$$\beta = \frac{2.06ms}{8.33ms} \pi = 0.777 \text{ rads}$$

Back EMF was measured to be 100V, by applying the values the following equation is populated and then worked through.

$$V_{mean} = \frac{1}{\pi} [100(1.254 - 0.777)] + \frac{V_{max}}{\pi} (\cos 1.254 - \cos (\pi + 0.777))$$

$$V_{mean} = 125.06V$$

On comparison the calculated Vmean of 125.06V and the measured Vmean from figure 13 is 131V it is clear that the results are very close and the difference can be put to rounding's and simulation inconsistencies with measurements.

4. Practical DC Drive investigation

The following is a practical experiment using a Parker 514DC drive which will run an appropriate motor. The picture below illustrates the setup used.

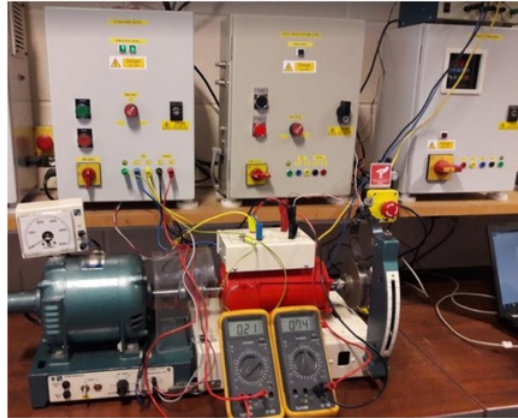


Figure 17 - No load 4.1 DC drive no load.

You could have explained the practical setup in more detail first to allow your reader to fully understand what you were doing and how the results were obtained.

4.1.1. Forward operation

The first experiment is to capture the waveforms for Current and voltage with no load applied to the motor.

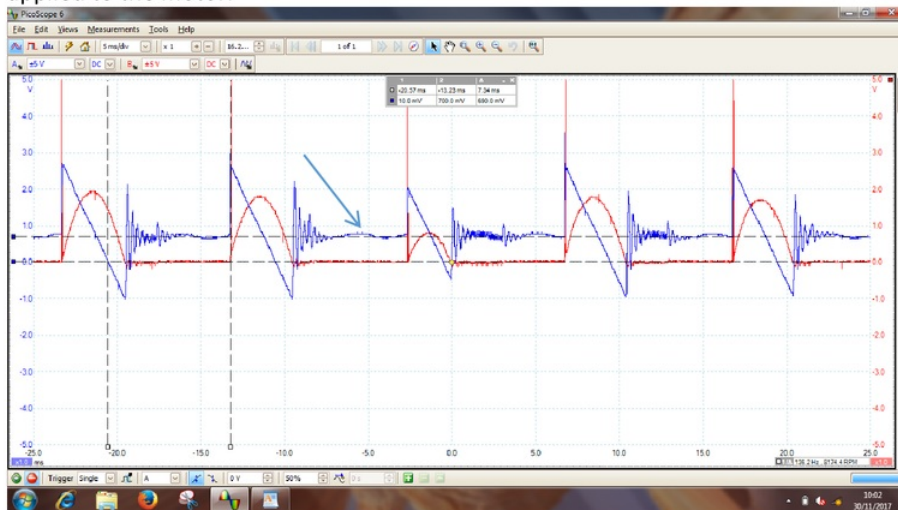


Figure 18 - Experiment 1.1

It is first noticeable that the current is discontinuous; therefore back-emf is present and signified by the arrow. The measured value of Voltage was 74V and the current shown on the multimeter was 0.22A. The cursors on the graph are lined up with α giving a value of 7.34ms.

As this is 50hz which is 0.02s for 2π . Therefore for π this is 0.01s then the firing angle is.

$$\alpha = \frac{7.34ms}{0.01} \pi = 2.3rads$$

This next screenshot is of the measurement of β .

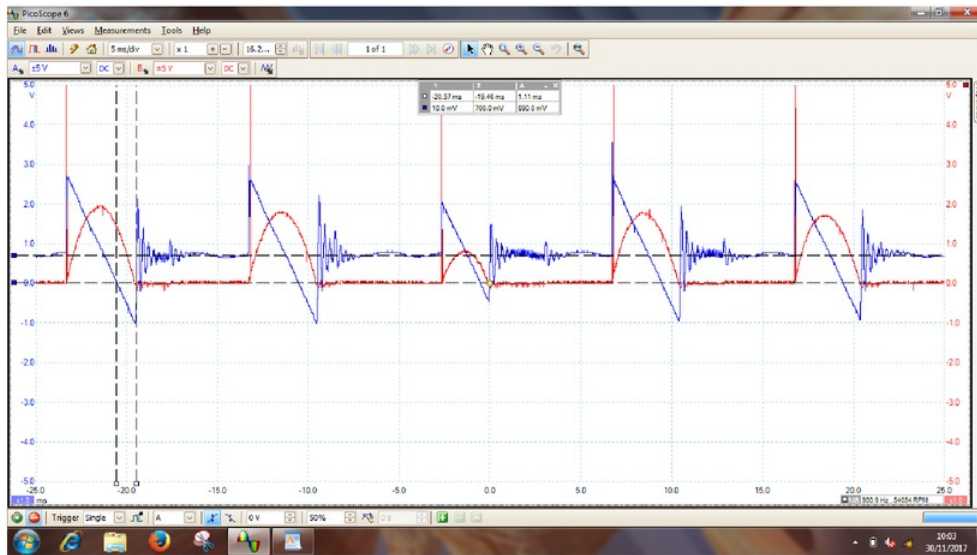


Figure 19 - Experiment 1.2

It can be seen that the time measured for $\beta = 1.11\text{ms}$.

Therefore

$$\beta = \frac{1.11\text{ms}}{0.01} \pi = 0.35\text{rads}$$

$$V_{\text{max}} = 240V_{\text{rms}} = 339V$$

Back EMF appears to be approximately 7 on the screenshot; this can be multiplied by a factor of 10 for the real value as the amplifier operates at a gain of 10.

$$\text{Therefore Back-EMF} = 70V$$

By populating the V_{mean} equation the following is shown.

$$V_{\text{mean}} = \frac{1}{\pi} (70(2.3 - 0.35)) + \frac{339}{\pi} (\cos 2.3 - \cos(\pi - 0.35))$$

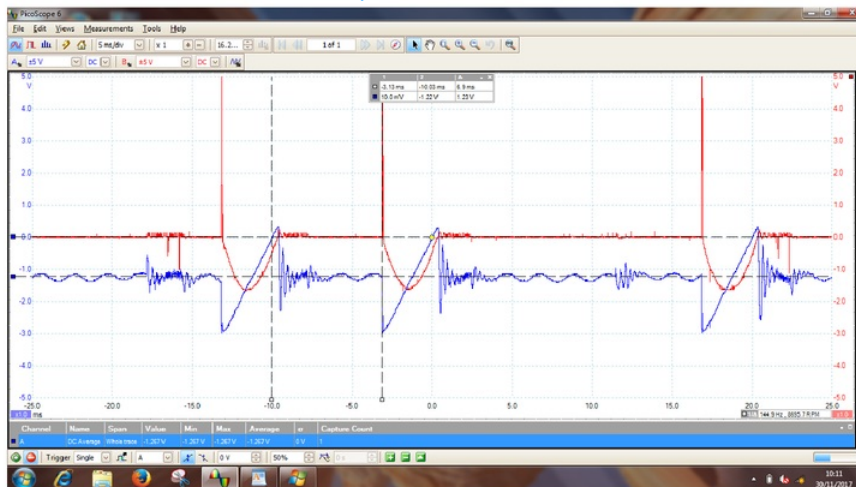
$$\text{Therefore } V_{\text{mean}} = 73.15V$$

The practical results for V_{mean} are 74V, the differences are very small and can be down to rounding's during the calculations.

4.1.2. Reverse Operation

For the next experiment the motor will be operated in reverse and waveforms measured. The measured value of the Average voltage was -125V and the current was -0.25A.alpha

write in the past tense when referring to an experiment you carried out in the past, you could have said "the motor was operated in reverse"



a photo of the multimeters is needed to prove these values

text is very small, Picoscope screen image could have been enlarged to see the values.

Figure 20 - No load reverse alpha

It can be seen that the measurement for α is 6.9ms on the screenshot. Therefore

$$\alpha = \frac{6.9\text{ms}}{0.01} \pi = 2.167\text{rads}$$

The following is a screenshot of the measurement of β .

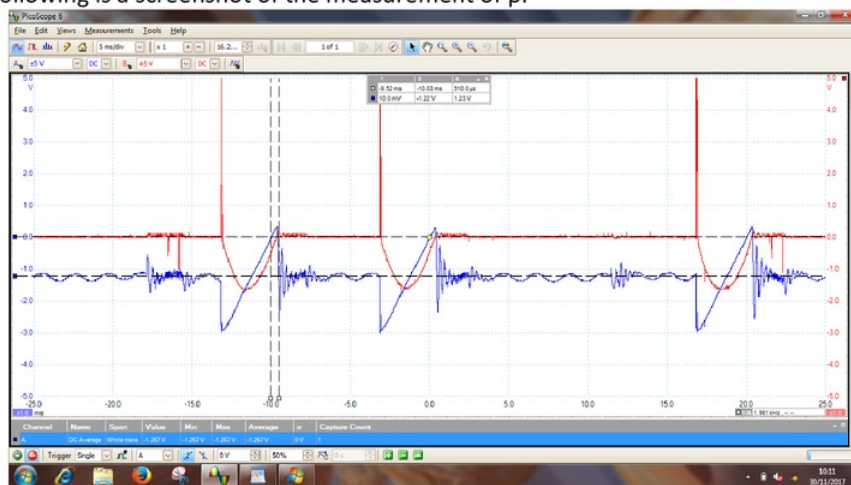


Figure 21 - no load reverse operation beta

It can be seen that the time measured for $\beta = 1.11\text{ms}$. Therefore

$$\beta = \frac{510\mu s}{0.01} \pi = 0.051 \text{ rads}$$

Back EMF appears to be approximately 11 on the screenshot; this can be multiplied by a factor of 10 for the real value.

Therefore Back-EMF = 110V. It is clear that although the motor is running in reverse it has increased in speed compared to before. This signified by the back emf being larger and it is known that as the armature speeds up the Back emf increases (Lander, 1993).

By populating the Vmean equation the following is shown.

$$V_{mean} = \frac{1}{\pi} (110(2.167 - 0.051)) + \frac{339}{\pi} (\cos 2.167 - \cos(\pi - 0.051))$$

Therefore Vmean = 121.25V

The practical results for Vmean are -122V, as before the differences are very small and could be due to approximations and rounding's. The negative measured value is only due to the motor running the opposite direction and if the leads to the multimeter had been swapped the positive reading would be shown.

It can be seen that the reverse operation graph is a flipped forward operation graph, with a larger voltage applied due to a smaller α applied. The current waveform is approximately the same as there is no load applied.

4.2 DC Drive with 3 different loads applied

The following is an experiment with three different loads applied at a set speed. The first experiment is with a 0.2NM applies using a Prony brake. The measure voltage was 123V with a current of 0.66A.

It is immediately noticeable that the current demand has increased due to the applied load, there is still a discontinuous current present and so back emf is shown.

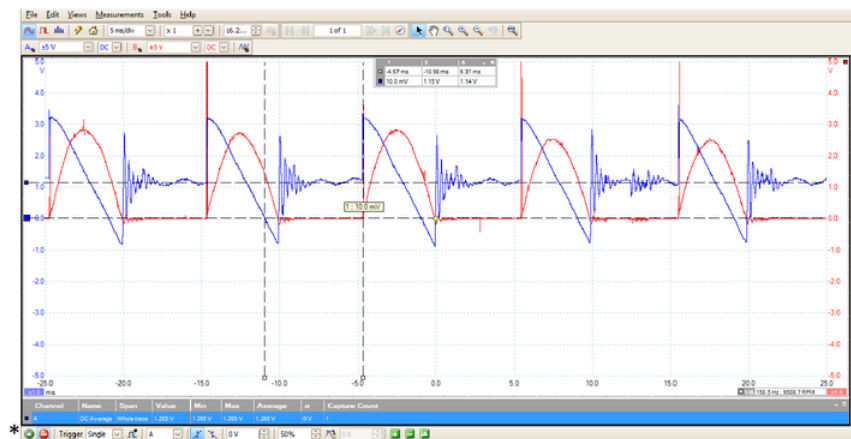


Figure 22 - Load 0.2nm load

It can be seen that the graph illustrates that the drive has produced an average voltage of 123V for the speed required.

In this next screenshot a new load of 0.4Nm is applied. $v = 125\text{V}$ $I = 1\text{a}$ (0.4Nm)

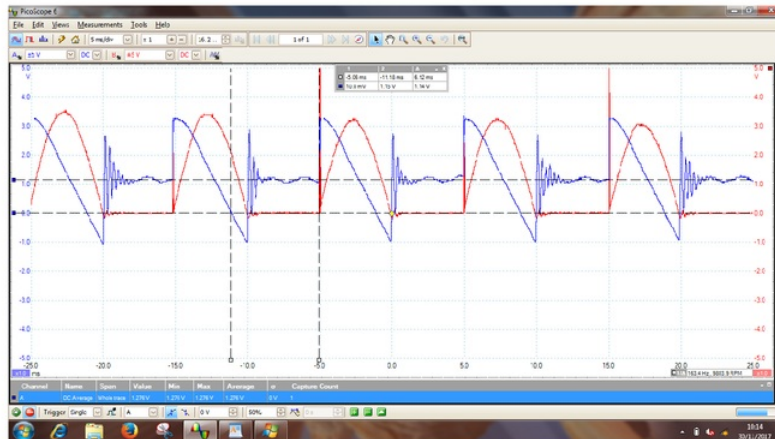


Figure 23 - 0.4nm load

It can be seen that the graph illustrates that the drive has increased the V_{mean} from 123V to 125V. This is also noticeable on the red waveform with slightly larger amplitude.

The measured current has increased to 1A from 0.66A; this is due to the increase in load applied. When observing the blue waveform the back emf is still present, this is due to the discontinuous current.

The final experiment is to apply a load of 0.6Nm. $v = 127\text{V}$ $I = 1.37\text{a}$ (0.6Nm)

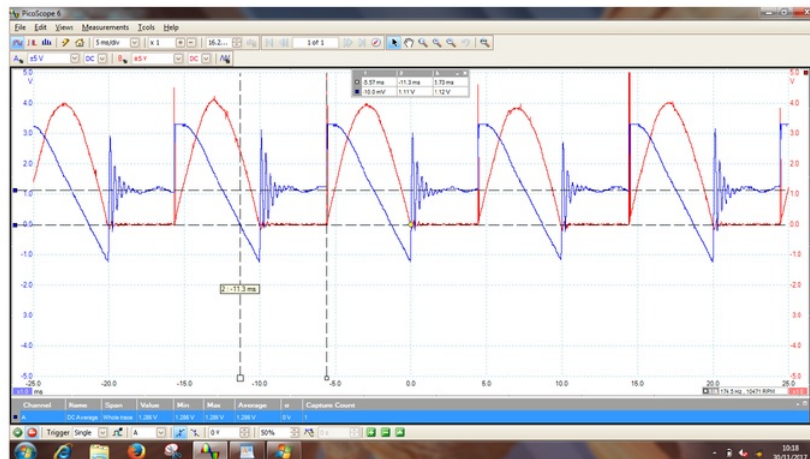


Figure 24 = 0.6nm load

The measured voltage has increased again to 127V; this will in turn produce a larger current which is measured as 1.37A. When observing the graph in figure 23 it can be seen that the graph illustrates that the drive has increased the amplitude of the voltage and as before the current amplitude has also increased as per the measured values.

In summary, the drive is programmed to overcome the momentary reduction in speed due to the additional loading. Therefore it applies an increased voltage, this in turn increases the current that enables the motor to increase the torque required to reach the speed setpoint. This is noticeable when comparing the screenshots of figure 21, 22 and 23 with the increasing waveform amplitudes.

4.3. Demonstration of regenerative braking.

In this experiment a switch on the VSD drive will be operated to enable feedback. This will allow for regenerative braking. This will be evidenced below and waveforms captured and analysed.

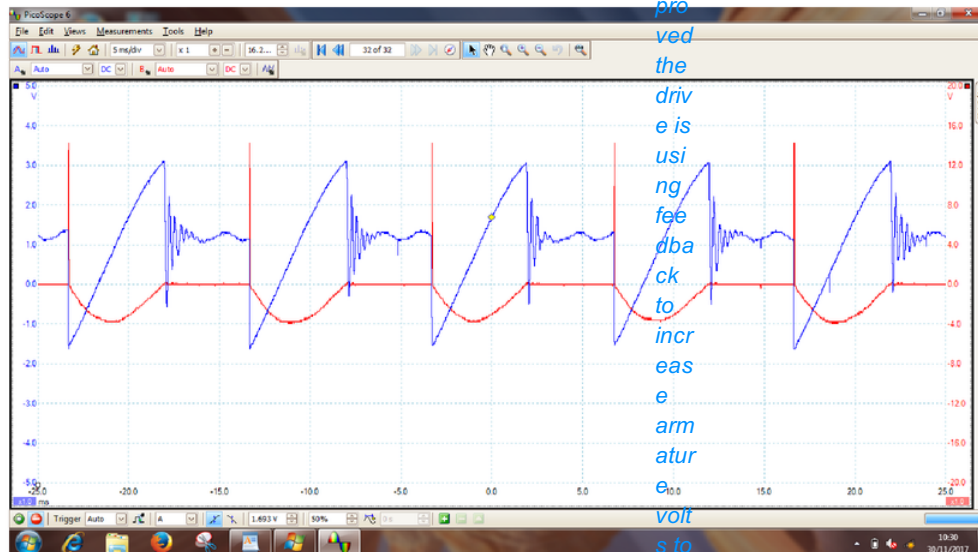


Figure 25 - Regenerative braking

When the motor is driven faster than its synchronous speed regenerative braking occurs. This is evidenced in figure 24. The current waveform in red is in the negative region and the firing angle has also flipped for the voltage. This is due to a negative slip as the motor is attempting to hold back or brake the rotor whilst it is being driven past slip the motor will generate leading power factor current that flows back to the supply (Lander, 1993). It is clear that the experiment matches the theory.

good
observations

You
have
already
provided
the
drive
is
using
feedback
to
increase
armature
voltage
to
maintain
the
speed

4.4. Four quadrant operation.

was

An experiment of four quadrant operation will be carried out below with speed and average current trace over a long period collected.

Below is a screenshot showing 4 quadrant of operation. This was produced by changing from forward motoring to reverse motoring quickly and back again.

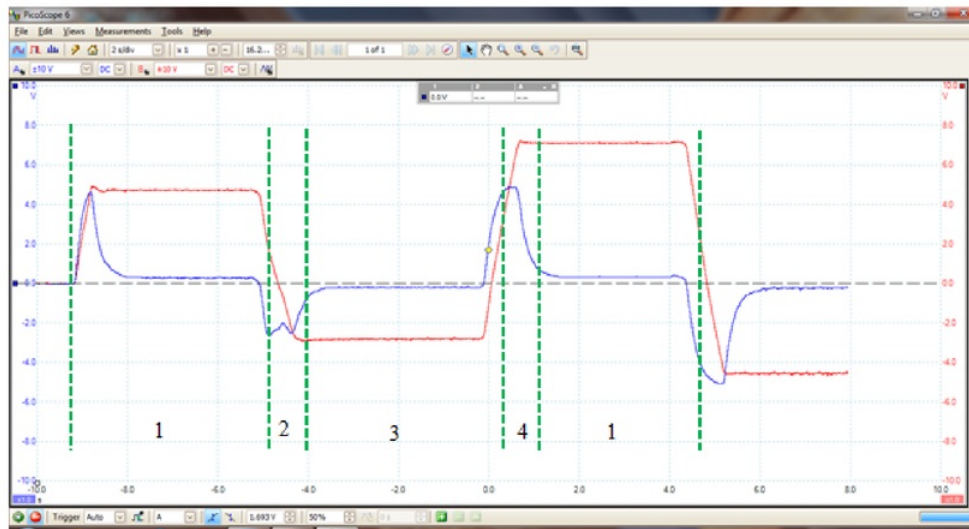


Figure 26 - Four quadrants

Figure 25 illustrates the 4 quadrants of operation, these are as follows.

1. Motoring Clockwise.
2. Breaking (regenerative).
3. Anticlockwise motoring.
4. Breaking (Plug).

It can be seen that the motor will generate during forward braking but in reverse direction it will plug brake. Plug braking is not an efficient method of braking as it requires additional power to develop counter torque; this creates wasted energy that is lost in heat which can damage the varnish on the windings.

It can be seen that the experiment matches up with the research regarding 4 quadrants operation.

4.5. Drive tuning of the control loops.

For this practical suitable adjustment to the drive control loops will be made this will illustrate the influence upon stability at start-up. As voltage is proportional to speed the steady state voltage of 4.58V is proportional to the set speed of the motor.

This graph is of the motors performance with the parameters for k_p and k_i set at minimum.

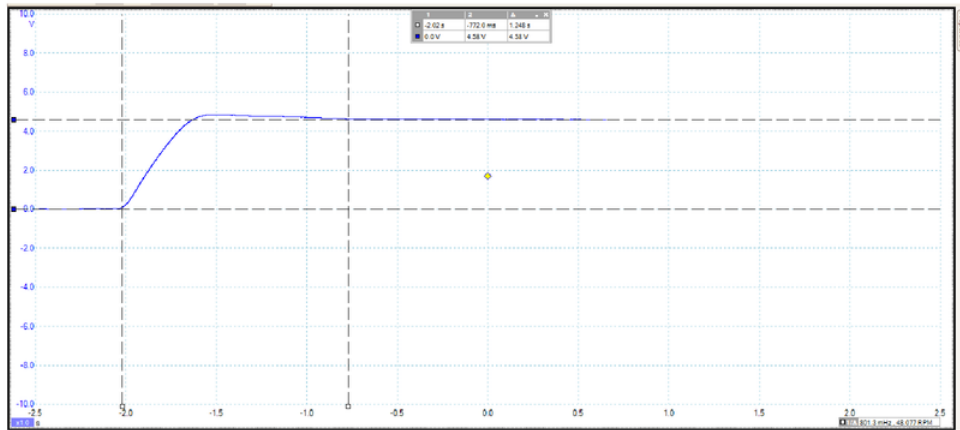


Figure 27 - Min k_p and k_i

In this graph it can be seen that when minimal proportional and integral gain is applied the motor takes 1.248s to reach a steady state speed at 4.58V. It is noticeable that there is a slight overshoot before the motor reaches the steady state.

In this graph k_p is set to maximum and k_i is set to minimum

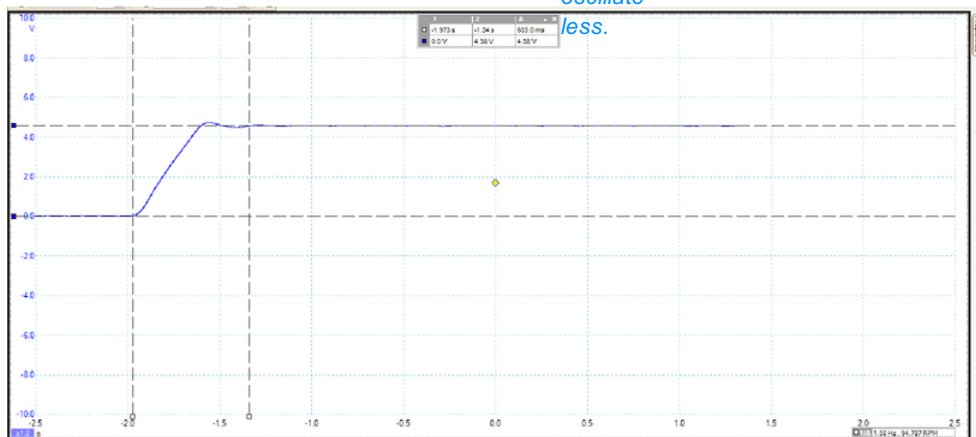


Figure 28 - k_p max k_i min

It can be seen that the motor reaches set speed far quicker at 0.633s than the previous experiment of 1.248s. However the initial stability is reduced as the motor overshoots the speed setting and then overcompensates due to the maximum k_p and undershoots before settling.

Oscillations
do not mean
instability
What you
could say is
that it settles
quicker or
oscillate
less.

In this experiment K_p has been set to minimum and k_i is set to maximum.

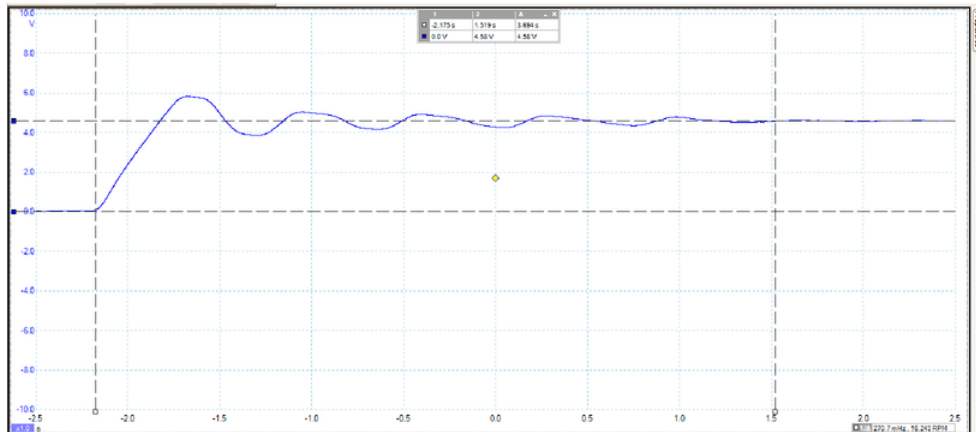


Figure 29 - k_p min and k_i max

In this experiment it can be seen that the speed response of the motor has now become very unstable and takes a greater amount of time to reach steady state that being 3.694s. This is due to the nature of k_i where it applies a control dependant on time and so reacts very quickly when set to maximum. This in turn creates many overshoots and undershoots until it reaches steady state.

In this experiment k_p is set to max and k_i is set to max,

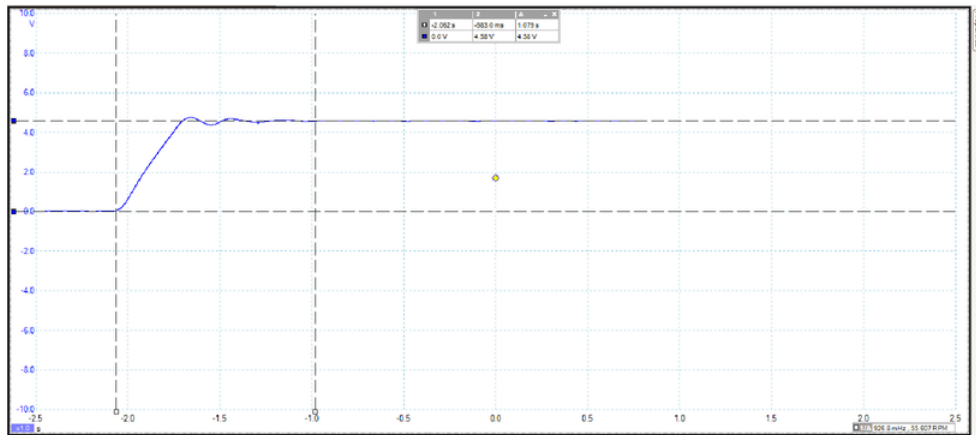


Figure 30 - max k_p and max k_i

This response illustrates slightly better control compared to the last experiment with steady state being reached in 1.079s. It is clear that this is not the best response so far as there is still some instability. It is clear that a smaller k_i is needed and a trimmed k_p required.

For the final experiment of speed control k_p and k_i is set to the middle setting.

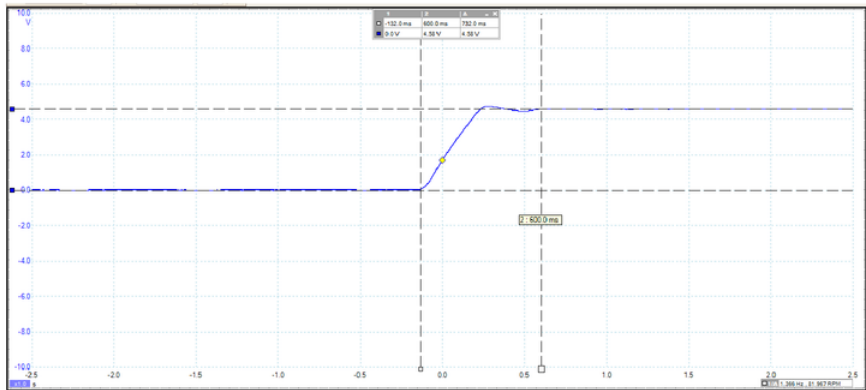


Figure 31 - k_p and k_i set to mid

It is immediately obvious that the instability has settled down and although not the fastest to reach steady state it does achieve it at 0.732s. *oscillations do not mean instability. What you could say is that it settles quicker or oscillate less.*

In summary it is clear in this experiment that by applying maximum proportional gain and minimal integral gain the most stable and quickest response is created.

This result does conflict with the theory states that with only proportional gain applied the response would not be able to reach steady state (Hughes, 2013). Therefore to reach steady state a value of integral would be required as k_i control increments or decrements its control dependent on error over time.

This would leave me to believe that the drive is applying additional control to allow the motor to achieve set point speed.

When observing the manual the drive has an "Inherent over speed" control (Parker, 2016). This can be viewed in the appendices as Annexe 1.

4.6 Analysis of results

It is clear that by utilizing a DC drive a motor can be applied to a variety of application.

If the application required forward and revers operation the drive is able to provide this by utilizing the inbuilt dual bridge circuit as per the research.

If the application of the motor requires it to drive at a set speed with changing loads, it has the ability to increment and decrement voltage to compensate for the torque required to compensate for the loading and in turn meet the set point speed. This altering voltage is delivered by firing the thyristors at set angles to create an average voltage.

If plug braking or regenerative braking is required this can be easily utilized due to the four quadrant operation available due to the bridge circuit, this was illustrated clearly.

With the addition of speed control added to the drive, it can be seen that desired control methods can be used. For example a fast or slow ramp up time or speedy response to altering loads.

5. Conclusion and Recommendations

5.1 Objectives achieved

- This assignment demonstrates research was carried out and scrutinised for single and three phase rectifier circuits and a good understanding shown with in depth knowledge of waveforms and formulae worked through.
- It can be seen that research was carried to illustrate configuration of a DC drive and the control techniques used within section 2.5.
- A model of single phase circuit with set component values was thoroughly analysed with waveforms and measured values compared to theory.
- Many practical experiments were carried out on a DC drive. It can be seen that speed and load control experiments were analysed as well as four quadrant operation investigated and is demonstrated within the whole of section 4.
- The practical experiment of speed control was carried out successfully. It was clearly analysed against theory slight discrepancies were found and answered.

5.2 Achieved aim

The aim of this assignment was to understand and demonstrate an investigation into DC drive and the technique employed for speed control.

It is clear that when summarising the entire report a good understanding was demonstrated. Full analysis of speed control technique was also demonstrated.

6. Citation

Works Cited

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<http://www.electronics-tutorial.net>, 2016. *Three Phase Full Wave Controlled Rectifier*. [Online]

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Hughes, A., 2013. *Electric motors and drives*. 4th ed. Oxford: Newnes.

Lander, C. W., 1993. *Power Elecronics*. Third ed. Berkshire: McGraw.

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[Accessed 10 01 2018].

Rashid, m. H., 2014. Power Electronics. In: *Devices, circuits and application*. Harlow: Pearson, p. 710.

7. Appendices

7.1. Annexe 1

TECHNICAL SPECIFICATION

General

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 $\pm 10V$	100 Kohm
	Positive Trim Setpoint	0 to $\pm 10V$	100 Kohm
	Negative Trim Setpoint	0 to $\pm 10V$	100 Kohm
	Current Limit	0 to +7.5V	50 Kohm
	Current Demand	0 to $\pm 10V$	100 Kohm
	Tachogenerator Input	0 to $\pm 350Vdc$	220 Kohm
	Thermistor / Microtherm Input	<200 ohm = Normal >1800 ohm = Overtemperature	5 Kohm
Outputs Analogue	Setpoint Ramp	0 to $\pm 10V$	5 mA
	Total Setpoint	0 to $\pm 10V$	5 mA
	Speed	0 to $\pm 10V$	5 mA
	Current Demand	0 to $\pm 10V$	5 mA
	Current Meter Bipolar or Modulus	0 to $\pm 5V$ (0 to 1cal)	5 mA
		See SW1/8	
	+10V Reference	+10V	5 mA
	-10V Reference	-10V	5 mA
Digital Inputs	Run	+10 to +24V	100 Kohm
	Enable	+10 to +24V	100 Kohm
	Stall Override	+10	100 Kohm
Digital Inputs	Health	+24V	50 mA Source
Digital Outputs	Zero Speed or Setpoint	+24V	50 mA Source

Investigation into Convertors

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

60/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

Text Comment. did you mean to say "from"?

QM

WC

Word choice error:

Sometimes choosing the correct word to express exactly what you have to say is very difficult to do. Word choice errors can be the result of not paying attention to the word or trying too hard to come up with a fancier word when a simple one is appropriate. A thesaurus can be a handy tool when you're trying to find a word that's similar to, but more accurate than, the one you're looking up. However, it can often introduce more problems if you use a word thinking it has exactly the same meaning.

PAGE 6

Text Comment. Incorrect, as this equation does not contain the firing angle.

PAGE 7

Text Comment. $\pi + \alpha$

Text Comment. this is only true for a purely resistive load, the assignment specifically asked for an inductive load

Text Comment. for an inductive load, there wouldn't be a 1 in the brackets

PAGE 8

Text Comment. this is not an appropriate image for this level

Text Comment. helpful image

Text Comment. good observations

Text Comment. a good explanation offered.

Text Comment. can you account for the small difference in the voltage reading to your calculations?

Text Comment. You could have explained the practical setup in more detail first to allow your reader to fully understand what you were doing and how the results were obtained.

Text Comment. write in the past tense when referring to an experiment you carried out in the past, you could have said " the motor was operated in reverse"

Text Comment. a photo of the multimeters is needed to prove these values

Text Comment. text is very small, Picoscope screen image could have been enlarged to see the values.

Text Comment. You have already proved the drive is using feedback to increase armature volts to maintain the speed.

Text Comment. good observations

PAGE 23

Text Comment. was

QM

Sp.

Spelling error

QM

Sp.

Spelling error

PAGE 24

Text Comment. Oscillations do not mean instability. What you could say is that it settles quicker or oscillate less.

PAGE 25

PAGE 26

Text Comment. oscillations do not mean instability. What you could say is that it settles quicker or oscillate less.

QM

Sp.

Spelling error

PAGE 27

PAGE 28

PAGE 29

GRADING FORM: CSG-RUBIC

RUSSELL MAGUIRE

60

RESEARCH-INFORMED LITERATURE

Section 1: Your research - Good evidence of



background research with helpful diagrams.
However, some of your equations are not quite correct. (21/30) Section 5: Your use of Harvard for citing and listing – A range of sources cited and listed correctly. (3/5)

24

KNOWLEDGE AND UNDERSTANDING



Section 2: Explanation of simulation - A good explanation given, however, only two thirds of this task was completed. (3/5) Section 3: Explanation of practical experiment –Good. However, you could have explained the practical setup in more detail first to allow your reader to fully understand what you were doing and how the results were obtained.. (3/5)

6

ANALYSIS



Section 2: Analysis of results from simulation - Good analysis evident with some attempt to explain the differences between theory and simulation. However, only two thirds of this task was completed.(5/10) Section 3: Analysis of results from practical experiment – Very good analysis given. Photos of multimeter readings would have improved the evidence presented and a summary table for results would be helpful. (7/10) Section 4: Overall conclusions and recommendations –You have reviewed the assignment aims and objectives and stated that they have been met. Further marks were available for a summary of what exactly you have learnt about controlled rectifiers and DC drives. No recommendations have been made on further investigations. (4/10)

16

PRACTICAL APPLICATION AND DEP.



Section 2: Simulation - Good use of MultiSIM but only two thirds of the task was carried out. (3/5)
Section 3: Practical experiment - Very good. but more photos were needed. (4/5)

7

SKILLS FOR PROFESSIONAL PRAC.



All sections - Report is well presented and structured with numbered and listed figures. However, pages should have been numbered also and one figure is of poor quality. (7/10) Section 4: Team role - No explanation given. (0/5)

7