

assignment 2

by Gareth Wilkins

AN EXCELLENT REPORT THROUGHOUT WITH VERY
GOOD USE OF THE WORD COUNT. EXCELLENT
KNOWLEDGE WAS DEMONSTRATED AND CRITICAL ANALYSIS
WAS EVIDENT FROM THE DETAILED CONCLUSIONS.

MARK AGREED


FILE	13876_GARETH_WILKINS_ASSIGNMENT_2_179200_291471031.PDF (2.63M)		
TIME SUBMITTED	06-MAY-2021 09:06PM (UTC+0100)	WORD COUNT	4903
SUBMISSION ID	152037075	CHARACTER COUNT	26753

Course: HND Electrical and Electronic Engineering
Module: SGEE5006 Power and Machines
Assignment: 2. DC motors and Drives, and AC Transmission Lines
Name: Gareth Wilkins
University number: 1809804
Date submitted: 06/05/2021
Word count: 2583

Contents

List of figures	3
1. Executive summary.....	4
2. Research	5
2.1 DC motor applications.....	5
2.2 Methods of control of DC machines from an AC supply	6
2.3 Construction and operation of a single quadrants DC drive such as the Parker 512c.....	7
3. Simulation of a Half-Controlled Rectifier Circuit.....	9
4. Practical Investigation into a Single Quadrant DC drive	11
5. Simulation of a Medium Length Transmission Line	13
6. Conclusions and Recommendations.....	16
7. Team Working	17
8. Works Cited	18
9. Appendix.....	19
9.1 Simulation of a full half-controlled rectifier calculations.....	19
9.2 Practical experimentation oscilloscope readings and calculations.....	27
9.3 Medium length Transmission line calculations.....	35

List of figures

Figure 1: Thyristor converter armature torque and speed control of DC motor	8
Figure 2: Practical set-up of DC motor supplied by a Parker 512c drive.....	11
Figure 3: Continuous current waveform with 1.5Nm of torque	12
Figure 4: Nominal π equivalent circuit of medium length transmission line.....	13
Figure 5: Nominal π equivalent circuit results.....	14
Table 1: Simulation results for half controlled rectifier circuit	9
Table 2: Comparison of calculated and simulated half controlled rectifier circuit	10
Table 3: Loading effect on motor results	10
Table 4: Back EMF at continuous current phase and voltage theoretical and simulated value comparison	10
Table 5: Table of comparison of practical and theoretical average armature voltage values.	11
Table 6: Nominal π equivalent circuit component values.....	13
Table 7: Medium length transmission line impedance characteristics.....	13
Table 8: Comparison table of theoretical and simulated medium length transmission line (Sending end)	14
Table 9: Comparison table of theoretical and simulated medium length transmission line (Receiving end).....	14
Table 10: Comparison table of theoretical and simulated medium length transmission line power.....	15
Table 11: Comparison table of theoretical and simulated medium length transmission line efficiency.....	15

1. Executive summary

This report evaluates the established theory of dc motor principles with simulated and practical investigation. Research was performed on industrial application of the dc motor where it was discovered DC motors were the prominent choice for motor speed control before the advent of variable frequency drives for AC machines. Originally DC was produced from a DC generator to permit control of DC machines. This was superseded by power electronic drives. A single quadrant drive construction and operation was evaluated establishing it can only operate in the forward direction. Simulations of a half-controlled rectifier demonstrated the effect of thyristor firing angles and average armature voltage. Simulating differing back emf values provided continuous and discontinuous current waveforms. Following the simulation, a practical was conducted with a single quadrant drive. The motor was subjected to various speeds and loads. The current waveforms were observed, and average armature voltage and current operating mode was distinguished. A medium length transmission line nominal π equivalent circuit was constructed and appropriate calculations were completed to obtain transmission line characteristics. A conclusion was constructed detailing the significant discoveries with particular emphasis on dc drive continuous and discontinuous current waveforms. It was recommended that it would have been beneficial to have compared a practical application with an AC drive motor.

*An excellent
summary*

2. Research

2.1 DC motor applications

The DC motor was the routine choice for applications that required speed or torque control up until the advent of the inverter-fed a.c. motors in the 1980s. While the prevalence of the inverter fed a.c. motors incorporate a significant segment of the market D.C. motors continue to be competitive in larger rating functions of several hundred kW where drip proof motors are tolerable (A Hughes, 2013). DC motors are the motor of choice for applications requiring constant low speed torque or adjustable torque. Repair and maintenance of DC motors are simpler compared to the AC models. The speed-torque curve produced by a DC motor is linear. Many factories are equipped with the apparatus required to utilise DC motors. The upgrading to an AC model would incur significant costs. DC motors are not susceptible to harmonic effect that could damage to equipment causing problems. (Control Global, 2019)

The scope of the d.c. motor range from traction systems, lathe machines and rolling mills (Circuit Globe, 2021). The performance of a d.c. motor can be predicted with a simple equivalent circuit. The fundamental structure of the d.c machine remains the same from power ranges of several megawatts to modest levels. The dc machine incorporates two separate electrical circuits constituting the field windings and the armature circuit (Elprocus, 2021). The d.c machine can operate at any desired voltage however it is conventional for the working voltages to extend from 6V to 700V. Small d.c. motors of up to a few hundred watts output can run at 12,000 rpm but ordinarily the medium and large motors are intended to run at speeds below 3000rpm. D.C motors were conventionally classified as shunt, series or separately excited. These classifications denoted the field and armature interconnection which defined its operating characteristics (Electrical Desk, 2021). Traction applications utilised the series motor due to its high starting torque. Applications where constant speed was required employed shunt connected motors. These methods have been superseded as the advent of power electronic devices have enabled the separately excited machine to be tailored for any application (A Hughes, 2013).

Spelling

DC motor are inherently proficient at providing torque proportionally to current into their overload zone making them capable for applications that require an intermittent boost of torque (Drive and Automation, 2021). To increase the speed of a dc motor the notion of field weakening is performed where the field flux is reduced. This however has a proportionally negative effect on the torque. Therefore, applications that do not require full torque at high speed can utilise field weakening strategies. The maximum speed however seldom exceeds

four times the base speed. In conclusion at beneath base speed, the speed is governed by the armature voltage where the field flux is maximum. Exceeding base speed requires maximum armature voltage while reducing field flux. The available maximum torque declines proportionally with the reducing of flux (A Hughes, 2013).

Motor suitability for specific applications is achieved by the evaluation of the torque speed characteristic with the operating diagram of the motor (ICEEET, 2019). The maximum rating of a motor is determined by the acceptable heat level of the armature conductors. Powering a d.c motor directly with rated voltage from standstill is unacceptable as the inrush current would be significant as no back e.m.f is present. It is crucial that current is maintain within its specified boundaries for converter drives as thyristor and transistor components lack overcurrent capacity resulting in destruction. Closed loop current limiting is an attribute of motor and drive arrangements which prevent overcurrents. Habitually motor current is permitted to attain 1.5 rated current for no longer than sixty seconds (A Hughes, 2013).

2.2 Methods of control of DC machines from an AC supply

Pre 1960 the only method of attaining a variable dc supply required for speed control was obtained from a dc generator. Typically, the generator's prime mover was driven by an induction motor at a set speed and the generated voltage was adjusted by varying the generator field. This setup was termed the Ward Leonard which were succeeded by controlled mercury arc rectifiers in the 1950s (Electrical 4 U, 2020). The advent of thyristor converter superseded these methods due to higher efficiency, swifter response, and overall lower costs. While the advantages are obvious the rectifier does not provide pure dc.

Power electronic drives are operated to supply the d.c motor which expend a.c. power from the utility supply and rectify it to d.c. The thyristor drive obtains its supply from the utility supply. Also, higher voltages are possible. A three-phase supply is favoured due to the waveforms being smooth. The primary power circuit comprises a six-thyristor bridge circuit that provides dc to the motor armature following the rectification of the ac utility supply (Kim, 2017). Thyristor firing angles are varied providing an average dc voltage enabling motor speed to be controllable. The d.c. produced by the rectifier is of a coarse disposition with a prominent ripple at the output. The ripple element causes pulsating fluxes in the motor yielding considerable eddy current losses. Subsequently it is customary to associate motors of laminated construction with thyristor drives. Control circuits are implemented to observe variables of importance and produce the required firing pulses to sustain constant speed despite any fluctuations in the load. Generally acknowledged the speed of the motor is established by the firing angle of the converter (A Hughes, 2013).

Drive current waveform characteristics are defined as continuous or discontinuous. Continuous current describes the circumstance of no occurrence of the current interrupting. Continuous current is advantageous as the mean voltage supplied from the drive is exclusively governed by the firing angle and is detached from the load current. Discontinuous current transpires where the bottom of the current ripple converges on the zero-current line. The armature inductance influences the current characteristic. Discontinuous current is typically seen in small motors with low inductance under light loads. Discrete pulses of current that transpire only when the armature is connected to the supply. For the period of zero current symbolising no thyristor is conducting, and the motor is freewheeling from the supply. In discontinuous mode the only way to increase current in the armature is to decrease the speed. This produces an unfavourable torque speed curve as an increment in the load torque results in a noticeable decrease in speed. Discontinuous current establishes a higher average voltage. In continuous current mode the voltage is unaffected and an increase in load is encountered by increasing armature current (A Hughes, 2013). Correctly cited

2.3 Construction and operation of a single quadrant DC drive such as the Parker 512c

A single quadrant DC drive is restricted to operating in the forward direction. The excitation of the field is static, and the speed control is governed by the variable armature voltage. A thyristor converter armature torque and speed controller is shown in figure 1. The 512 is single phase Shown is a three phase six pulse converter connected to the armature and a three-phase supply. A single-phase bridge rectifier provides the field current I_f . External inductor L_1 is occasionally required when armature inductance is not sufficient but typically not required. External inputs constituting speed, current and torque are fed to a gate triggered processor. The processor can be configured to set desired torque and speed values. The measured values are equated with the desired value and the processor produces the required gate pulses to achieve proximity of desired and actual values. Drive limitations are configured to prevent the motor exceeding its operating rating. During start up the current is monitored so as not to allow overload. Generally, the firing angle of 15-20 degrees is obtained when the motor reaches full speed (Wildi, 2014). Not related to the 512

You should have looked at the manufacturer's datasheet

incorrect, the 512 is a single phase 2 thyristor rectifier wit two diodes

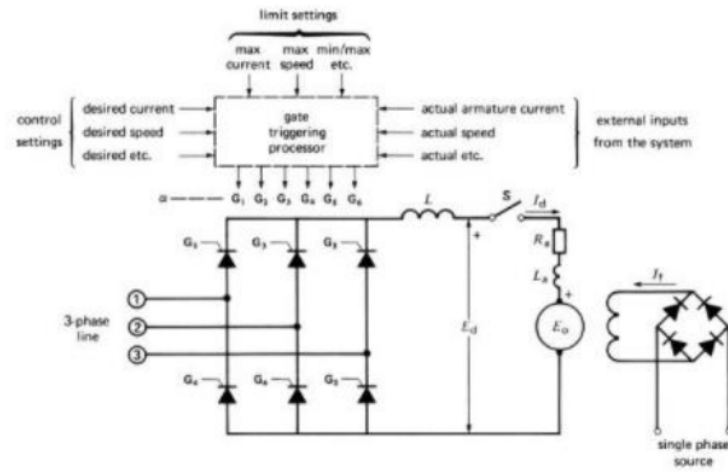


Figure 1: Thyristor converter armature torque and speed control of DC motor

3. Simulation of a Half-Controlled Rectifier Circuit

It is a shame that you didn't go back at this point and correct your research on the 512 because you state here that it is a single phase drive

To replicate the Parker 512c single quadrant drive a MultiSim single-phase full wave controlled rectifier model was produced. The circuit comprises two thyristor T1 and T2, two diodes D2 and D3 allowing full wave rectification with half control of the thyristors. Diodes act as the commutators as no negative voltage exists owing to the commutative loop which permits the thyristors to be deactivated. Phase angle controller U1 generates a pulsed output on T1 and T2 as the phase angle is determined by the α setpoint which in this instance is the dc power source V2. The crossover is identified by Ph+ and Ph-. The motor characteristic is denoted by resistor R1 and inductor L1. DC source V3 signifies the back emf of the motor. The isolation transformers Tx1 and Tx2 separate the pulses generated by the phase angle controller that could reach voltages exceeding the supply.

The phase angle of the half-controlled rectifier circuit model was varied by adjusting the setpoint angle of the controller by adjusting V2's value. Three values of phase angles were selected, and the values are tabulated in table 1. To obtain the value of T1 which signifies the time taken to cross over, the cursor of the oscilloscope is located on the cross over point which enables the calculation of β . To attain T2's value a cursor was placed on the firing point of the location of the thyristor where the elapsed time was noted which permitted the calculation of α . The results are tabulated in table 1 see appendix 9.1 for run simulations.

Table 1: Simulation results for half controlled rectifier circuit

Measured values of simulated half- controlled rectifier		
Phase angle	T1 Value (ms)	T2 Value (ms)
115	0.495	6.231
95	1.714	5.142
65	3.253	3.536

Table 2: Comparison of calculated and simulated half controlled rectifier circuit

Phase angle			Voltage		
Simulated	Calculated	Difference	Simulated	Calculated	Difference
115	114.372	0.628	125.326	125.228	0.095
95	95.472	0.472	136.288	135.1229	1.1651
65	65.178	0.178	155.722	155.19	0.532

Table 2 demonstrates that the calculated and simulated values for voltage and phase angle are similar. The minor discrepancies can be attributed to cursor positioning on the oscilloscope or rounding to the nearest number.

To observe the effect of mechanical loading the models firing angle was set at 80° . The disturbances were simulated by varying the value of back emf by altering the dc source V3. The back emf values are tabulated in table 3 with the accompanying t2 measurements.

Table 3: Loading effect on motor results

Simulated loading effect on motor	
Back emf value	T2 measurement
110	2.475
90	4.373
80	4.208

The resultant simulation waveforms can be found in appendix 9.1. The 110V and 90V delivered discontinuous current and 80V provided continuous current as the current did not touch zero. The phase angle and average armature voltage was calculated and compared with the simulated values see appendix 9.1 for calculations and table 4 for results. The minor discrepancies can be attributed to cursor positioning accuracy and rounding of numbers.

Table 4: Back EMF at continuous current phase and voltage theoretical and simulated value comparison

Phase angle			Voltage		
Simulated	Calculated	Disparity	Simulated	Calculated	Disparity
80	80.19	0.19	124.964	125.586	0.622

4. Practical Investigation into a Single Quadrant DC drive

To investigate the practical application of a single quadrant drive an experiment was conducted. This experiment incorporated a dc motor, a Parker 512c DC drive, Prony brake and an oscilloscope. The practical setup is shown in figure 2. Under no load conditions three speed setpoint were observed and the resultant voltage and current waveforms obtained. The results and calculations are shown in appendix 9.2.



Figure 2: Practical set-up of DC motor supplied by a Parker 512c drive

The practical measurements are compared with the calculated theoretical results of average armature voltage in table 5.

Table 5: Table of comparison of practical and theoretical average armature voltage values.

Average armature voltage		
RPM	Practical (V)	Calculated (V)
502	35.9	39.266
1003	66.05	73.9512
1500	105.8	107.2715

Implementing the prony brake to the motor enabled the armature current waveform to be analysed under varying loads. It was observed at low load the DC drive current characteristic was discontinuous. Increasing the load decreased the t_1 value. With a value of 1.5Nm applied the current was continuous as the current waveform does not touch the zero-current value. This is illustrated in figure 3. Under low load from theory, it was predicted that the current would be discontinuous as the motor is of insignificant size and has a low armature inductance. Continuous current operation is desirable as the average voltage supplied by the drive is solely determined by the firing angles of the thyristors and separate from the load current.

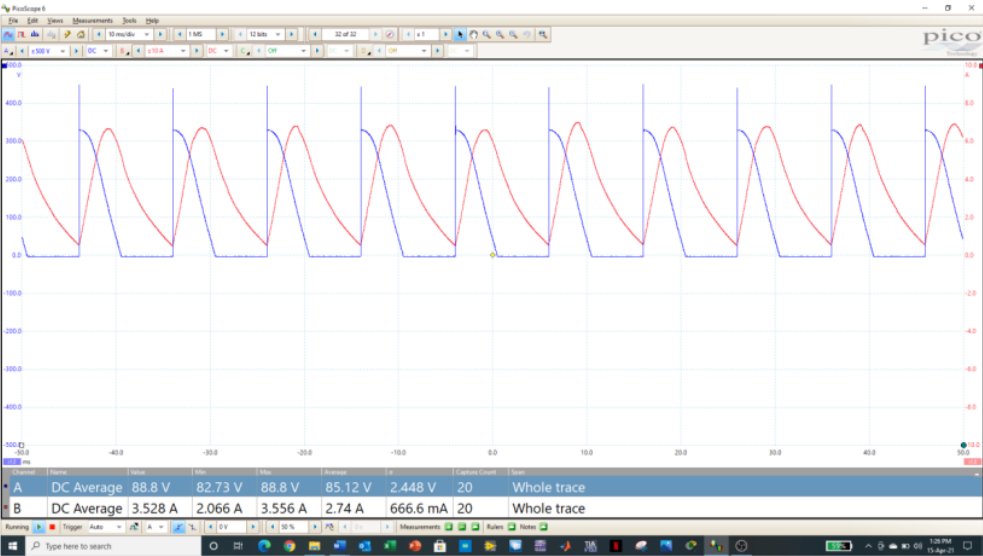


Figure 3: Continuous current waveform with 1.5Nm of torque

5. Simulation of a Medium Length Transmission Line

A nominal π equivalent circuit of a medium length transmission line is shown in figure 4. The component values are presented in table 6.

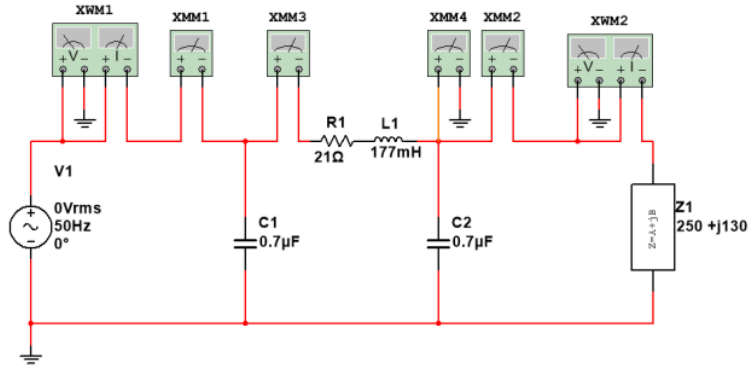


Figure 4: Nominal π equivalent circuit of medium length transmission line

Table 6: Nominal π equivalent circuit component values

Nominal π equivalent circuit component values		
Component	Identification	Value
Resistor	R1	21 Ω
Inductor	L1	177mH
Capacitor	C1 and C2	0.7 μ F
Load impedance	Z1	250 + j130

The component values permitted the calculation of the series and shunt impedance with the result shown in table 7. The calculations can be found in appendix 9.3.

Table 7: Medium length transmission line impedance characteristics

Medium length transmission line impedance characteristics		
Series impedance	21 + j55.606	59.44 $\angle$ 69.311°
Shunt impedance	$j439 \times 10^{-6}$	$439 \times 10^{-6} \angle 90^\circ$

To evaluate the calculations an equivalent circuit was produced on Multisim supplied by a 95.32761KVrms AC source determined by the calculations in appendix 9.3. A comparison table of the theoretical values and simulated measurements are shown in tables 8, 9 and 10.

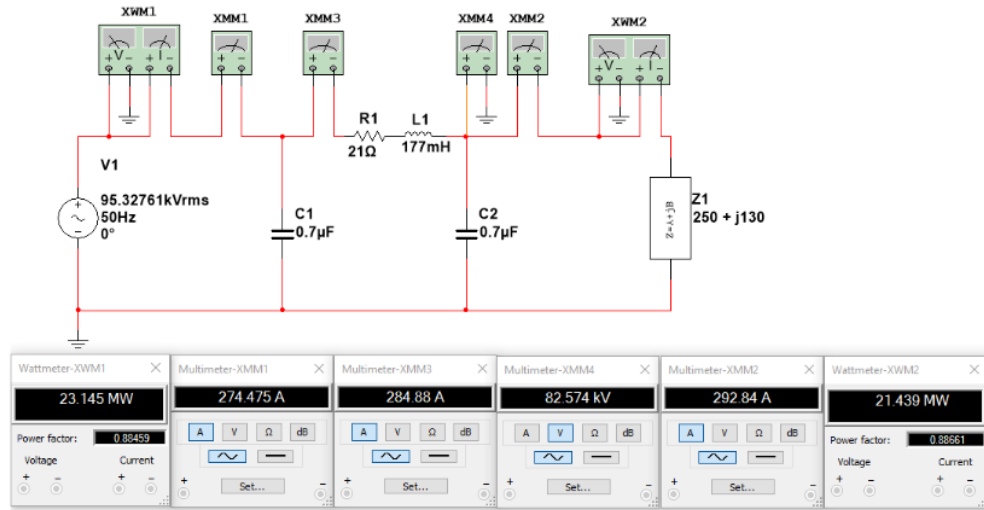


Figure 5: Nominal π equivalent circuit results

Table 8: Comparison table of theoretical and simulated medium length transmission line (Sending end)

Comparison table of Theoretical and simulated medium length transmission line (Sending end)			
	Theoretical	Simulated	Disparity
Sending End voltage	95327.61 $\angle$ 7.233° V	95327.61 $\angle$ 7.233° V	n/a
Current Sending End	274.844 $\angle$ -20.502° A	274.48A	0.364
Sending End p.f.	0.8851 Lagging	0.88460 Lagging	0.0005
I1	285.214 $\angle$ -24.241° A	284.884A	0.33

Table 9: Comparison table of theoretical and simulated medium length transmission line (Receiving end)

Comparison table of Theoretical and simulated medium length transmission line (Receiving end)			
	Theoretical	Simulated	Disparity
Vtage	82596V	82573V	23
Current	293.124A	292.842A	0.282
p.f.	0.88722 Lagging	0.88661 Lagging	0.00061

Table 10: Comparison table of theoretical and simulated medium length transmission line power

Comparison table of medium length power			
	Theoretical	Simulated	Disparity
Sending End Power	23.19MW	23.146MW	0.044
Receiving End Power	21.48MW	21.439MW	0.041

Table 11: Comparison table of theoretical and simulated medium length transmission line efficiency

Comparison table of medium length transmission line efficiency			
	Calculated efficiency	Simulated efficiency	Disparity
Sending end	23.19MW	23.146MW	
Receiving end	21.48MW	21.439MW	

Evaluating the theoretical and simulated results concludes that the disparity is negligible. The source of the inconsistencies can be accredited to calculation rounding.

6. Conclusions and Recommendations

The DC motor research established that although the AC motor dominates the motor speed control market the DC machine nevertheless comprises characteristics which are desirable. The speed-torque characteristic produced by a DC motor is far more linear compared with the inverter fed a.c motor. The simulation of the half-controlled rectifier circuit demonstrated the effect of varying the thyristor firing angle on the resultant current waveform. It was observed that reducing the firing angle increased the armature average voltage. Continuous and discontinuous current was analysed by adjusting the back emf value. It was observed that decreasing the DC source eventually led to continuous current operation.

Spelling

Ensuing the simulations, a practical was conduct with a single quadrant dc drive motor arrangement. Incremental speed points were sampled, and the resultants current waveforms were observed. As the motor was operating at no load the current was discontinuous. Increasing the speed resulted in a lower firing angle and an increase of average armature voltage. Increasing the applied load eventually led to continuous current. It is desired for dc drives to operate in this mode as voltage supplied by the drive is wholly determined by the firing angles of the thyristors and separate from the load.

Good
understa
nding

Medium length transmission line characteristics were evaluated by a nominal π equivalent circuit. Theoretical calculations enabled the calculation of the sending voltage. The simulated and theoretical results were comparable with any discrepancies attributed to decimal place rounding. It would have been beneficial to have compared the practical application performance of an inverter fed ac machine with the dc drive machine. Nonetheless the basic structure and operation of a DC drive is reflected in modern ac drives.

7. Team Working

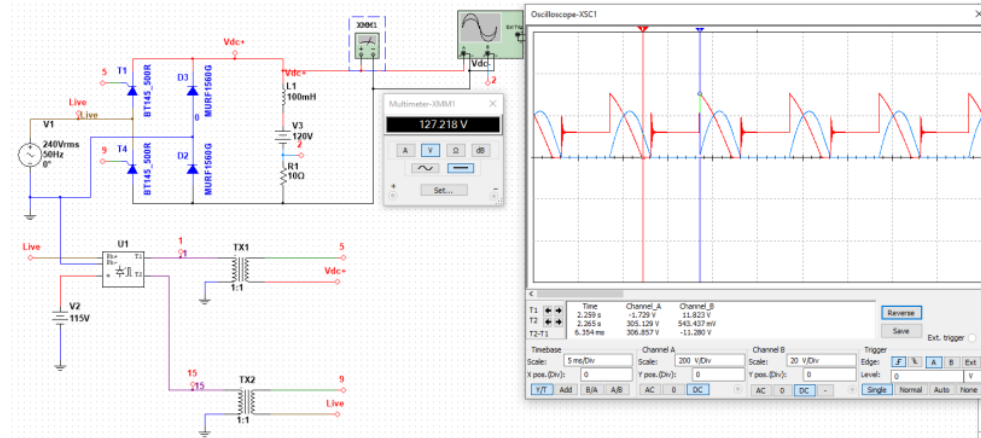
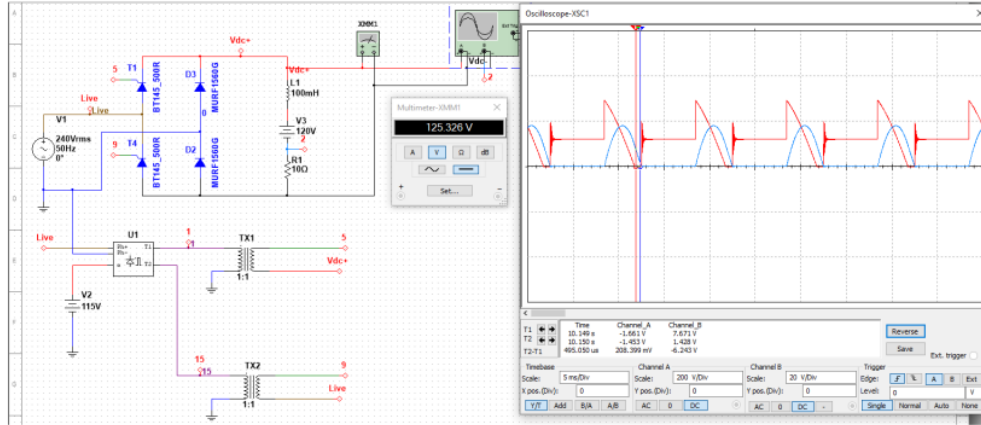
As a group the Parker 512cc single quadrant drive was examined for its speed and applied load characteristics. An assessment of the test area was performed and appropriate P.P.E and social distancing was implemented to undertake the task. Author was tasked with establishing an appropriate speed for the experimentation. Gentle incrementation in speed was performed attentively listening to Liam's instruction as he was reading the tachometer speed measurement. Mathew obtained the current and voltage waveforms and recorded the samples required to evaluate performance. Before experiment completion as a team the recorded results were discussed and evaluated to ensure all evidence was acquired and that the results produced a similar outcome to the prediction.

8. Works Cited

- A Hughes, B. D. (2013). *Electric Motors and Drives: Fundamentals, Types, and Application* (Fourth Edition ed.). Oxford: Newnes.
- Circuit Globe. (2021, 05 02). *Circuit Globe*. Retrieved 05 02, 2021, from <https://circuitglobe.com/applications-of-dc-machines.html>
- Control Global. (2019, 08 14). *Control Global*. Retrieved 05 03, 2021, from Control Global: <https://www.controlglobal.com/blogs/guest-blogs/advantages-of-dc-motors-in-industrial-applications/>
- Daware, K. (2020, 05 02). *Electrical Easy*. Retrieved 05 02, 2021, from Electrical Easy: <https://www.electricaleasy.com/2012/12/basic-construction-and-working-of-dc.html>
- Drive and Automation. (2021, 05 02). *Drive and Automation*. Retrieved from Drive and Automation: <http://www.drivesandautomation.co.uk/useful-information/dc-motor/>
- Electrical 4 U. (2020, 10 26). *Electrical 4 U*. Retrieved from Electrical 4 U: <https://www.electrical4u.com/ward-leonard-method-of-speed-control/>
- Electrical Desk. (2021, 05 02). *Electrical Desk*. Retrieved from Electrical Desk: <https://www.electricaldeck.com/2021/01/types-of-dc-motors-shunt-series-compound-motors.html>
- Elprocus. (2021, 05 02). *Elprocus*. Retrieved 05 02, 2021, from Elprocus: <https://www.elprocus.com/dc-machine-types-and-their-applications/>
- ICEEET. (2019, 09 27). Retrieved 05 02, 2021, from ICEEET: <https://www.iceeet.com/speed-torque-characteristics/>
- Kim, S.-H. (2017). *Electric Motor Control*. (First, Ed.) Elsevier Science.
- Wildi, T. (2014). *Electrical Machines, Drives, and Power Systems* (Sixth Edition ed.). Essex: Pearson Education Limited.

9. Appendix

9.1 Simulation of a full half-controlled rectifier calculations



$$\text{Full period} = \frac{1}{f} = \frac{1}{50\text{Hz}} = 20\text{ms} \text{ half cycle} = 20 \times 0.5 = 10\text{ms}$$

$$\beta = \frac{t_1}{10\text{ms}} \times \pi \text{ and } \alpha = \frac{t_2}{10\text{ms}} \times \pi$$

$$\beta = \frac{t_1}{10\text{ms}} \times \pi = \frac{0.495 \times 10^{-3}}{10} \times \pi = 0.1555 \text{ rads}$$

$$\alpha = \frac{t_2}{10ms} \times \pi = \frac{6.354 \times 10^{-3}}{10} \times \pi = 2.0841 \text{ rads}$$

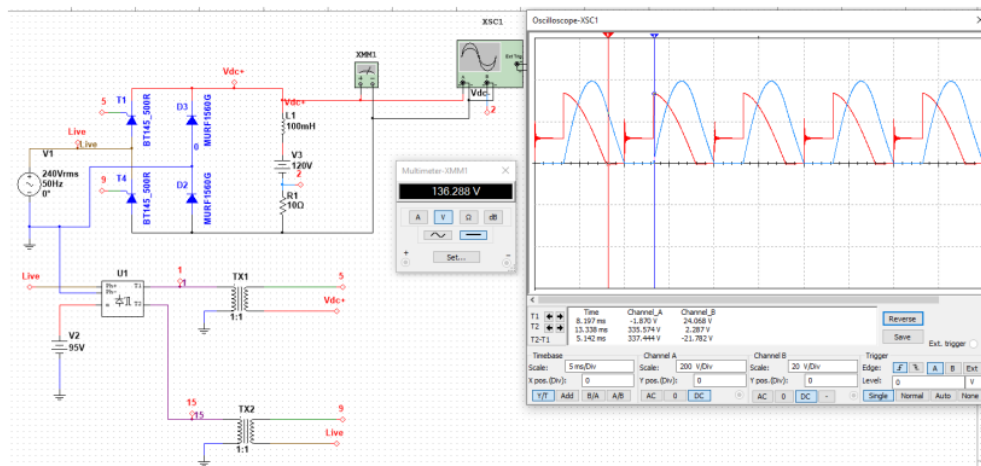
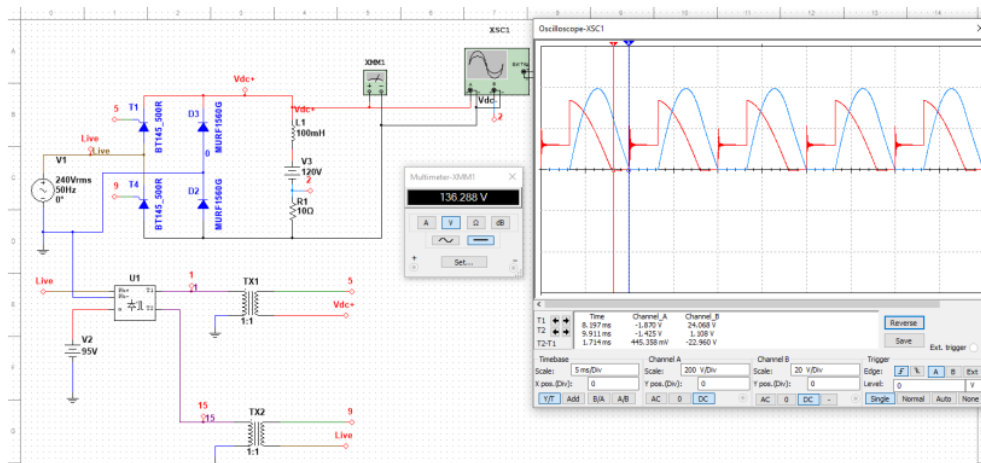
$$\frac{E}{\pi}(\alpha - \beta) + \frac{V_{pk}}{\pi}(1 + \cos(\alpha))$$

$$= \frac{115}{\pi}(2.0841 \text{ rads} - 0.1555 \text{ rads}) + \frac{337.224}{\pi}(1 + \cos(2.0841)) = 70.5976 + 54.63071$$

$$= 125.22831 \text{ v}$$

Phase angle:

$$t_2 \times 180^\circ = 0.6354 \times 180^\circ = 114.372^\circ$$



$$\frac{1}{f} = \frac{1}{50} = 20ms \text{ half cycle} = 20 \times 0.5 = 10ms$$

$$\beta = \left(\frac{t1}{\text{Half Cycle}} \right) \times \pi = \left(\frac{1.714 \times 10^{-3}}{10} \right) \times \pi = 0.5384 \text{ rad}$$

$$\alpha = \left(\frac{t2}{\text{Half Cycle}} \right) \times \pi = \left(\frac{5.142 \times 10^{-3}}{10} \right) \times \pi = 1.6154 \text{ rad}$$

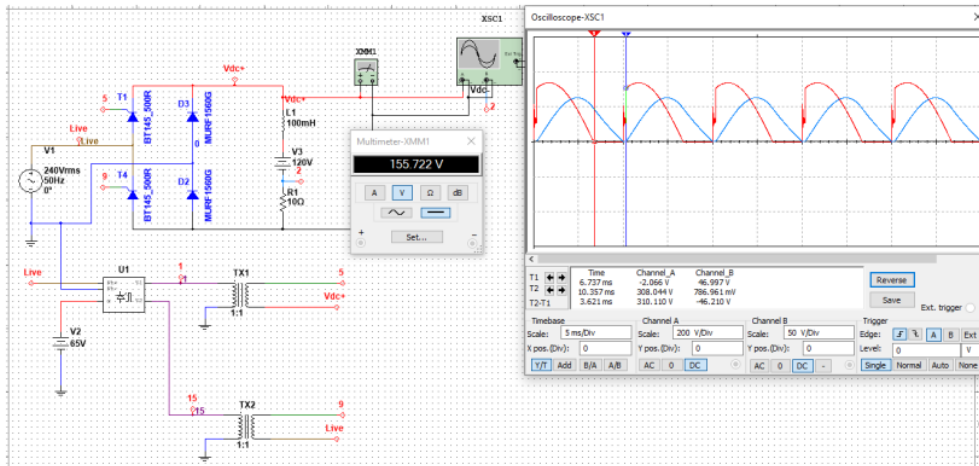
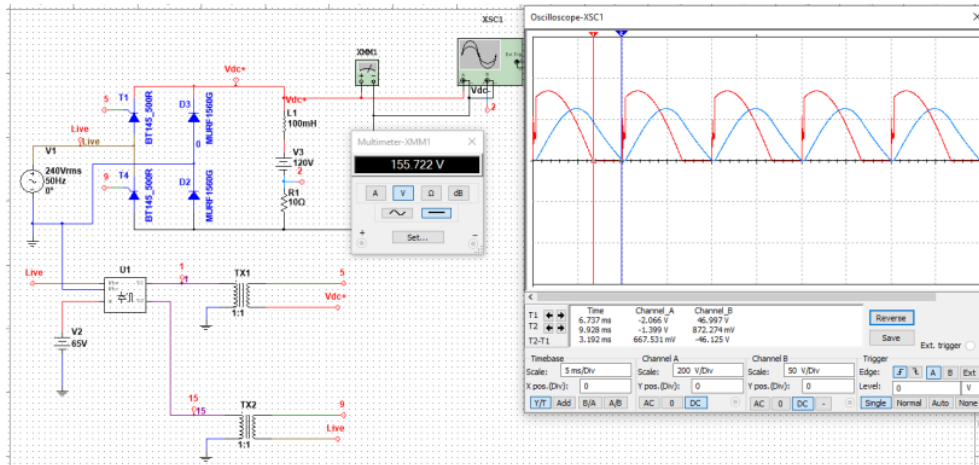
$$\frac{E}{\pi} (\alpha - \beta) + \frac{Vpk}{\pi} (1 + \cos(\alpha))$$

$$= \frac{95}{\pi} (1.6154 - 0.5384 \text{ rad}) + \frac{337.224}{\pi} (1 + \cos(1.6154)) = 32.5679 + 102.555$$

$$= 135.1229v$$

Phase Angle

$$t2 \times 180^\circ = 0.5304 \times 180 = 95.472^\circ$$



$$\frac{1}{f} = \frac{1}{50} = 20ms \text{ half cycle} = 20 \times 0.5 = 10ms$$

$$\beta = \left(\frac{t1}{\text{Half Cycle}} \right) \times \pi = \left(\frac{3.192 \times 10^{-3}}{10} \right) \times \pi = 1.0028rad$$

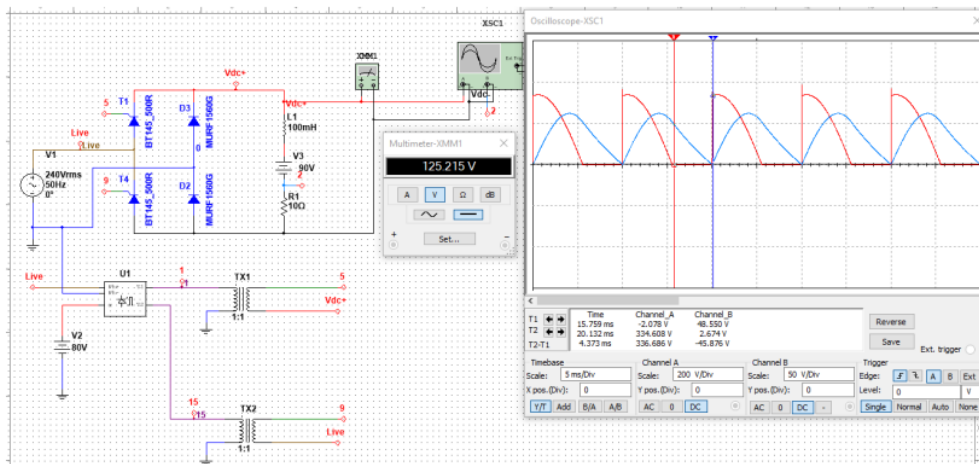
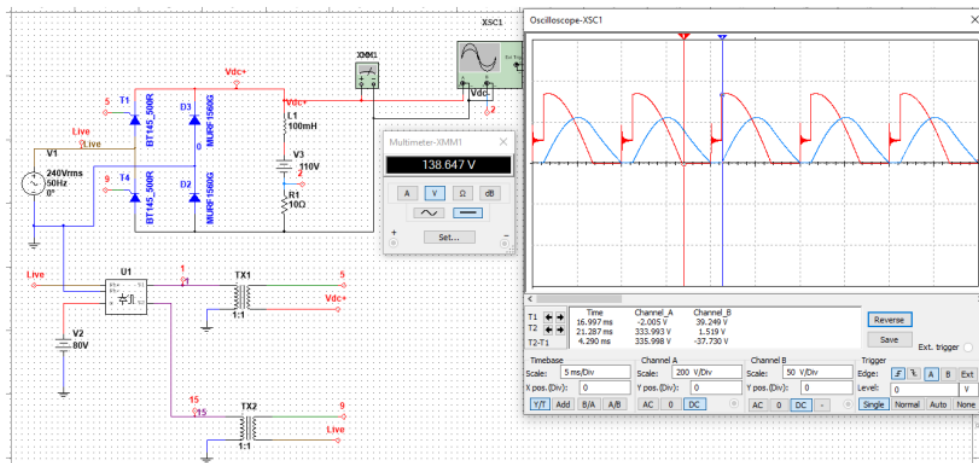
$$\alpha = \left(\frac{t2}{\text{Half Cycle}} \right) \times \pi = \left(\frac{3.621 \times 10^{-3}}{10} \right) \times \pi = 1.1376 rad$$

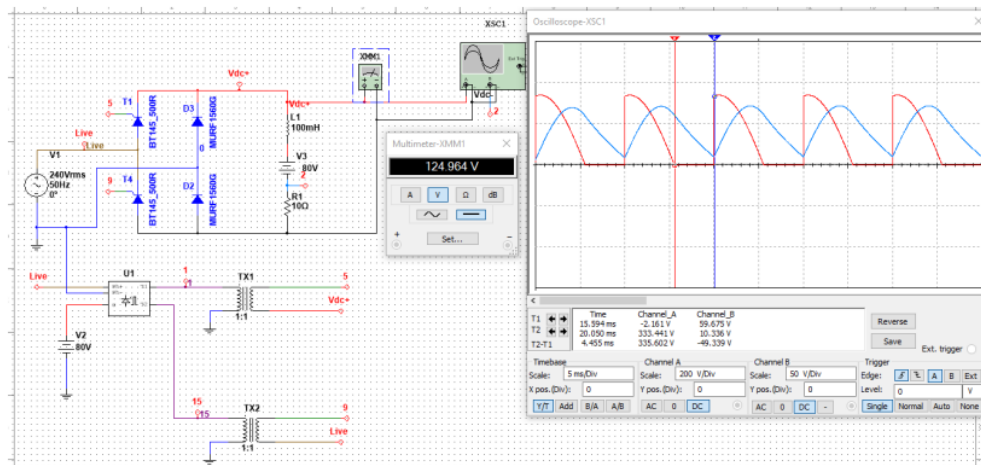
$$\frac{E}{\pi}(\alpha - \beta) + \frac{Vpk}{\pi}(1 + \cos(\alpha))$$

$$= \frac{65}{\pi} (1.1376 - 1.0028 \text{ rad}) + \frac{337.224}{\pi} (1 + \cos(1.1376)) = 2.7890 + 152.401 = 155.19v$$

Phase Angle

$$t2 \times 180^\circ = 0.3621 \times 180 = 65.178^\circ$$





$$\frac{1}{f} = \frac{1}{50} = 20\text{ms half cycle} = 20 \times 0.5 = 10\text{ms}$$

$$\alpha = \left(\frac{t_2}{\text{Half Cycle}} \right) \times \pi = \left(\frac{4.455 \times 10^{-3}}{10} \right) \times \pi = 1.4 \text{ rad}$$

Average Voltage

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

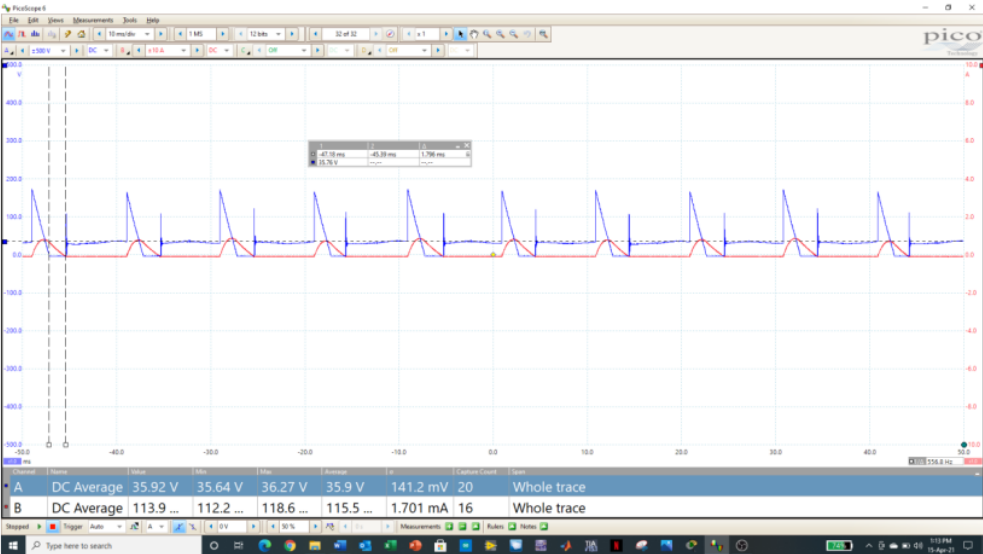
$$= \frac{337.224}{\pi} (1 + \cos(1.4)) = 125.586\text{V}$$

Phase Angle

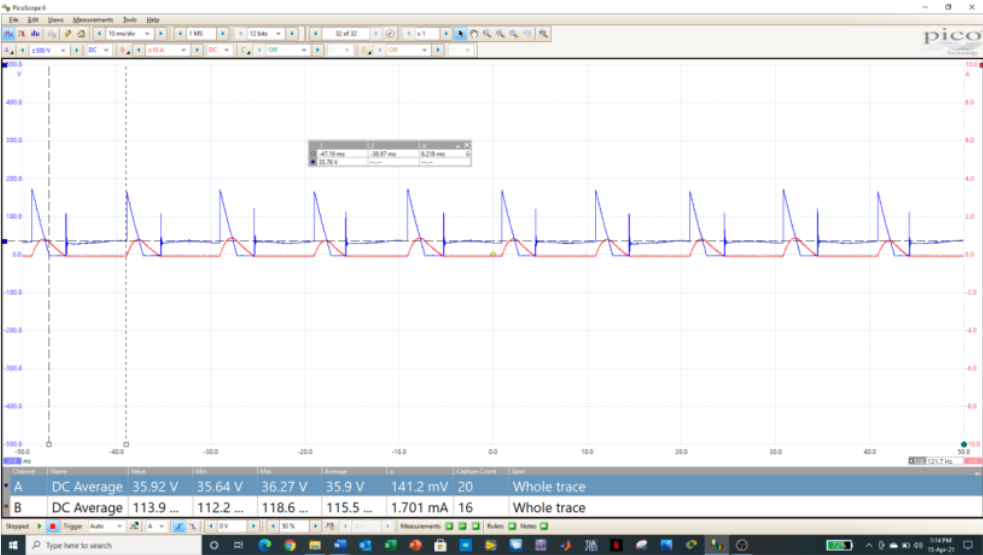
$$t_2 \times 180^\circ = 0.4125 \times 180 = 80.19^\circ$$

9.2 Practical experimentation oscilloscope readings and calculations

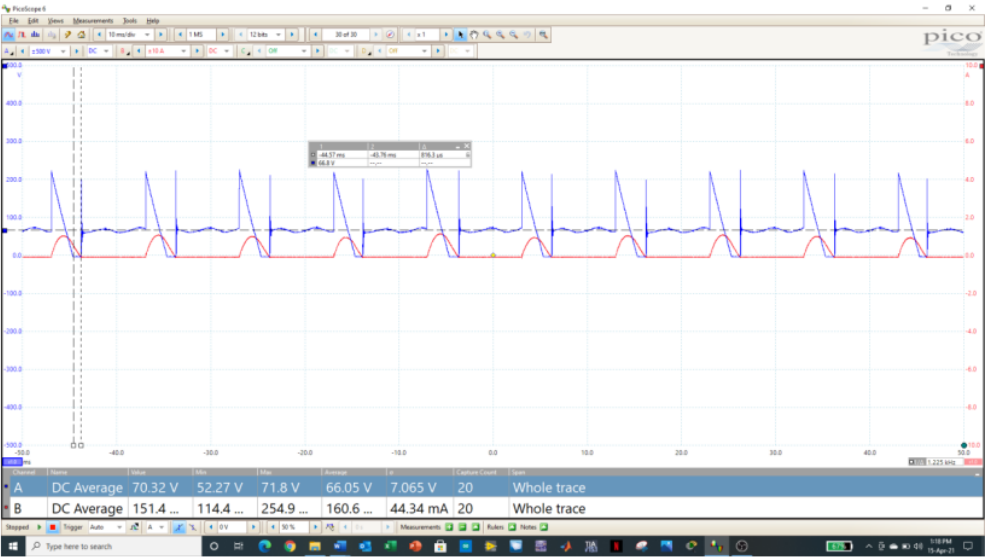
502rpm



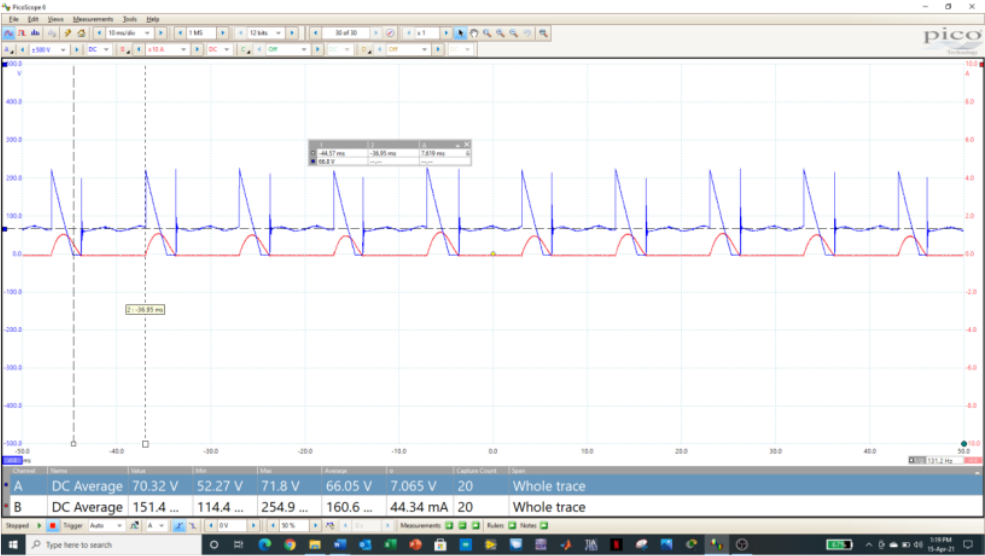
502rpm



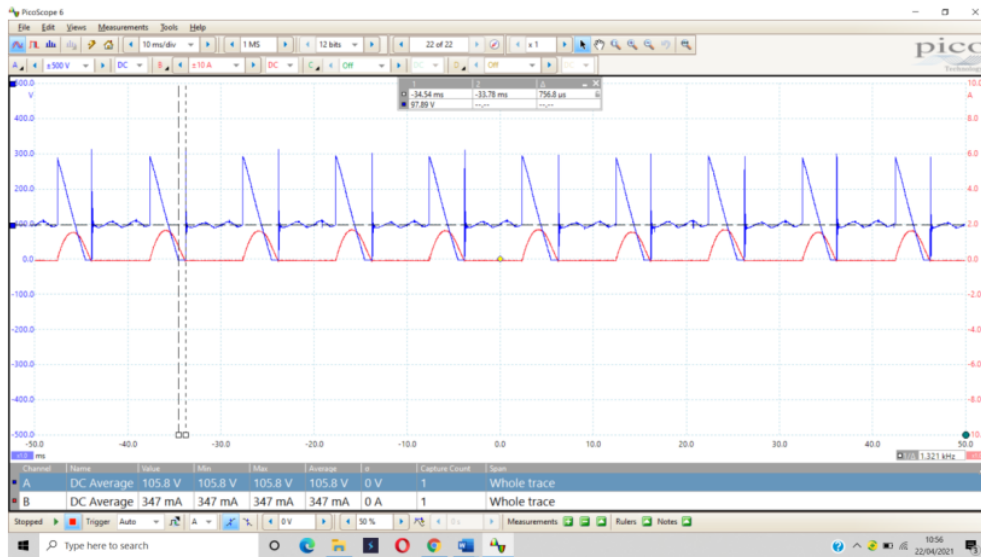
1003rpm



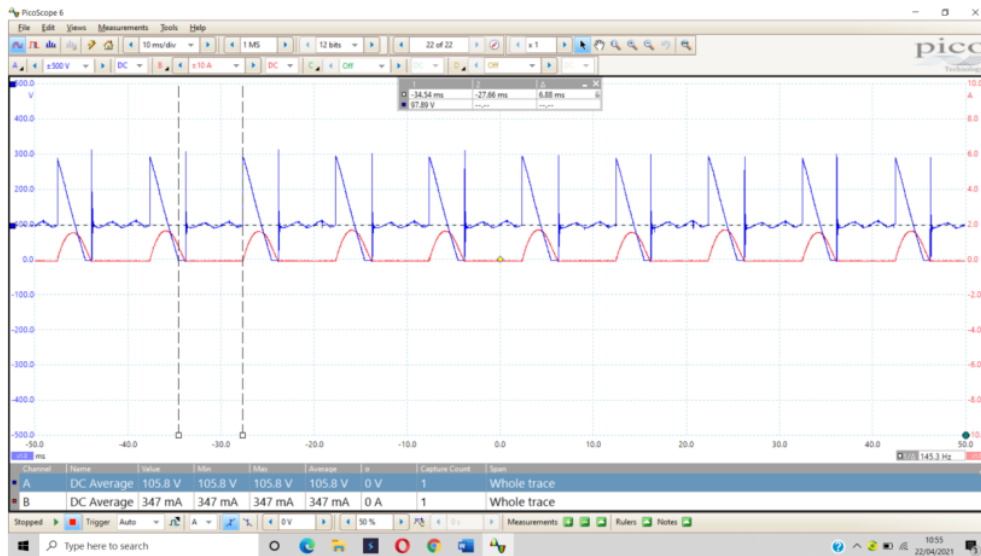
1003rpm



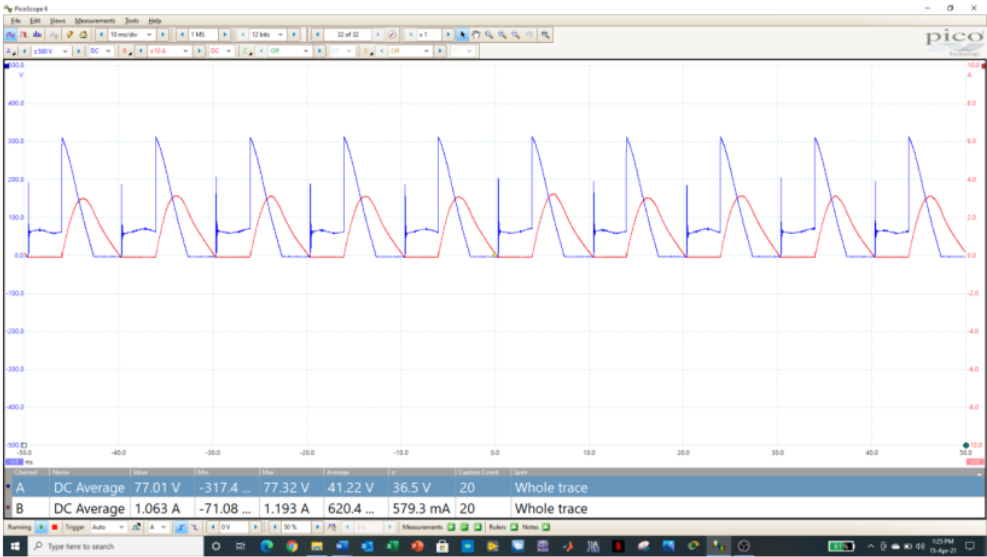
1500rpm



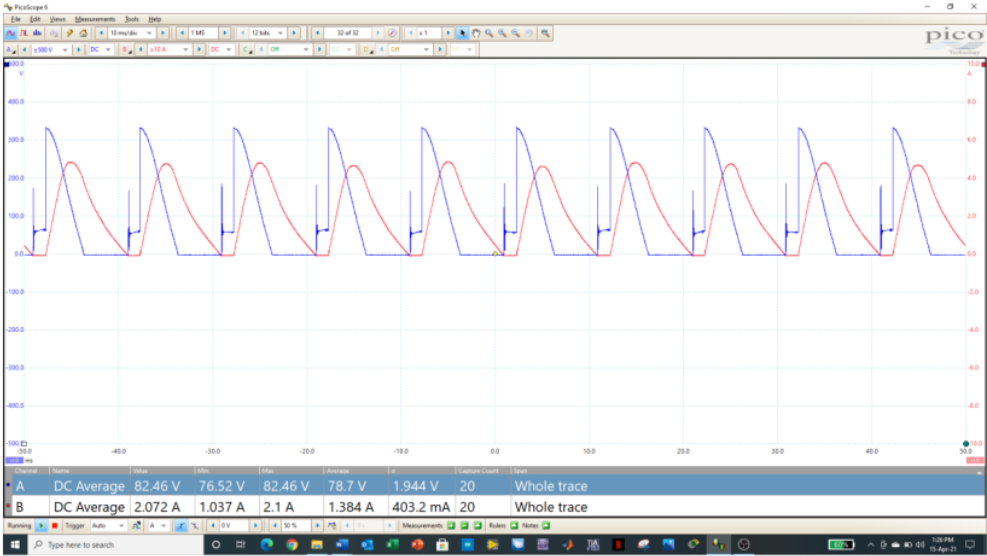
1500rpm



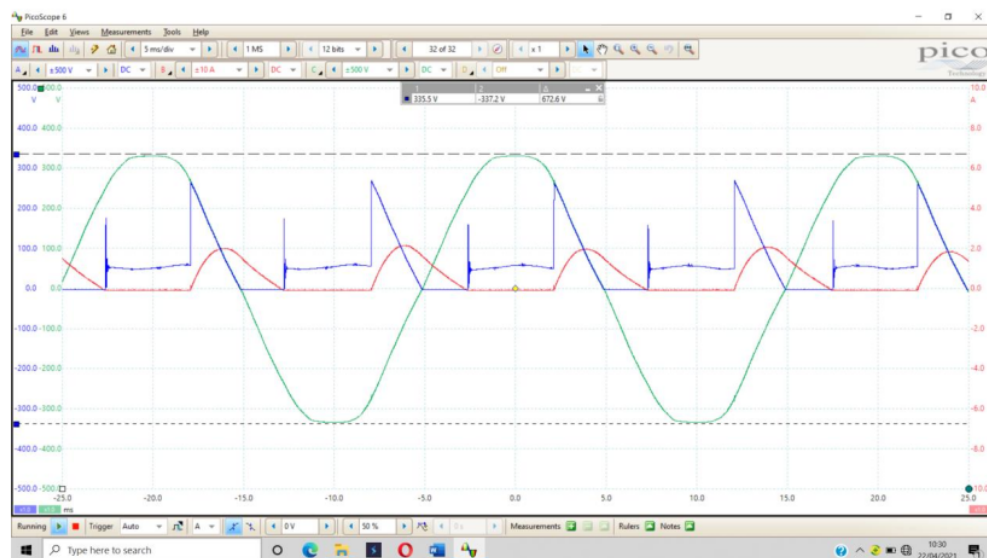
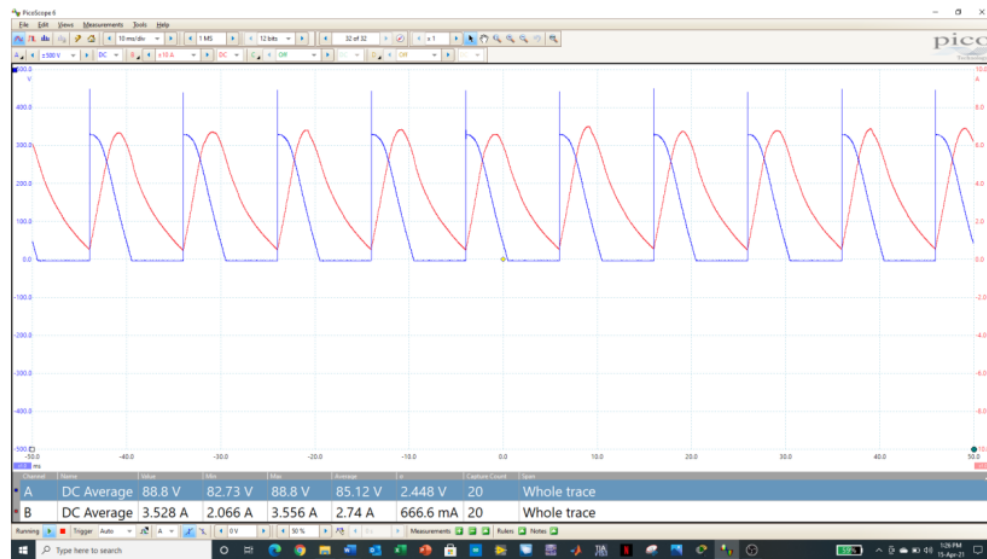
0.5nm



1nm



1.5nm



$$\text{Full period} = \frac{1}{f} = \frac{1}{50\text{Hz}} = 20\text{ms half cycle} = 20 \times 0.5 = 10\text{ms}$$

$$\beta = \frac{t_1}{10ms} \times \pi \text{ and } \alpha = \frac{t_2}{10ms} \times \pi$$

$$\beta = \frac{t_1}{10ms} \times \pi = \frac{1.796 \times 10^{-3}}{10} \times \pi = 0.5642 \text{ rads}$$

$$\alpha = \frac{t_2}{10ms} \times \pi = \frac{8.218 \times 10^{-3}}{10} \times \pi = 2.5818 \text{ rads}$$

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

$$= \frac{35.76}{\pi}(2.5818\text{rads} - 0.5642\text{rads}) + \frac{335.5}{\pi}(1 + \cos(2.5818)) = 22.96586 + 16.30032$$

$$= 39.266v$$

Phase angle:

$$t_2 \times 180^\circ = 0.7619 \times 180^\circ = 137.142^\circ$$

$$\text{Full period} = \frac{1}{f} = \frac{1}{50\text{Hz}} = 20\text{ms half cycle} = 20 \times 0.5 = 10\text{ms}$$

$$\beta = \frac{t_1}{10ms} \times \pi = \frac{0.8163 \times 10^{-3}}{10} \times \pi = 0.25645 \text{ rads}$$

$$\alpha = \frac{t_2}{10ms} \times \pi = \frac{7.619 \times 10^{-3}}{10} \times \pi = 2.39358\text{rads}$$

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

$$= \frac{66.8}{\pi} (2.39358 \text{ rads} - 0.25645 \text{ rads}) + \frac{335.5}{\pi} (1 + \cos(2.39358)) = 45.4420 + 28.5092$$

$$= 73.9512 \text{ v}$$

Phase angle:

$$t_2 \times 180^\circ = 0.7619 \times 180^\circ = 137.142^\circ$$

$$\text{Full period} = \frac{1}{f} = \frac{1}{50 \text{ Hz}} = 20 \text{ ms half cycle} = 20 \times 0.5 = 10 \text{ ms}$$

For a half period the length is 10ms which relates to π rad.

$$\beta = \frac{t_1}{10 \text{ ms}} \times \pi \text{ and } \alpha = \frac{t_2}{10 \text{ ms}} \times \pi$$

$$\beta = \frac{t_1}{10 \text{ ms}} \times \pi = \frac{0.756 \times 10^{-3}}{10} \times \pi = 0.2375 \text{ rads}$$

$$\alpha = \frac{t_2}{10 \text{ ms}} \times \pi = \frac{6.88 \times 10^{-3}}{10} \times \pi = 2.1614 \text{ rads}$$

Average voltage

$$v_{av} = \frac{1}{\pi} \left\{ E(\alpha - \beta) + \int_{\alpha}^{\pi} V_{pk} \sin \theta \, d\theta \right\} = \frac{E}{\pi} (\alpha - \beta) + \frac{V_{pk}}{\pi} (1 + \cos(\alpha))$$

$$= \frac{97.89}{\pi} (2.1614 \text{ rads} - 0.2375 \text{ rads}) + \frac{335.5}{\pi} (1 + \cos(2.1614)) = 59.9475 + 47.3240$$

$$= 107.2715 \text{ V}$$

Phase angle:

$$t_2 \times 180^\circ = 0.23 \times 180^\circ = 41.4^\circ$$

9.3 Medium length Transmission line calculations

Impedance

$$\begin{aligned}Z_s &= 21 + j\omega \times 177\text{mH} \\&= 21 + j \times 2\pi \times 50 \times 177 \times 10^{-3} \\&= 21 + j55.606\Omega\end{aligned}$$

Convert to polar form

$$\begin{aligned}\sqrt{21^2 + 55.606^2} &= 59.44 \\ \tan^{-1}\left(\frac{55.606}{21}\right) &= 69.311 \\ &= 59.44\angle 69.31^\circ\end{aligned}$$

Shunt admittance

$$\begin{aligned}Y &= j\omega \times C = j \times 2 \times \pi \times 50 \times 1.4 \times 10^{-6} \\ Y &= j439 \times 10^{-6}\end{aligned}$$

To Polar form

$$Y = j439 \times 10^{-6} \angle 90^\circ$$

Provided that the receiving end is 293.124A 82.596KV with a power factor of 0.88722 lagging
:

$$VRN = 82.596KV$$

$$\begin{aligned}IRN &= 293.124 \angle \cos^{-1}(0.88722) \\ &= 293.124 \angle -27.47^\circ\end{aligned}$$

Nominal π circuit :

$$\begin{aligned}
 I_1 - IRN + VRN \times \frac{Y}{2} \\
 = 293.124\angle -27.474^\circ + 82596\angle 0^\circ \times \frac{439 \times 10^{-6}}{2} \angle 90^\circ \\
 = 293.124\angle -27.474^\circ + 18.13\angle 90^\circ
 \end{aligned}$$

Converting to cartesian form:

$$293.124 \cos(27.474) = 260.066$$

$$293.124 \sin(27.474) = 135.232$$

$$260.066 - j135.232 + j18.13 = 260.066 - j117.102$$

Converting back to polar form:

$$\sqrt{260.066^2 + 117.102^2} = 285.214$$

$$\tan^{-1}\left(\frac{117.083}{260.075}\right) = 24.241$$

$$= 285.214\angle -24.241^\circ$$

Voltage at Sending end:

$$V_{SN} = V_{RN} + I_1 \times Z_s$$

$$82596 \angle 0^\circ + 285.214\angle -24.241^\circ \times 59.44 \angle 69.311^\circ$$

$$= 82596\angle 0^\circ + 16953.12\angle 45.07^\circ$$

Then into cartesian form:

$$16953.12 \cos(45.07) = 11973.01$$

$$16953.12 \sin(45.07) = 12002.3 = 11973.01 + j12002.3$$

$$82596 + 11973.01 + j12002.3 = 94569.01 + j12002.3$$

To polar form:

$$\sqrt{94569.01^2 + 12002.3^2} = 95327.61$$

$$\tan^{-1}\left(\frac{12002.3}{94569.01}\right) = 7.233^\circ$$

$$= 95327.61 \angle 7.233^\circ V$$

Sending end current:

$$I_{SN} = I_1 + V_{SN} \times \frac{y}{2}$$

$$260.066 - j117.02 + 95327.61 \angle 7.233^\circ \times \frac{439 \times 10^{-3}}{2} \angle 90^\circ$$

$$= 260.066 - j117.02 + 20.924 \angle 97.223^\circ$$

Into cartesian form:

$$20.924 \cos(97.223) = -2.631$$

$$20.924 \sin(97.223) = 20.758$$

$$= -2.631 + j20.758$$

$$260.066 - j117.02 - 2.631 + j20.758$$

$$= 257.435 - j96.262$$

Return to polar form:

$$\sqrt{257.435^2 + 96.262^2} = 274.844$$

$$\tan^{-1}\left(\frac{96.262}{257.435}\right) = 20.502^\circ$$

$$= 274.844A \angle 20.502^\circ$$

Difference in angle between current and voltage on sending end

$$VSN\emptyset - ISN\emptyset$$

$$7.233^\circ - (-20.502^\circ)$$

$$= 27.735^\circ$$

Sending end power factor

$$\cos(VSN\emptyset - ISN\emptyset)$$

$$= \cos(27.735^\circ)$$

$$0.8851 \text{ Lagging}$$

Medium length transmission line tabulated calculations

	Voltage	Current	p.f.
Sending	95327.61	274.844	0.8851

Power line efficiency

Sending end :

$$P = I \times V \times P.F$$

$$274.844 \times 95327.61 \times 0.8851$$

$$= 23.19MW$$

Receiving end:

$$\begin{aligned}P &= I \times V \times P.F \\293.124 \times 82586 \times 0.88722 \\&= 21.48MW\end{aligned}$$

assignment 2

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

75/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

Text Comment. An excellent summary

PAGE 5

Text Comment. should be the other way around as induction motors have no brushes

QM

Spelling
Spelling error

PAGE 6

QM

Spelling
Spelling error

Text Comment. Neither does a DC generator

QM

Repetition
Already stated elsewhere, repeating information is considered boring by your reader

Text Comment. Also, higher voltages are possible

PAGE 7



Correctly cited

Citation method conforms to Harvard standard, well done.

Text Comment. The 512 is single phase

Text Comment. Not related to the 512

Text Comment. You should have looked and the manufacturer's datasheet

PAGE 8

Text Comment. incorrect, the 512 is a single phase 2 thyristor rectifier wit two diodes

PAGE 9

Text Comment. It is a shame that you didn't go back at this point and correct your research on the 512 because you state here that it is a single phase drive

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16



Spelling

Spelling error

Text Comment. Good understanding

PAGE 17

PAGE 18

PAGE 19

PAGE 20

PAGE 21

PAGE 22

PAGE 23

PAGE 24

PAGE 25

PAGE 26

PAGE 27

PAGE 28

PAGE 29

PAGE 30

PAGE 31

PAGE 32

PAGE 33

PAGE 34

PAGE 35

PAGE 36

PAGE 37

PAGE 38

PAGE 39

GRADING FORM: NEW CSG-RUBRIC

GARETH WILKINS

75

1. ENGAGEMENT WITH LITERATURE



Engagement with a wide range of literature, including sources retrieved independently. Selection of relevant and credible sources. Very good use of referencing, with no/very few inaccuracies or inconsistencies. (13/20)

13

2. KNOWLEDGE AND UNDERSTANDING



Exceptionally detailed knowledge and outstanding critical understanding of the well-established concepts and principles of the subject and the main methods of enquiry. May go beyond established theories. (17/20)

17

3. COGNITIVE AND INTELLECTUAL



Excellent critical evaluation and analysis of concepts and principles leading to logical, evidence-based, reasoned arguments and judgements. Explicit recognition of other stances and a strong awareness of the limits of their knowledge. A capacity for independent thought and ability to 'see beyond the question', suggesting some grasp of the broader field and wider concepts. (16/20)

16

4. PRACTICAL APPLICATION



An advanced application of a range of established methods, materials, tools and/or techniques. The context of the application is well considered, and insightful. Consistent, accurate and logical application of theory to practice, making well-developed links between the two. Can identify problems and propose excellent, creative solutions outside the context in which they were first studied. (15/20)

15

5. TRANSFERABLE SKILLS



Can communicate professionally confidently and consistently in a suitable medium for the audience. Work is coherent, very fluent and is presented proficiently. Can work autonomously with initiative. Where relevant can work professionally within a team, showing leadership skills as appropriate, and meeting obligations. Demonstrates excellent skills for employment requiring the exercise of personal responsibility and decision-making and an appetite for further development. (14/20)

14