

Assignment 1

by Gareth Wilkins

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Assignment: Investigation into DC drives and control methods

Name: Gareth Wilkins

University number: 1809804

Date submitted: 21 Jan 2021

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- 1. A good summary but it is too long*
- 2. Research is from text books mostly and from a small range of sources*
- 3. The drive selected for investigation is a single phase drive*
- 4. Simulated and practical results tally well with theory and calculation*
- 5. Report shows a good understanding of the field of study*

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1. Executive Summary

This report examines power electronic devices, circuits and drive systems. Research was conducted on the design features and control techniques utilised on four quadrant drives. To facilitate four quadrant operation two bridges are employed which comprise six thyristors each which enable full wave rectification. While one bridge operates as a rectifier the other operates as an inverter. Predominantly two control loops are exercised where the inner feedback loop regulates the current and the outer loop controls the speed and torque. The Parker 514c four quadrant DC drive was investigated with its design and control features described. The A hoist application was evaluated illustrating its operation with the drives four quadrant operation. The chopper fed drive was found to be operational in applications with a DC source. The single phase converter was investigated and found to be capable of performing four quadrant operation but significant switching would be involved which would also constitute extensive delay between quadrants. AC drives were discussed detailing the advancement in power electronics enabling AC drives to be near comparable with DC drives. AC motors also have the advantage of more ruggedness and less maintenance to list a few. A fully controlled three phase rectifier was constructed and a motor was modelled to compare theoretical and simulated results of average armature voltage. The theoretical and simulated results were comparable with any discrepancy due to rounding or component tolerance. The circuit was modified with an additional bridge and switching and the circuit operated with four quadrant functionality. A practical was executed to analyse the performance of a Siemens DCM four quadrant drive. All four quadrant operations were analysed. The drive was run in quadrant 1 with varying speed with constant torque. It was discovered that decreasing the speed resulted in decreasing the armature voltage, back EMF and power. The motor constants were obtained from the Picoscope which enabled the average armature voltage to be calculated. The calculated and measured average armature voltage were similar with minor discrepancy which was to be expected. Analysis was performed on the variation of the applied torque on the drive under constant speed. An overall conclusion was ascertained concluding that the simulation and practical supported the concept of four quadrant operation. Further investigation would be beneficial in the harmonic effect on the supply and regenerative braking as this will play a pivotal function in the development of sustainability in electrical engineering.

2. Research

Four quadrant operation of a dc motor can be achieved utilising a single converter combined with armature or field reversal. This method however necessitates significant switching. Field and armature reversal is not required when two converters operating in parallel are utilised (Wildi, 2014). A four-quadrant dc motor drive converter design is shown in figure 1. The four-quadrant dc drive comprises dual three phase converters for the power phase. The quadrant of operation determines which converter is energised. The direction of operation being forward and reverse are determined by converters 1 and 2 respectively. The switch between the converters is managed by the observation of speed, current command and zero crossing current signals. The selector block obtains these input signals and the pulse control signals are delivered to the applicable converter. The current and speed loops are mutually shared between converters. The control schematic of this is pictorially displayed in figure 2. Switching between the converters will only be achieved when a value of zero has been measured from the outgoing converter. The converter does not allow circulating current between the converters. The limitation with this system is the lengthier time for current transfer between the bridges. However, it does benefit from no requirement of an interphase reactor. The circulating current crossover control method allows quicker current crossover and high dynamic response. This configuration requires interphase reactors which present the associated losses during operation (Krishnan, 2001).

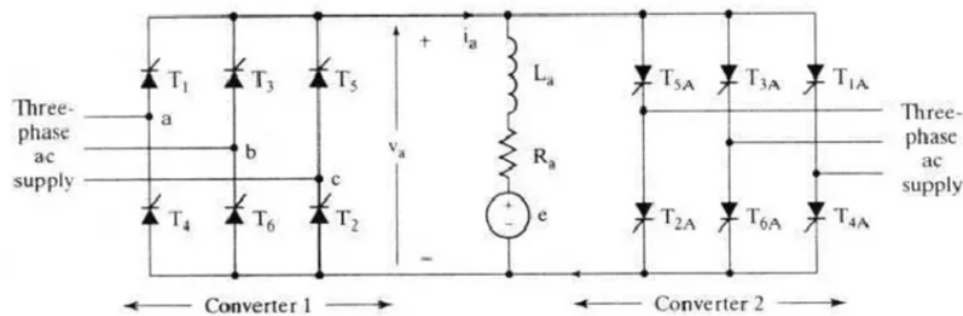


Figure 1: Dual converter four quadrant DC drive circuit

The control signal provided to the drive can be analogue or digital signals. Digital signals are the predominant choice now for drive manufacturers. The control systems function is to deliver speed control. The speed setpoint is the input where the output of the tachogenerator provides the feedback. The principle of operation of the system is relatively unpretentious. A sudden increase in the speed reference signal would result in a speed error signal characterised by

the math junction. The resultant speed error signifies that acceleration is needed, consequently requiring more torque. The output signal of the tachogenerator functions as the reference to the inner loop for the speed-error amplifier. With the current reference increase the current control loop being the inner feedback loop results in the increase armature current of the motor. This delivers additional torque and introduces acceleration. As the speed error diminishes the current and torque decrease proportionally to achieve an efficient approach to the speed setpoint (Drury, 2013).

The essential aspect of the drive system is the current loop. The current loop ensures that the physical motor current follows the current reference signal. The feedback signal of the motor current is compared with the current setpoint signal. The current error then dictates the firing angle of the thyristors hence the output voltage of the converter. A d.c. current transformer can provide the current feedback signal providing an output of analogue voltage in an isolated form. Alternatively, the mains supply lines may have current transformers or rectifiers to provide the signal. The current-error amplifier is customary to be a proportional integral type wherein the demanded and actual currents are equal in steady state conditions (Lander, 1993).

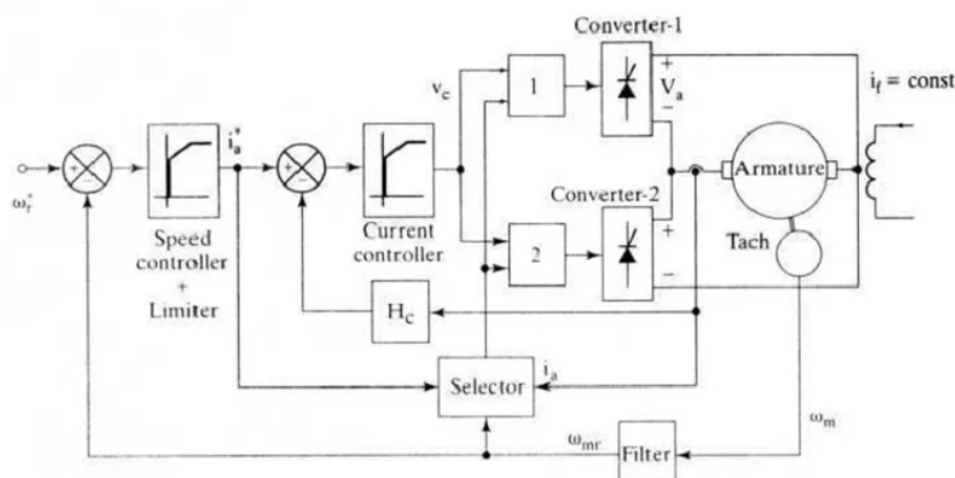


Figure 2: Schematic diagram of four quadrant drive with dual converter

Parker a well-established drive manufacturer has a diverse range of motor control options. A model which facilitates 4 quadrant operation is the DC514C series. The field control is delivered by the rectified supply to the F+ and F- connections of the DC motor. There are two bridges with six thyristors in each respectively. The current is monitored by the A.C.C.T rectifier which is proportional to the current going to the armature. The current is feedback to

the current PI controller which provides the firing pulses to the thyristors. The motor armature is connected via A+ and A- terminal connections. This tacho input provides feedback to the proportional integral speed controller. The drive comprises over current and stall detection to protect itself and the motor. (Parker, 2007).

The hoist is an industrial application where four quadrant DC drives are utilised. The hoist system comprises a steel wire which is wound round a drum which is coupled to the motor shaft. A cage for transporting material is attached to one side of the wire while a counterweight is attached to the other. The counterweight mass is greater than that of an empty case but lower than a fully laden cage. (Vidyarthiplus, 2013). The analysis of the drive can be simplified by the segmentation of the torque speed curve into their corresponding four quadrants. The moment when either the torque or speed intercept zero constitute the transition from one quadrant to the other. Figure 3 shows four quadrant operation which can be explained in the hoist application. Determining the direction of torque and speed the quadrant of operation can be established. The quadrant dictates if the machine operates as a motor or generator. Furthermore direction of current flow exposes which converter is in operation and whether it performs as a rectifier or an inverter (Wildi, 2014).

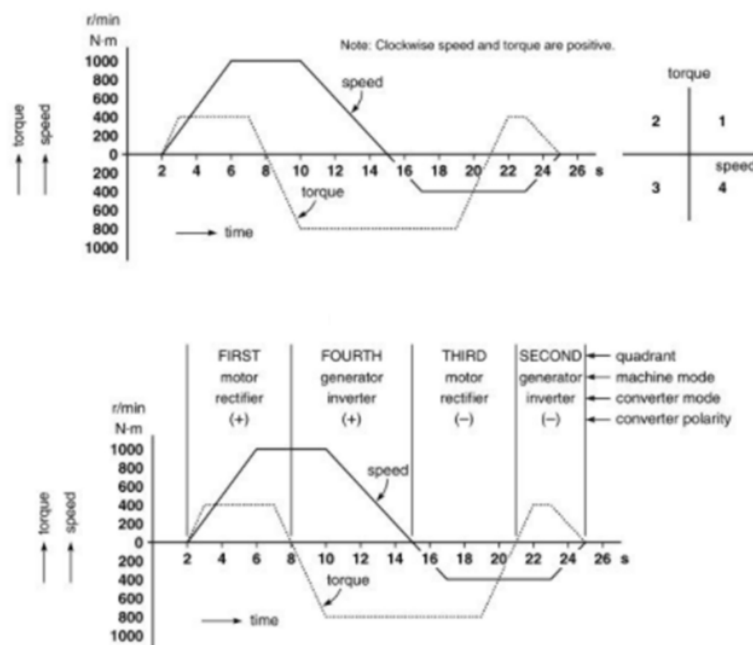


Figure 3: Four quadrant operation graphically displayed

First quadrant operation constitutes moving a fully laden cage upwards. This requires positive torque. This is forward motoring. Fourth quadrant operation is performed when a fully laden cage is lowered. The weight of the cage is greater than the counterweight, so power and speed are reversed so the drive is reverse regeneratively braking. Third quadrant operation is performed when an empty cage is lowered as the cage's weight is lower than the counterweight. The speed is negative and the power is negative this constitutes reverse motoring operation. Second quadrant operation is achieved when the empty cage is moved up as the counter weights mass is greater than the unladen cage. Regenerative braking allows a safe speed of ascent (Vidyarthiplus, 2013).

The chopper fed motor control philosophy and assembly are similar to that of the converter fed motor with the notable difference being the output voltage being the mark/space ratio in contrast to the firing angle for the converter (Drury, 2013). A chopper drive is used when the source is of constant voltage DC. The chopper produces a variable DC voltage by varying the on off times of the converter. A freewheeling diode and snubber circuit is connected across the transistors to limit the degree of voltage rise. A capacitor is connected across the dc source to maintain a constant voltage. The transistor base drive circuits are isolated as they reproduce and amplify the control signals to the output. A forklift truck is an application which uses four quadrant operation from a chopper drive. A typical fork lift is rated at 32VDC, 230A, 3600rpm. Due to the requirement of dual direction of rotation and the need recharge the batteries four quadrant chopper drives are employed. (Krishnan, 2001).

The single phase converter only has a single thyristor bridge which can only facilitate current in the single direction. The converter can facilitate four quadrant operation with a significant switching arrangement. Reversing contactors are not appropriate for applications that require rapid reversing or where zero torque is undesirable (Drury, 2013).

The control of AC machines is achieved by controlling the voltage and frequency. Advancement in power electronics AC drives allows four quadrants operation. AC machines also exhibit advantageous characteristics. The maximum operating voltage of an AC is 25Kv compared to the 1000V limit of DC machines. AC motors cost less, are more rugged and require less maintenance. AC machines can be constructed up to 50,000KW compared with the DC motors 2000kW (Wildi, 2014).

3. Simulation and Design Adaption

Simulation experiments were conducted where a DC motor was modelled as a load comprising an Inductance L, a resistor R and a back EMF E. The circuit is shown in figure 4. The simulation package MultiSim was utilised to produce armature voltage and current waveforms for a full wave, fully controlled three phase rectifier. Three firing angles of 30° , 40° and 45° were selected permitting continuous current operation. The measured V_{Max} value was 575.439V and is shown in appendix 8.1.

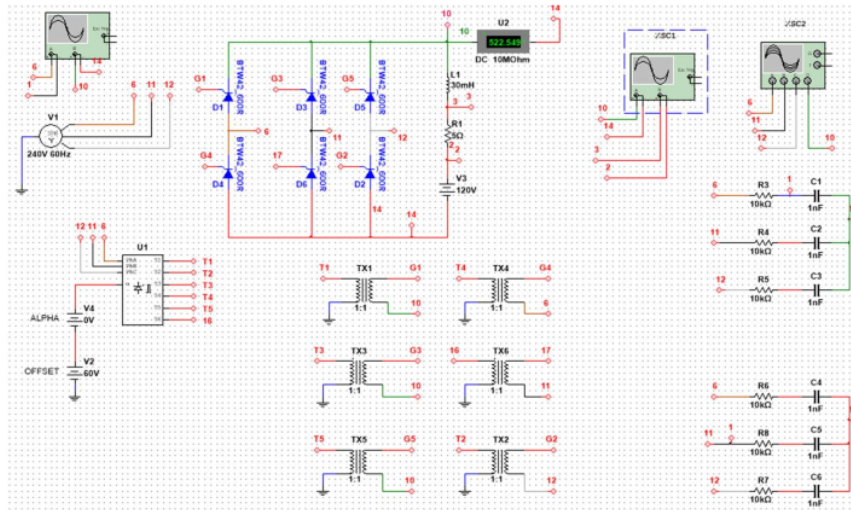


Figure 4: MultiSim rectifier circuit with DC motor model

The average armature voltage and all timings from the waveform can be found in appendix 8.2. The equation to calculate V_{Max} is

$$V_{mean} = \frac{3V_{max} \cos \alpha}{\pi}$$

The average armature voltage calculations can be found in appendix 7.3 with the simulation results. The comparison of theoretical and simulated results is tabulated in table 1.

Table 1: Comparison table of theoretical and simulated results

Phase angle (α)	Theoretical (V)	Simulated (V)	Discrepancy
30	475.851	475.583	0.002
40	420.915	420.909	0.006
45	388.525	388.441	0.084

The calculated and simulated results are comparable with only minor discrepancy. This was to be expected as the dissimilarity can be accounted for due to the simulator's rounding of figures and potential tolerance with components. Conducting this experiment with a physical dc motor would result in more notable discrepancies due to the motor losses.

The rectifier circuit is shown in figure 4. A 415V three phase supply is utilised which is connected to the phase angle controller. The phase angle α is variable and is altered by varying the dc supply. The output of the phase angle controller supplies the isolation transformers which separates the control from the power. The output of the transformer is fed to the thyristor bridge which dictates the DC output. The motor's back EMF is simulated by the 120V DC source. The motor characteristic is simulated by inductor L1 and resistor R1. To enable the waveform to be displayed on the picoscope a 1nF capacitor and 10k resistor is utilised as a buffer before inputting to the picoscope. The current circuit only allows single quadrant operation. The SCRs can only conduct in one direction therefore current cannot be reversed. To enable four quadrant operation the drive circuit was modified and can be seen in figure 6. An additional converter of opposing polarity was paralleled with converter 1. A switching arrangement was implemented to not allow both converters to be active at the same time. All four quadrants of operation were simulated and the resultant waveforms are shown in appendix 8.3.

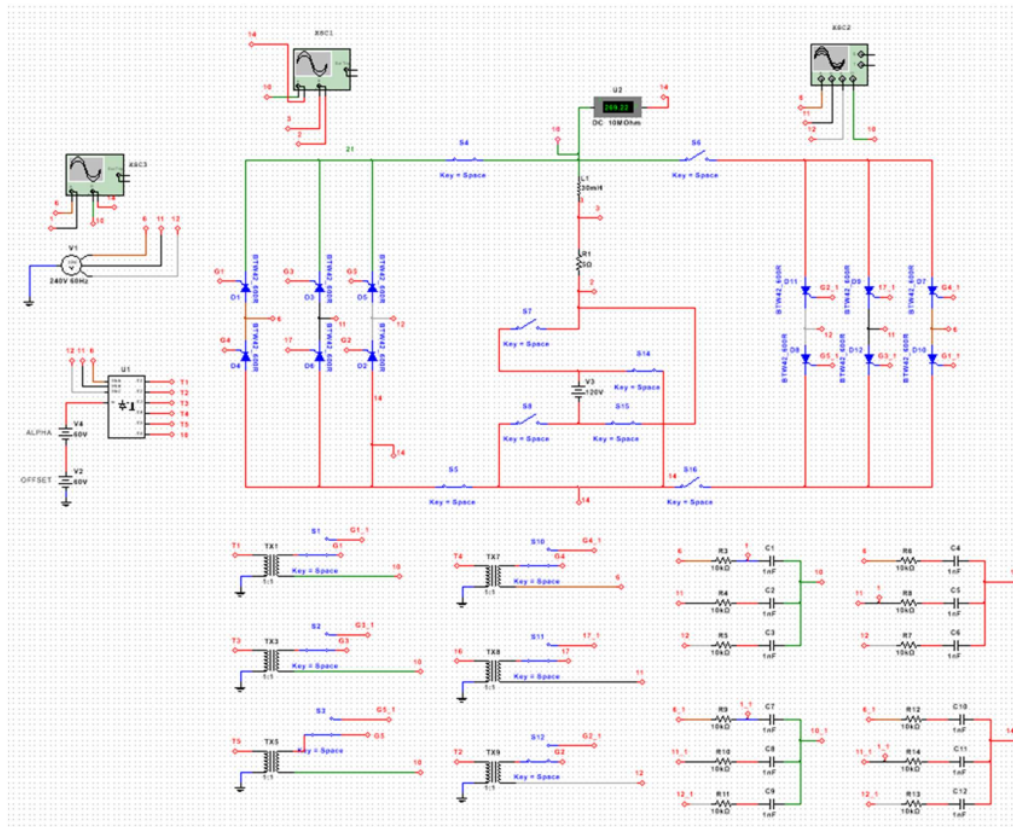


Figure 5: Modified circuit allowing four quadrant operation of DC drive.

On bridge 1 with alpha set at 40 a positive current and positive voltage was obtained which constitutes quadrant 1 operation motoring forward. On bridge 2 with alpha set at 100 a negative current and positive voltage was obtained which established quadrant 2 operation regenerative braking. On bridge 2 with alpha set at 40 both current and voltage were negative which represents motoring reverse. On bridge 1 with alpha set at 95 a positive current and negative current was obtained which signified reverse regenerative braking. The obtained results are tabulated in table 2.

Table 2: Tabulated results from modified circuit

Operation	Bridge	Voltage	Current
Quadrant 1 (FM)	1	+	+
Quadrant 2 (FR)	2	+	-
Quadrant 3 (RM)	2	-	-
Quadrant 4 (RR)	1	-	+

The modified circuit allowed successful four quadrant operation of the drive. The results align with established theory where altering the firing angle and bridge allows different quadrants of operation.

4. Practical Investigations

The practical investigation examined the Siemens motor-generator set. This set comprised the Siemens three phase DCM drive which is connected to the Siemens AC Drive which acts as a load. The AC and DC motors are connected by a means of a toothed belt. The feedback from the DC motor is provided by a tacho generator. The set is electrically supplied by a three phase 20A supply. The electrical panel contains line filters and reactors to reduce harmonic disturbances to the supply. A blower motor for cooling delivering ventilation allowing the dc motor to function continuously at full torque without overheating. The Siemens drives, PLC and HMI will communicate via ProfiNET. Analysis was performed by using the picoscope and power analyser instruments. The motor-generator block diagram is shown in figure 6.

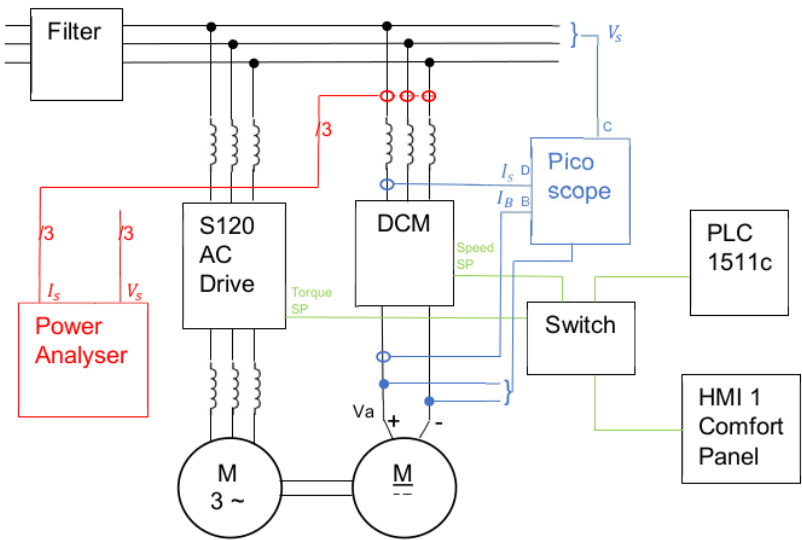


Figure 6: Block diagram of motor-generator set

Probes are situated to enable readings of armature voltage, line voltage, armature current and line current. The colour representing the parameter of measurement on the Picoscope are as shown in table 3.

Table 3: Picoscope waveform parameter colour

Parameter	Colour
armature voltage	Blue
Line voltage	Green

Armature current	Red
Line current	Brown

The power analyser was connected to the DC drive supply to provide measurement of power consumption and quality.

4.1 DC drive operation four quadrants

The dc drive was operated in all four quadrants with the resultant waveforms and HMI data shown in appendix 8.4. The results are tabulated in table 4.

Table 4: Practical results of four quadrant drive operation

	Armature volts	Alpha	Back EMF	Actual Speed	Power	Actual torque	Armature Current	Field Current
Q1	187.10	81.6614	182.007	+997.7	+0.27	+1.80	+1.45	18.643
Q2	172.44	115.6256	177.484	+1000.6	-0.27	-2.07	-1.54	18.657
Q3	-184.99	81.9031	- 178.149	-1002.4	+0.27	-1.89	-1.44	18.677
Q4	-173.28	114.6808	- 179.007	-1006.3	-0.29	+2.25	+1.57	18.657

In quadrant 1 the speed and torque are positive with positive armature voltage and current signifying motoring forward. In quadrant 2 the speed is positive, and the torque is negative. The armature voltage is positive, and the current is negative. This signifies forward regenerative braking. In quadrant 3 speed and torque are negative. Also, armature voltage and current are negative. This signifies reverse motoring. In quadrant 4 speed is negative and torque is positive. Also, armature voltage is negative and armature current is positive. This signifies regenerative braking in reverse. To conclude if speed and torque are the same sign the drive is motoring in either direction being quadrant 1 or 3. If speed and torque are opposite signs the drive is regeneratively braking in either direction being quadrant 2 and 4.

4.2 DC drive in quadrant 1 discontinuous current with three different values of speed with constant torque

The DC drive was operated in quadrant 1 with constant torque whilst varying the speed. The results can be found in appendix 8.5. The results are tabulated in tables 5-7. The results show that decreasing the speed decreased the armature volts, back EMF and power. The firing angle increased as the motor speed decreased which confirms established theory.

Speed 1 – 1904.3rpm

Table 5: Quadrant 1 - 1904.3 rpm at constant torque

Speed	Armature volts	Alpha	Back EMF	Power	Actual torque	Armature Current	Field Current
+1904.3	352.8	52.8278	339.384	+1.01	+3.60	+2.78	18.670
P (W)	PF	N(var)	cos	S(VA)	tan		
+1.027k	+0.533	1.630k	+0.637	1.927k	+1.210		

Speed 2 – 1803.8rpm

Table 6: Quadrant 1 – 1803.8 rpm at constant torque

Speed	Armature volts	Alpha	Back EMF	Power	Actual torque	Armature Current	Field Current
1803.8	331.08	57.2278	326.247	+0.92	+3.43	+2.57	18.636
P (W)	PF	N(var)	cos	S(VA)	tan		
+0.959k	+0.503	1.646k	+0.600	1.905k	+1.333		

Speed 3 – 1601.0 rpm

Table 7: Quadrant 1 – 1601.0 rpm at constant torque

Speed	Armature volts	Alpha	Back EMF	Power	Actual torque	Armature Current	Field Current
1601.0	300.07	61.2872	286.091	+0.78	3.40	+2.85	18.655
P (W)	PF	N(var)	cos	S(VA)	tan		
+0.853k	+0.444	1.720k	+0.531	1.919k	+1.595		

4.3 Motor constants

The drive was run in quadrant 1 to obtain the motor constants. The resultant picoscope results can be found in appendix 8.6. The armature voltage, back EMF and armature current measurements allowed the armature resistance to be calculated as shown:

$$V_a = E + I_a R_a + L \frac{di}{dt}, \text{ at peak current } L \frac{di}{dt} = 0$$

Therefore,

$$R_a = (V_a - E) / I_a = 15.53/3.553 = 4.371\Omega$$

4.4 Average armature voltage

The picoscope readings of the drive were obtained and the full calculation can be found in appendix 8.7.

$$E = 180.921V$$

$$\alpha = 81.4 = 1.4207\text{rad/sec}$$

$$V_{max} = 589.6V$$

$$V_{mean} = \frac{3}{\pi} [180.921 \times (1.4207 - 1.04719) + 589.6 \left(1 + \frac{1}{2} \times 0.1495 - 0.866 \times 0.9887 \right)]$$

$$V_{mean} = \frac{3}{\pi} [65.257 + 128.849]$$

$$V_{mean} = 185.358V$$

$$\text{Measured} = 186.29V$$

The calculated and measured values of average armature voltage are comparable. The difference can be attributed to cursor positioning and rounding.

4.5 Quadrant 1 increasing load torque

The drive was operated with continuous current in quadrant 1 and the load torque was increased. The results are shown in appendix 8.8 with the results tabulated in tables 8-10. Increasing the load results in an increase in back EMF and power.

Table 8: Quadrant 1 load torque 6.12Nm

Armature volts	Alpha	Back EMF	Actual speed	Power	Actual torque	Armature Current	Field Current
355.18	48.20	336.322	1900.2	1.69	6.12	1.69	18.633
P (W)	PF	N(var)	cos	S(VA)	tan		
1.676k	0.581	2.345	0.648	2.883k	1.177		

Table 9: Quadrant 1 load torque 4.7Nm

Armature volts	Alpha	Back EMF	Actual speed	Power	Actual torque	Armature Current	Field Current
353	49.5483	344.004	1904.8	1.33	4.70	3.65	18.700
P (W)	PF	N(var)	cos	S(VA)	tan		
1.336k	0.559	1.981	0.641	2.389	1.197		

Table 10: Quadrant 1 load torque 3.6Nm

Armature volts	Alpha	Back EMF	Actual speed	Power	Actual torque	Armature Current	Field Current
352.80	52.8278	339.384	1904.3	1.01	3.60	2.78	18.670
P (W)	PF	N(var)	cos	S(VA)	tan		
1.027k	0.533	1.630	0.637	1.927	1.210		

4.6 Drive performance evaluation

The drive performed four quadrant operation successfully. Under constant torque and varying the speed there was no significant affect on performance. With a speed setpoint the load torque was varied and the drive managed the disturbances. To conclude the drive is efficient at performing the demand that was applied.

5. Conclusions and Recommendations

The research provided the established theory of four quadrant operation of a dc drive. The drive can either operate as a motor or generator regenerative braking. Four quadrant operation can be achieved with a single bridge however this necessitates significant switching arrangements. A four quadrant drive habitually consists of a dual three phase converter. The quadrant of operation dictates the converter utilised. The four quadrants of operation are Quadrant 1 – Speed and torque positive, forward motoring, Quadrant 2 – Speed positive torque negative, Regenerative forward braking, Quadrant 3 – speed and torque negative, reverse motoring and Quadrant 4 – Speed negative torque positive, reverse regenerative braking. The power goes negative in quadrant 2 and 4 as torque and speed have different signs which is known as regenerative breaking. The simulated and practical results corresponded with the established theory. Further investigation could be performed on the harmonic effect on the supply by variation of the thyristor firing angle. Additional analysis could be performed on the regenerative braking with the chopper drive as this method will be the future will the advancement of electrical vehicles.

6. Team Working and Health & Safety Precautions

The team working element of this assignment involved the practical experimentation of the Siemens three phase DCM drive. Authors responsibility was to collect all the evidence and to ensure the specification of the brief had been achieved. Thomas' had the Picoscope software, so it was decided that we connect his laptop to attain the results. Following all government and college guidelines appropriate P.P.E. being a face covering was worn when working within 2m of one another. The external display above the motor-generator set was utilised so that all members of the team could participate and contribute to the obtainment and discussion of results.

7. Citation List

Drury, A. H. a. B., 2013. *Electric Motors and Drives Fundamentals, Types, and Applications*. 4th Edition ed. s.l.:Newnes.

Krishnan, R., 2001. *Electric Motor Drives Modeling, Analysis, and Control*. First Edition ed. New Jersey: Prentice-Hall.

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[Accessed 01 01 2022].

Vidarthiplus, 2013. *Vidarthiplus*. [Online]

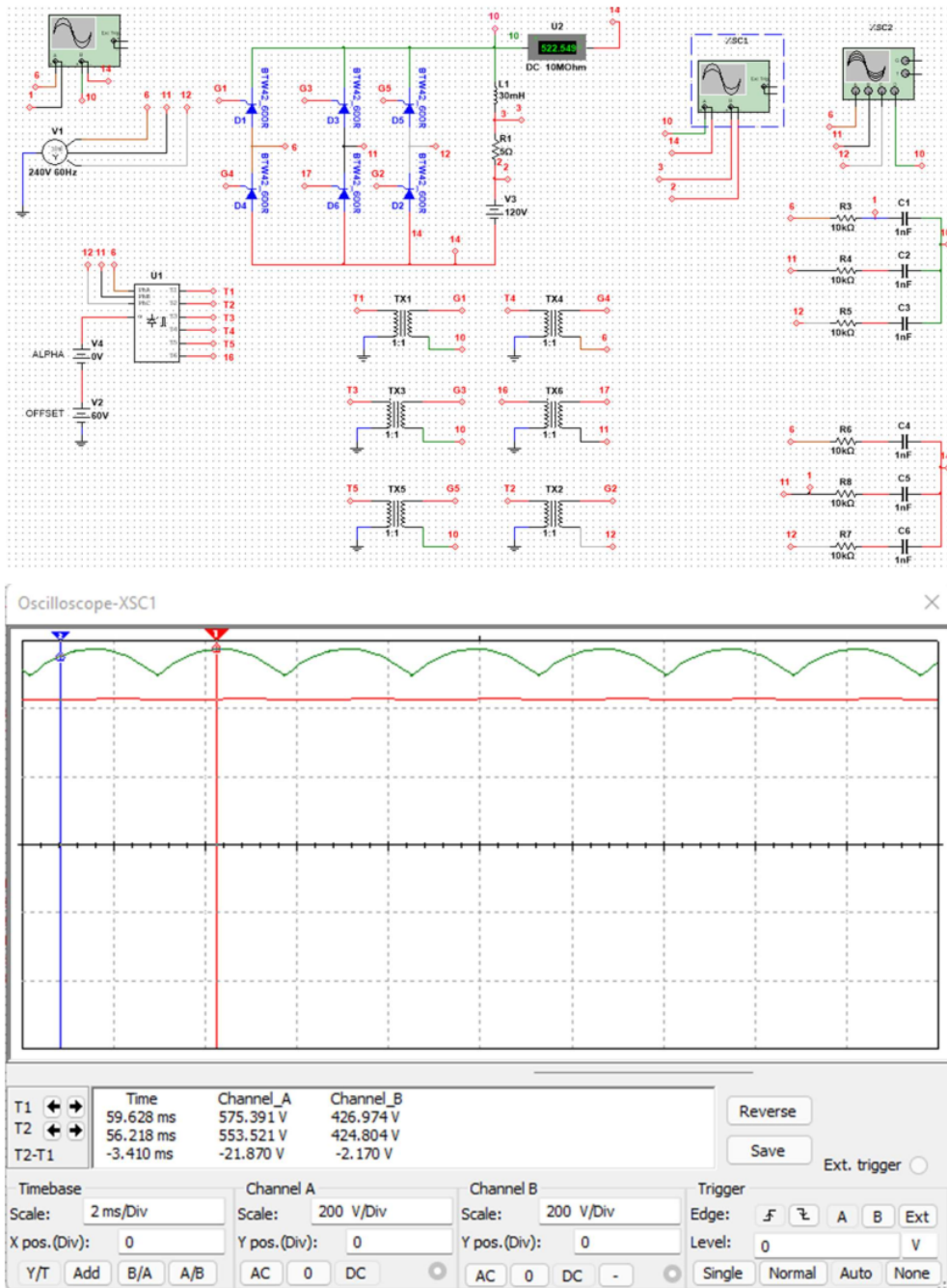
Available at: <http://www.vidarthiplus.in/2013/03/multiquadrant-operation-operation-of.html>

[Accessed 19 01 2022].

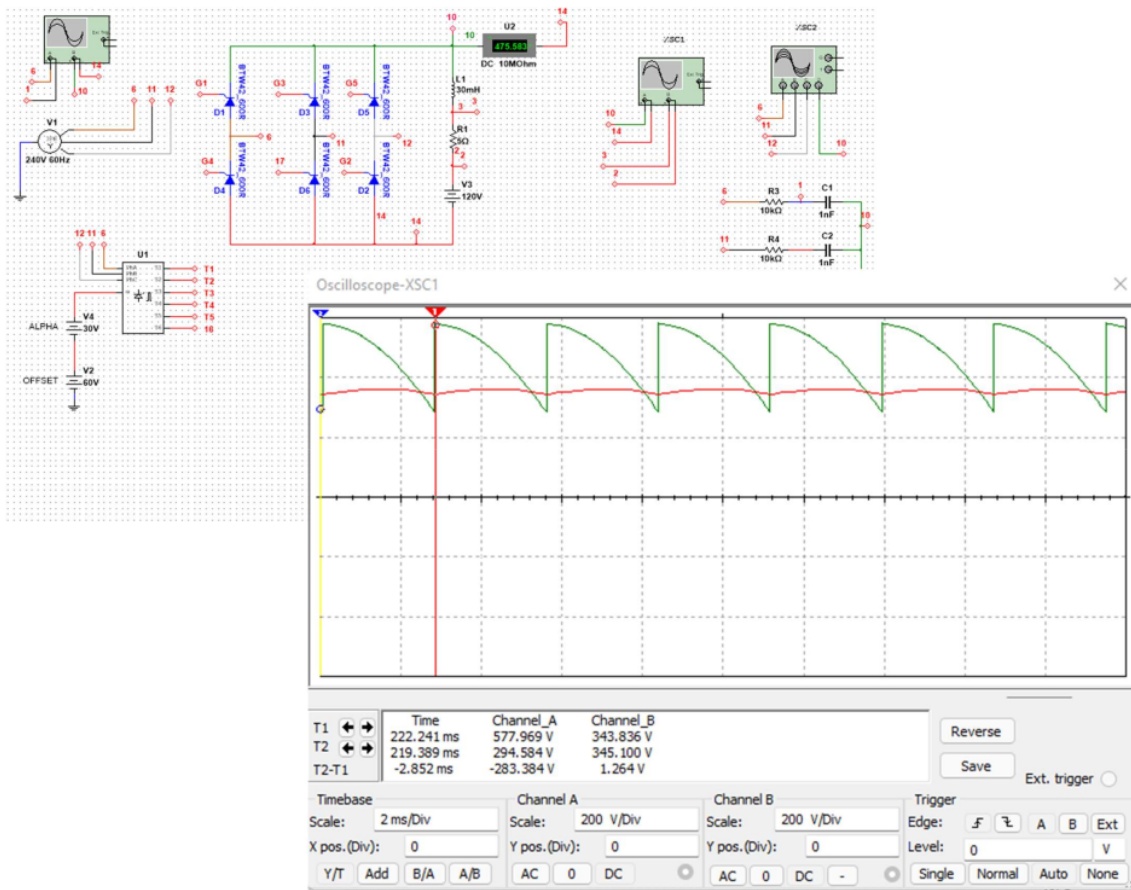
Wildi, T., 2014. *Electrical Machines, Drives, and Power Systems*. Sixth ed. Harlow: Pearson New International Edition .

8. Appendix

8.1 Rectifier circuit with alpha set a 0°



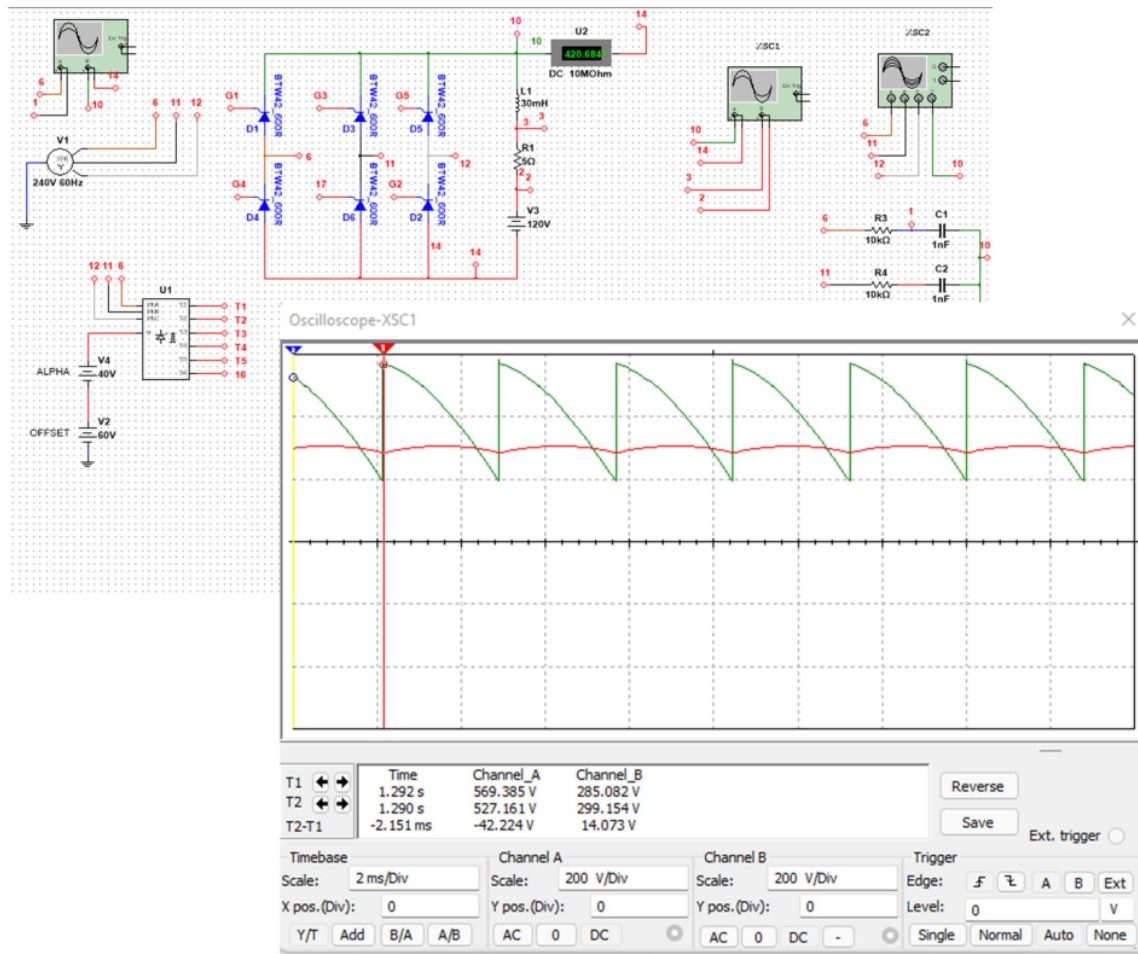
8.2 Rectifier circuit with varying values of alpha



$$V_{mean} = \frac{3V_{max} \cos \alpha}{\pi}$$

$$V_{mean} = \frac{3 \times 575.391 \cos 30}{\pi}$$

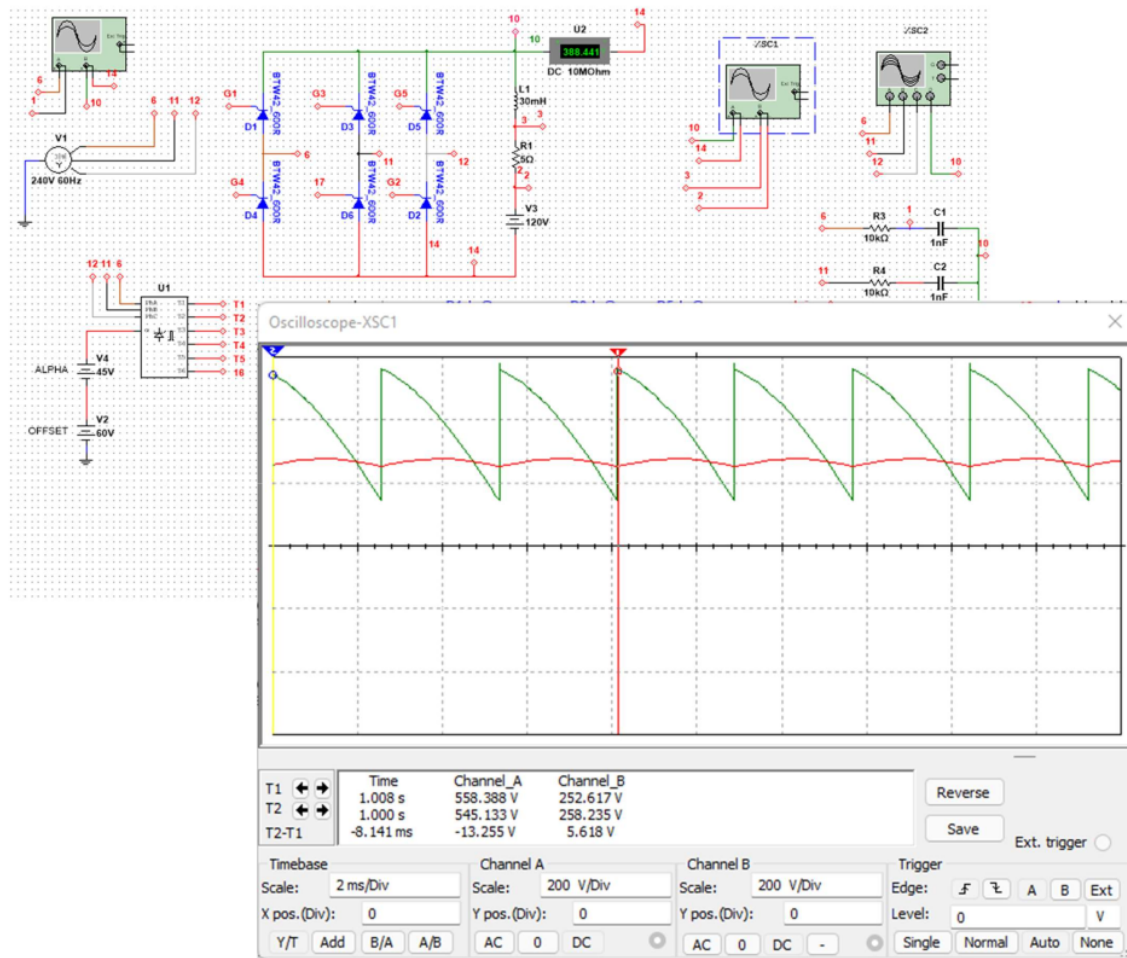
$$V_{mean} = 475.8511V$$



$$V_{mean} = \frac{3V_{max} \cos \alpha}{\pi}$$

$$V_{mean} = \frac{3 \times 575.391 \cos 40}{\pi}$$

$$V_{mean} = 420.909V$$



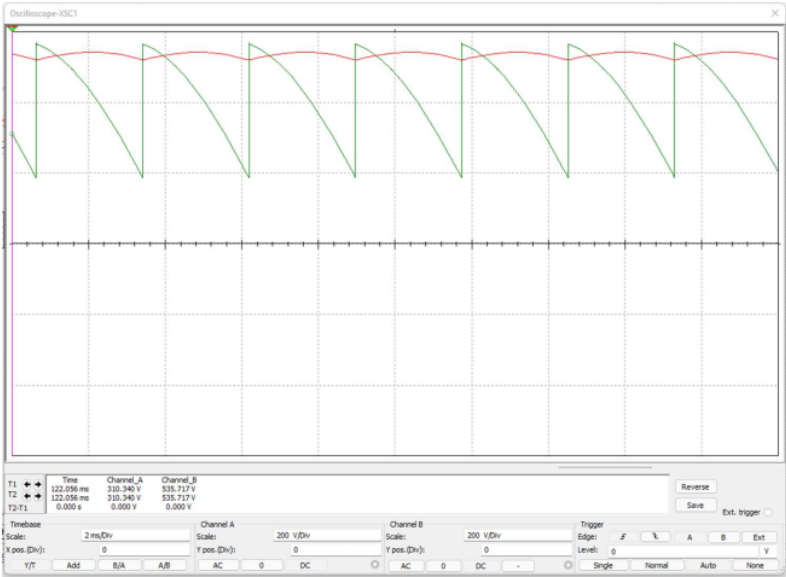
$$V_{mean} = \frac{3V_{max} \cos \alpha}{\pi}$$

$$V_{mean} = \frac{3 \times 575.391 \cos 45}{\pi}$$

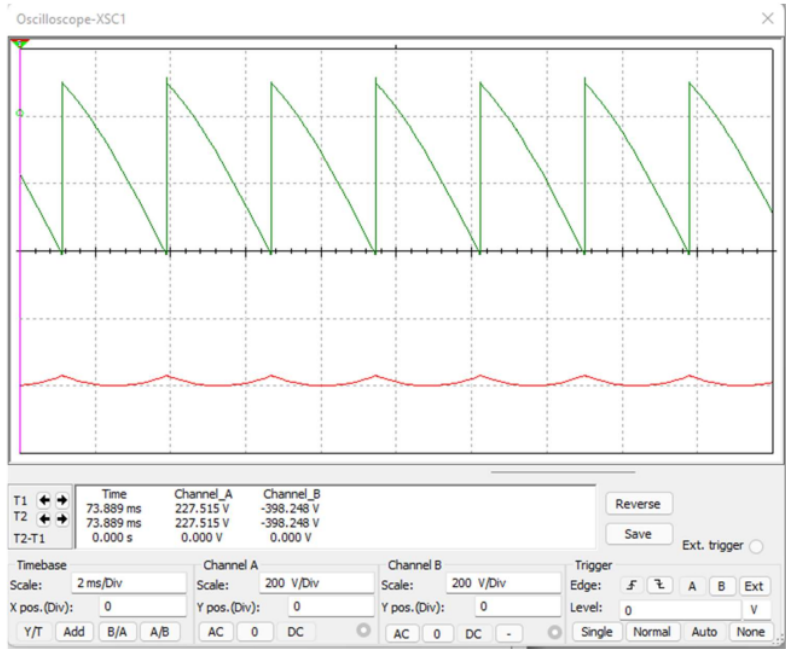
$$V_{mean} = 388.525V$$

8.3 Four quadrant operation of modified circuit

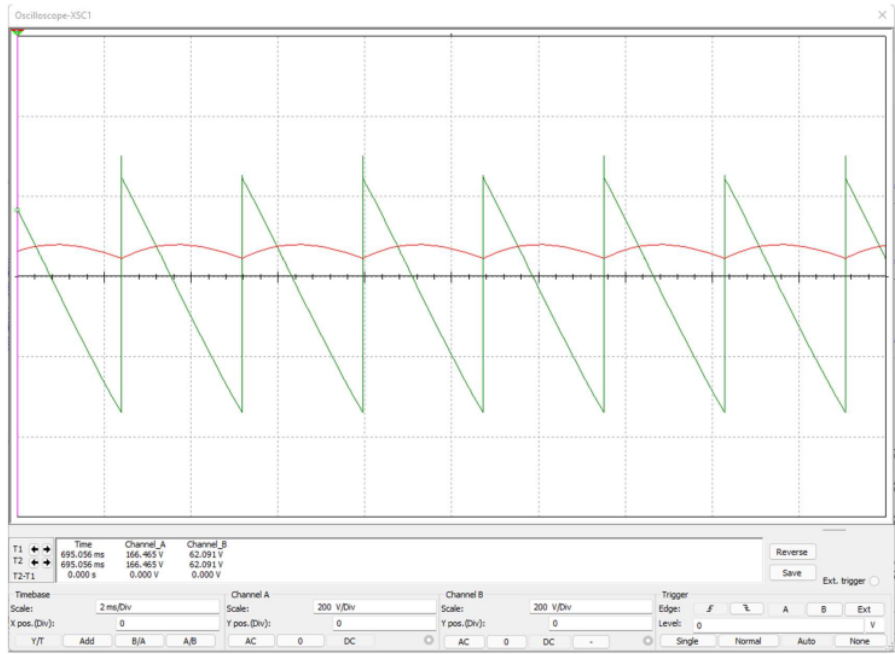
8.3.1 Quadrant 1



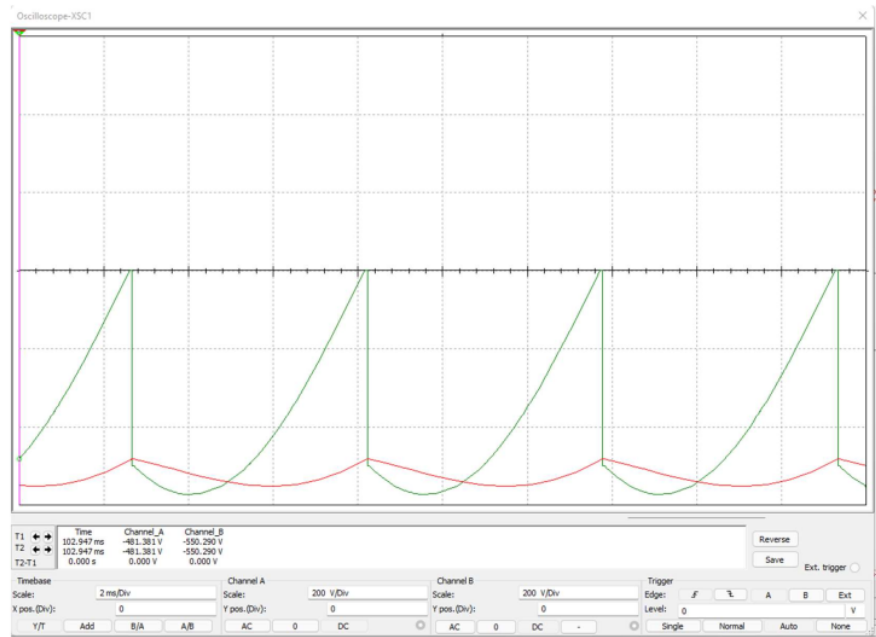
8.3.2 Quadrant 2



8.3.3 Quadrant 3

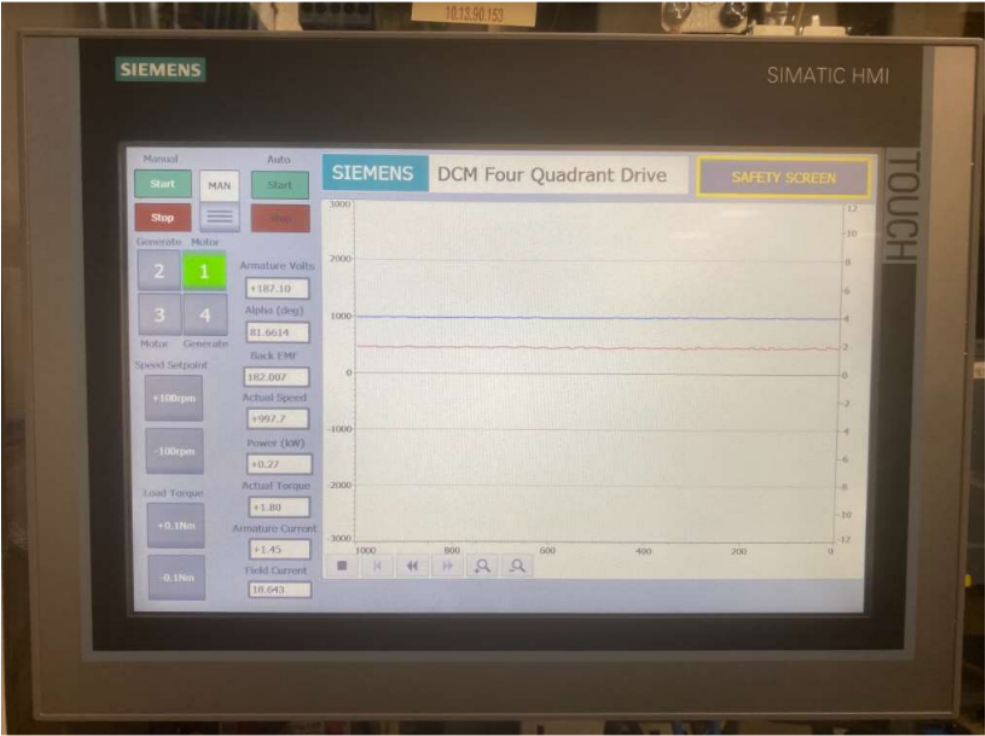
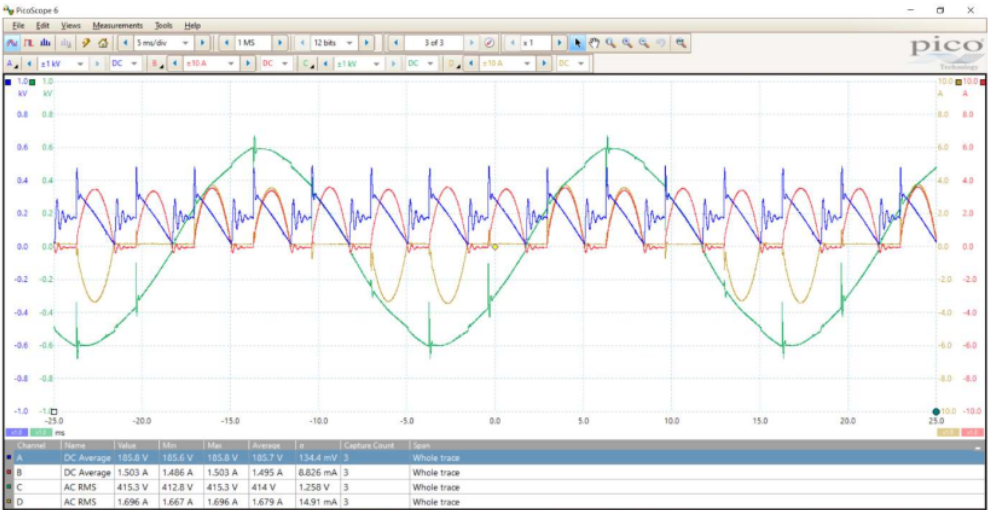


8.3.4 Quadrant 4

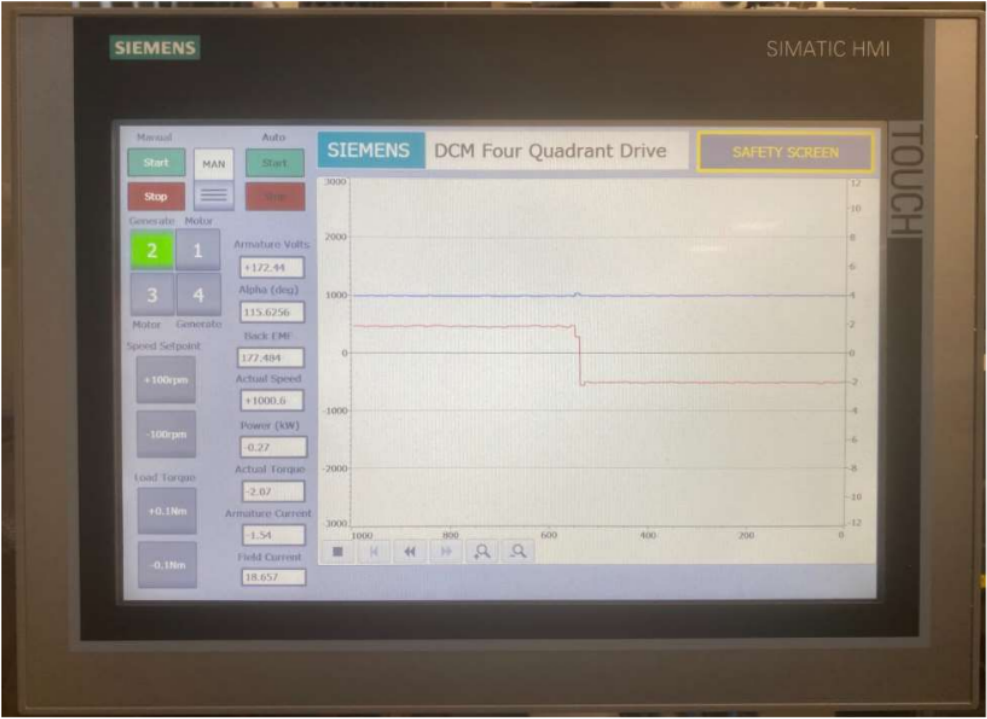
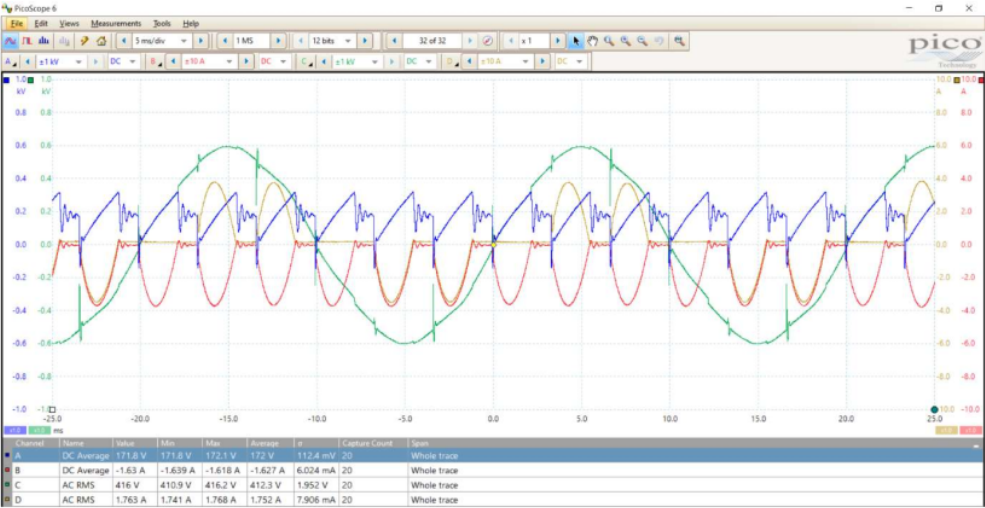


8.4 Four quadrant operation of Siemens DCM drive

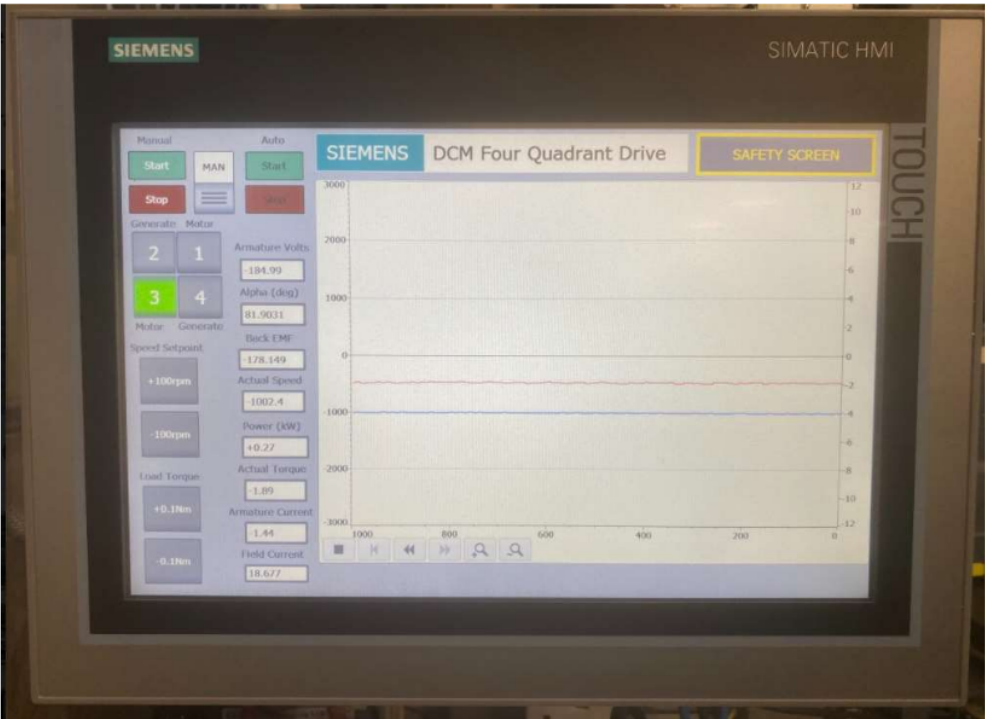
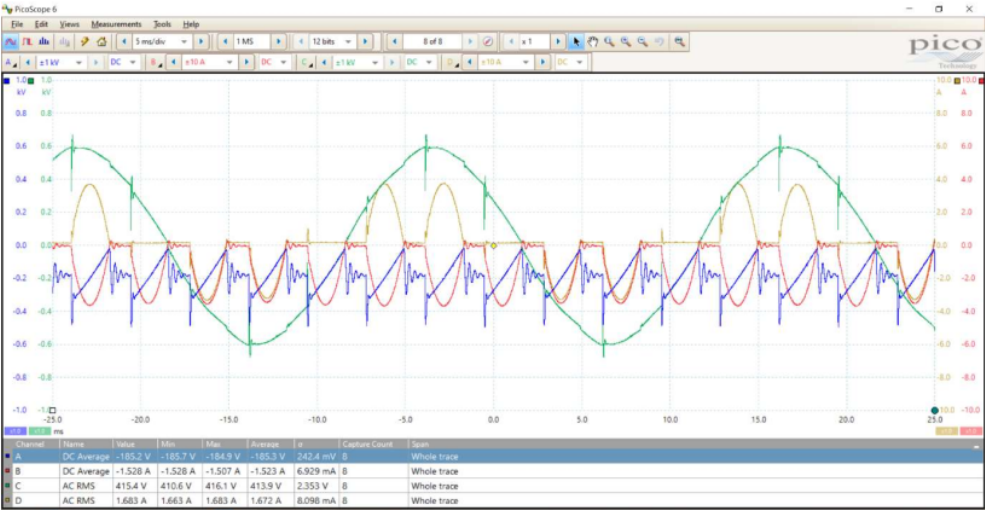
Positive Current – Bridge 1, Positive Voltage , Quadrant 1 , Forward Motoring, Alpha < 90



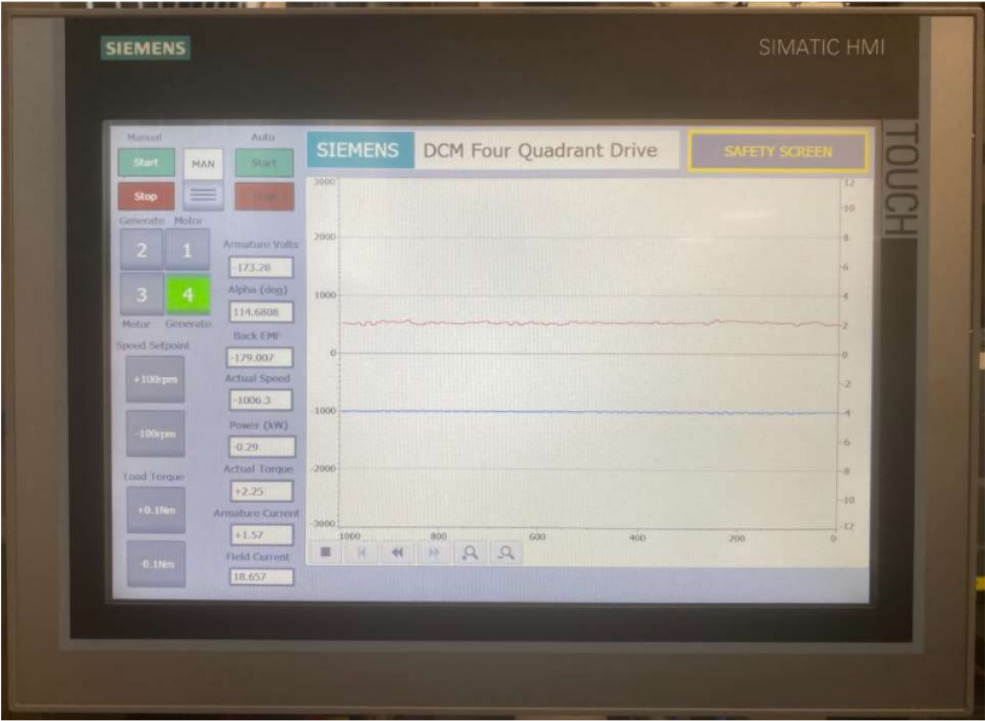
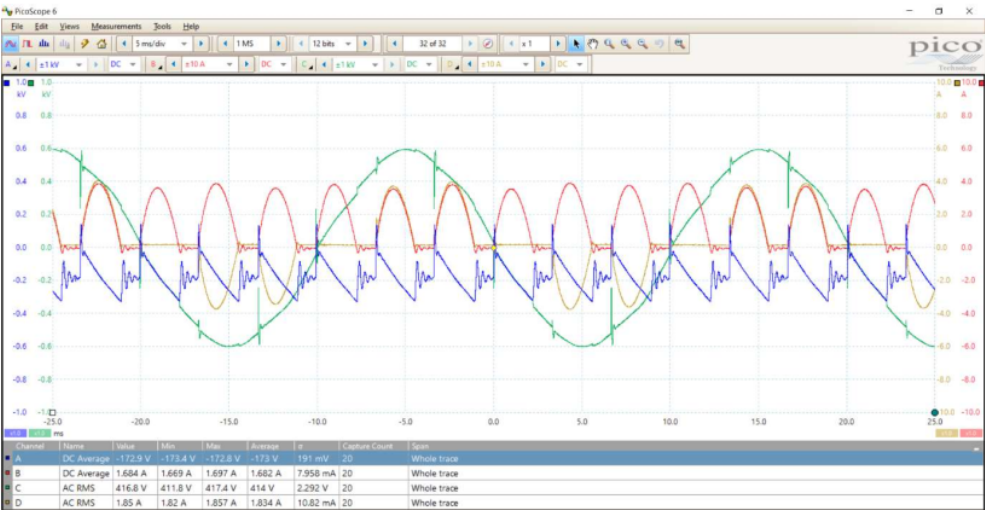
Negative Current – Bridge 2, Positive Voltage, Quadrant 2, Generating Forward, Alpha > 90



Negative Current – Bridge 2, Negative Voltage, Quadrant 3, Reverse Motoring



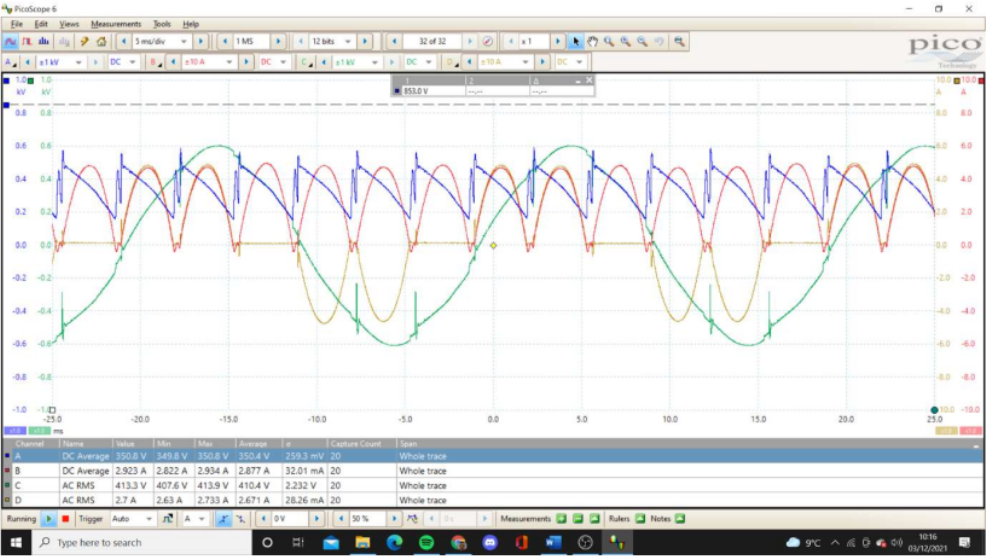
Positive Current – Bridge 1, Negative Voltage, Quadrant 4 , Generating Reverse



8.5 DC drive in quadrant 1 discontinuous current with three different values of speed with constant torque

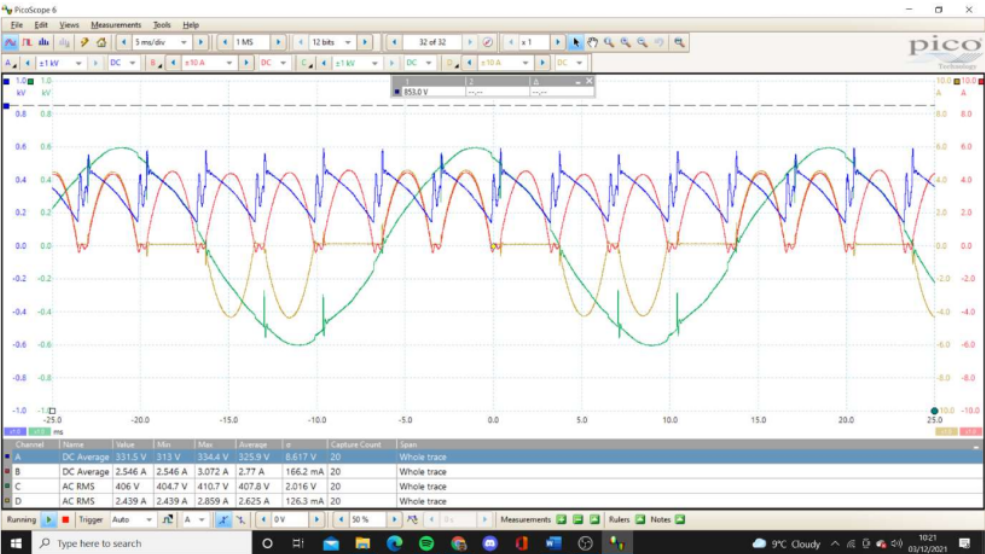
3 Different Speed Set-points

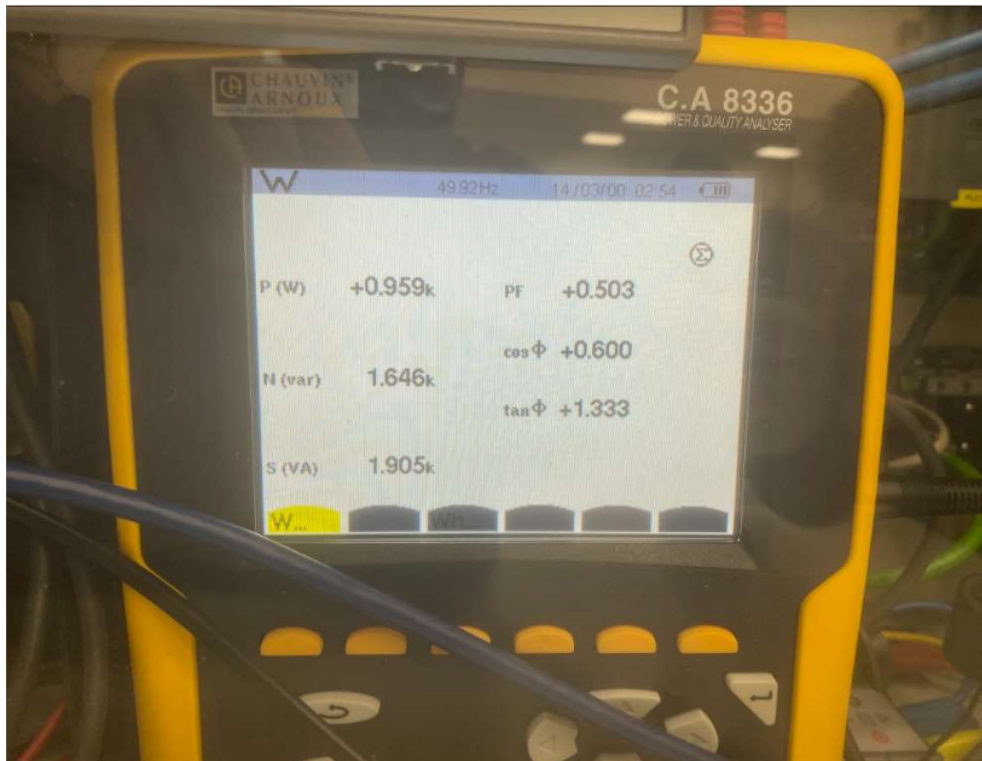
SP1



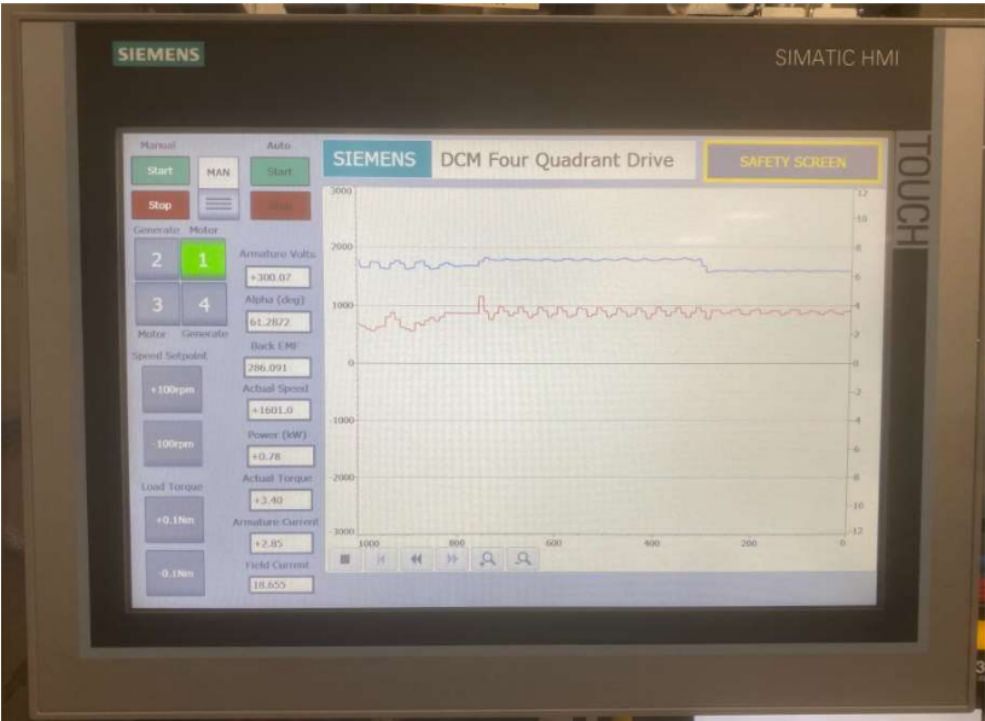
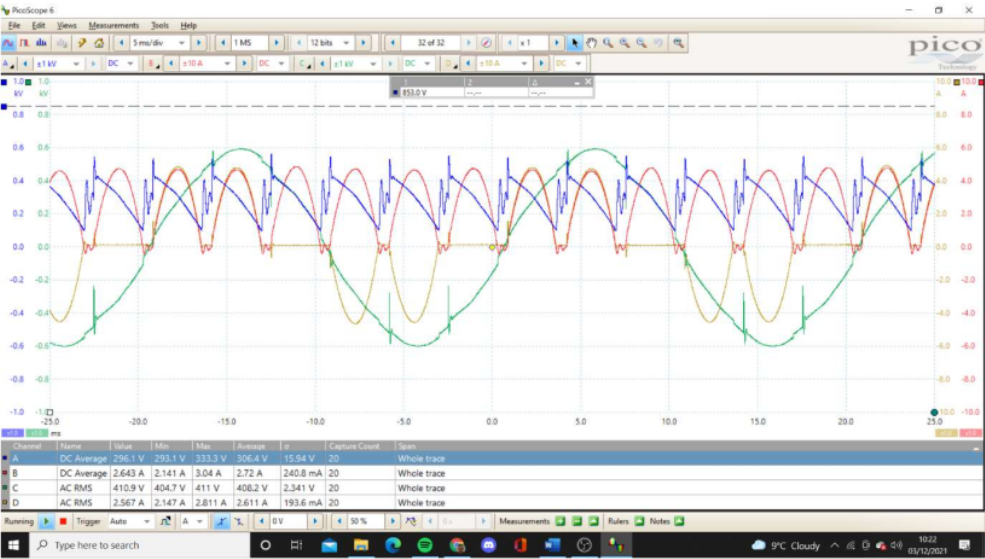


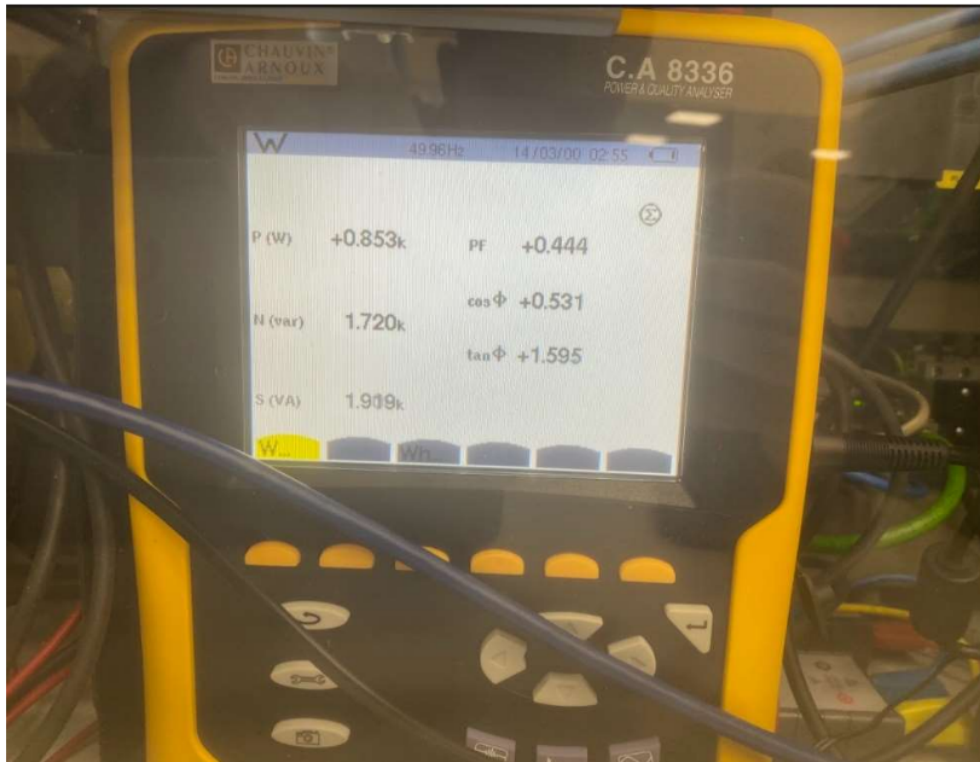
Speed SP2 2 –



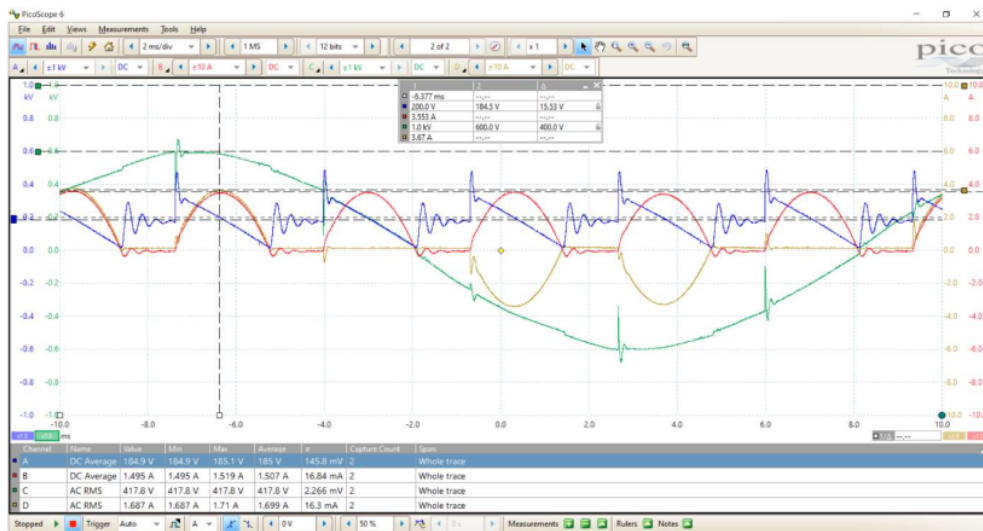


Speed SP3





8.6 Measurement for motor constants



$V_a = E + I_a R_a + L \frac{di}{dt}$, at peak current $L \frac{di}{dt} = 0$

Therefore,

$$R_a = (V_a - E) / I_a = 15.53 / 3.553 = 4.371$$

8.7 Calculation for average armature voltage

$$\gamma = \frac{\pi}{3} + \alpha - \frac{2\pi}{3}$$

$$= \alpha - \frac{\pi}{3}$$

$$V_{mean} = \frac{Area A + Area B}{\frac{\pi}{3}}$$

$$Area A = E \times \gamma$$

$$Area A = E \left(\alpha - \frac{\pi}{3} \right)$$

$$Area\ B = V_{max} \int_{\frac{\pi}{3}+\alpha}^{\pi} \sin(\theta) d\theta$$

$$V_{max} = [-\cos \theta]_{\frac{\pi}{3}+\alpha}^{\pi}$$

$$V_{max} = \left[-\cos \pi - -\cos \frac{\pi}{3} + \alpha \right]$$

$$E = 180.921V$$

$$\alpha = 81.4 = 1.4207 rad/sec$$

$$V_{max} = 589.6V$$

$$V_{mean} = \frac{3}{\pi} [180.921 \times (1.4207 - 1.04719) + 589.6 \left(1 + \frac{1}{2} \times 0.1495 - 0.866 \times 0.9887 \right)]$$

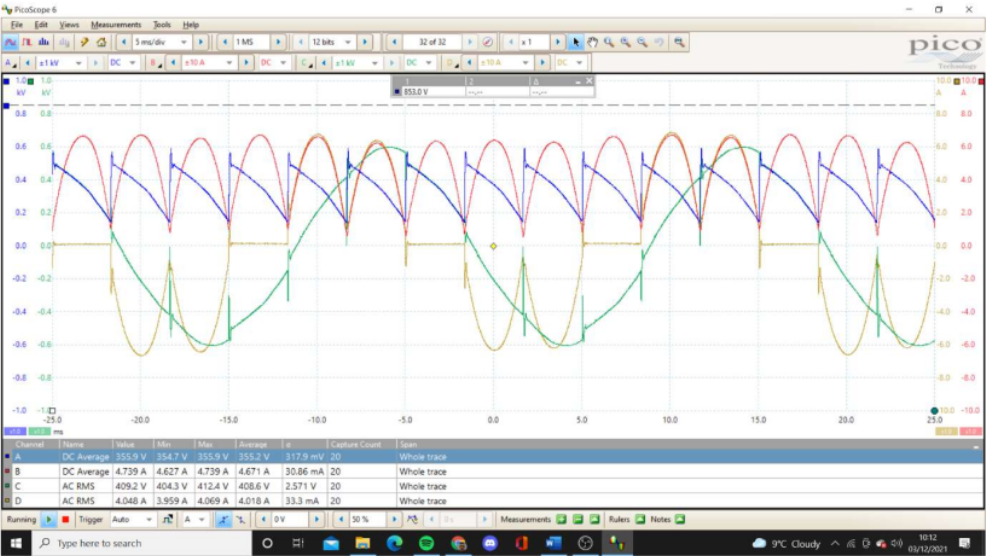
$$V_{mean} = \frac{3}{\pi} [65.257 + 128.849]$$

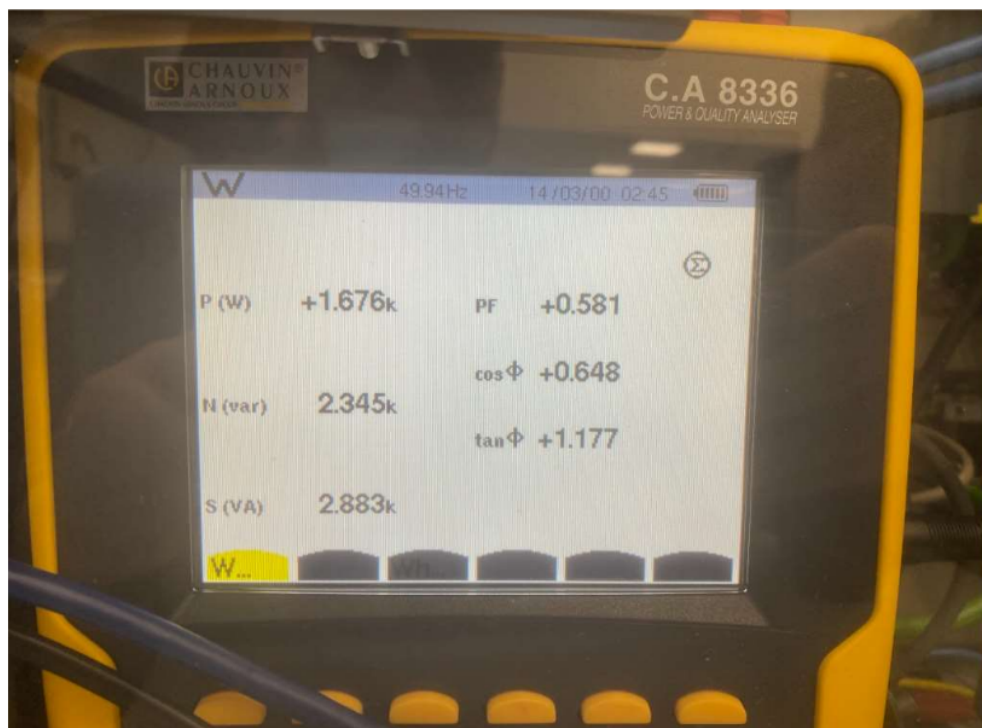
$$V_{mean} = 185.358$$

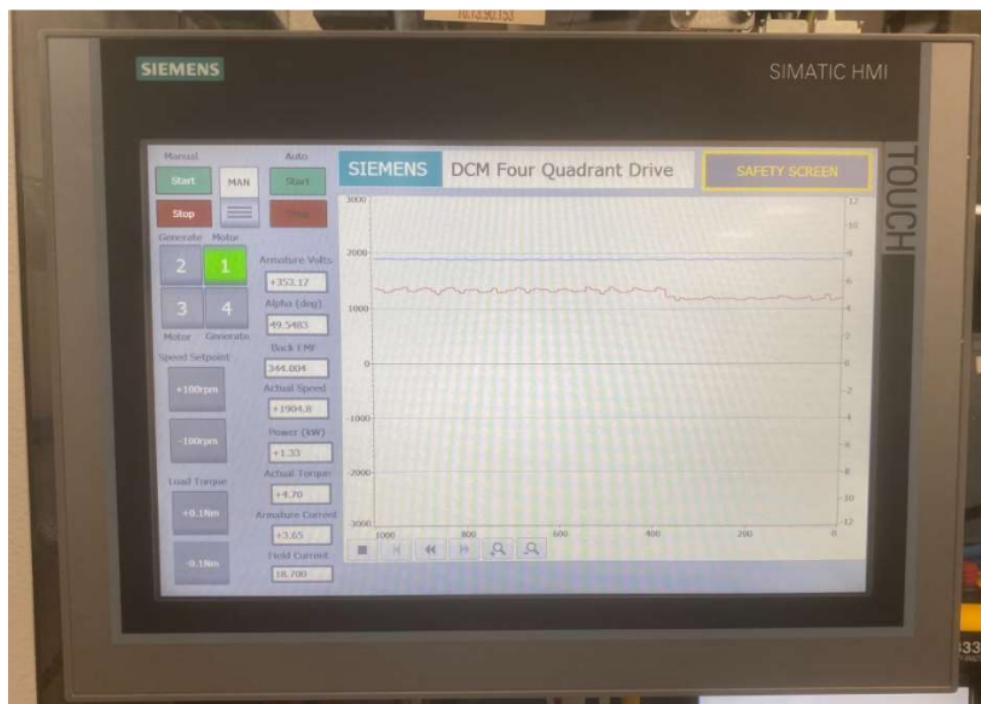
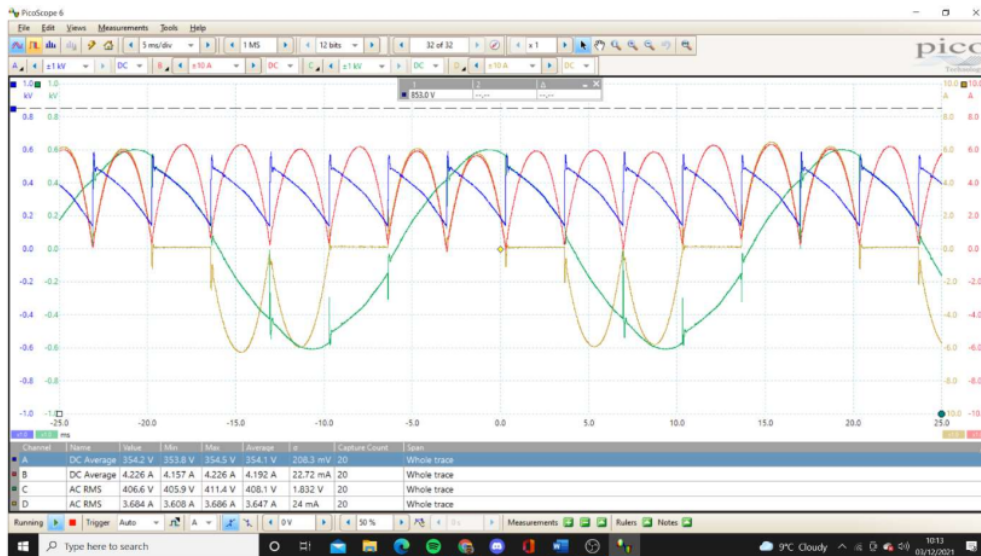
$$\text{Measured} = 186.29$$

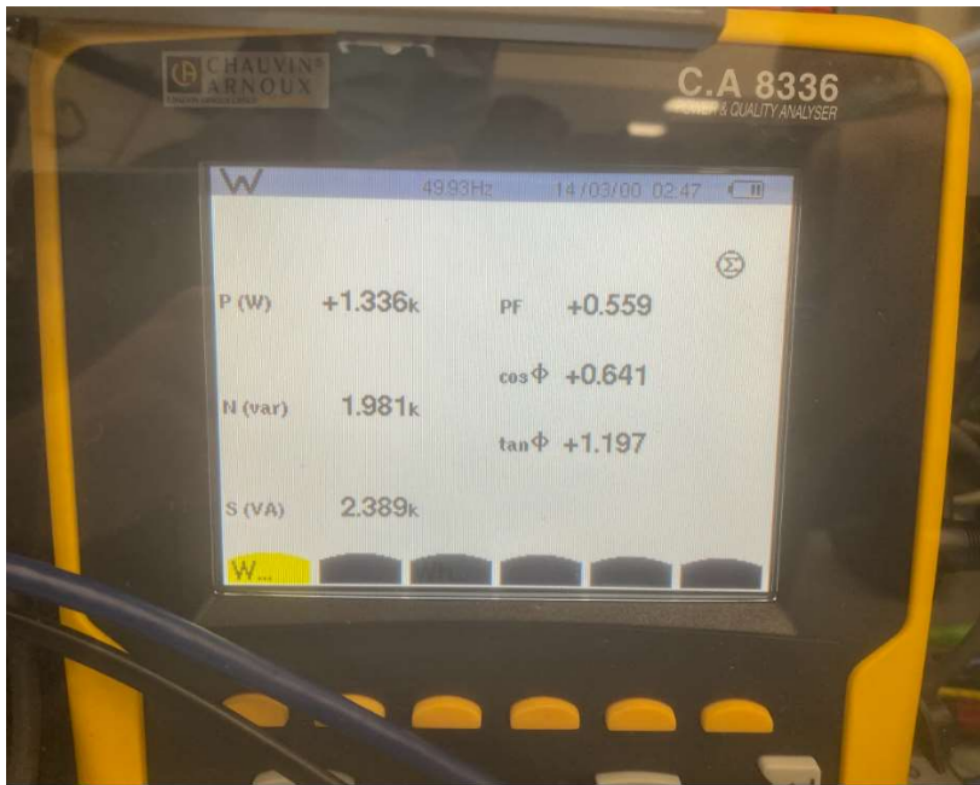
8.8 Quadrant 1 increasing load torque results

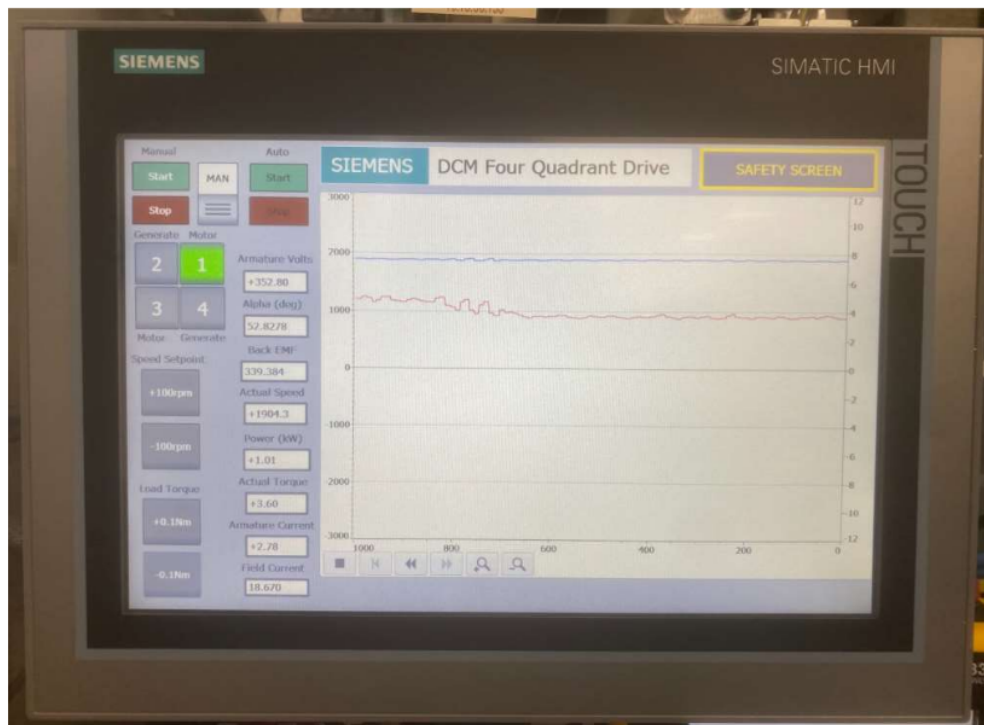
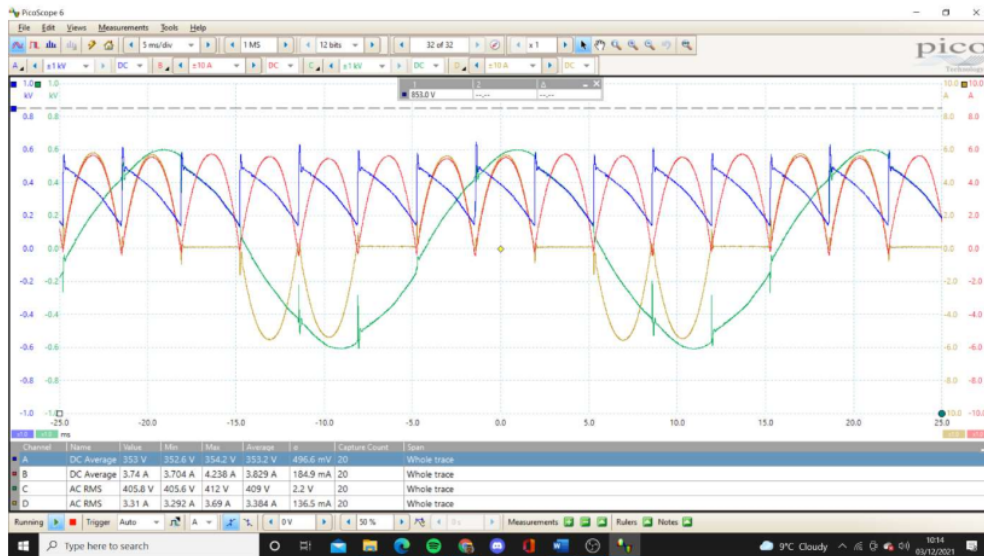
3 Different Torque Values













Assignment 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

62/100

PAGE 1

Text Comment. 1. A good summary but it is too long

Text Comment. 2. Research is from text books mostly and from a small range of sources

Text Comment. 3. The drive selected for investigation is a single phase drive

Text Comment. 4. Simulated and practical results tally well with theory and calculation

Text Comment. 5. Report shows a good understanding of the field of study

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GRADING FORM: NEW CSG-RUBRIC

GARETH WILKINS

62

1. ENGAGEMENT WITH LITERATURE

 Engagement with a limited range of mostly relevant and credible sources. (8/20)

8

2. KNOWLEDGE AND UNDERSTANDING

 Knowledge is reasonably extensive coherent and detailed. Exhibits very good understanding of the breadth and depth of established views, and the work is, at least in part, well-informed by current research and scholarship. (12/20)

12

3. COGNITIVE AND INTELLECTUAL



Excellent critical thinking, analysis, synthesis and evaluation. Ability to investigate contradictory or incomplete information and make strong, persuasive, arguments and sophisticated judgements. Some evidence of independent thought and ability to 'see beyond the question', suggesting a grasp of the broader field and wider concepts. (14/20)

14

4. PRACTICAL APPLICATION



An advanced application of a range of methods, materials, tools and/or techniques. The context of the application is well considered, and insightful. Application and deployment extend beyond established conventions. Can identify complex problems and propose excellent solutions. Innovation and creativity evident. (14/20)

14

5. TRANSFERABLE SKILLS



Can communicate professionally confidently and consistently in a suitable format. Work is coherent, very fluent and is presented professionally. Can work autonomously with initiative. Where relevant can work professionally within a team, showing leadership skills as appropriate, managing conflict and meeting obligations. Demonstrates excellent graduate employment skills and an appetite for further development (14/20)

14