

2017196

by Jack Rogers

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Good use of tables

1. Executive Summary

In this report a wide range of research will be gathered as there will be a focus on DC drives and its design and control techniques used. Also, a compatible example of a DC drive available will be researched and its specification will be shown. Applications and comparisons of the four quadrant DC drive will be given with a small conclusion of the research.

Next will be to design the four-quadrant circuit on Multisim and run a series of tests both simulated and practically using waveforms, HMI graphs and a Pico scope. *Tasks identified*

The series of tests will include alternating the speed and torque while recording all results from each test and comparing them.

Also, calculations will be made for the various speed setpoints and the motor constant in order to prove the testing from the practical.

After this an analysed conclusion will be written to discuss each test and simulation and to prove whether or not the experiment was successful.

Summary includes key points

2. Work plan for Life-long Learning

A report will be written to investigate the characteristics of a DC motor and drive while connected to an AC motor and how its variables are affected by alternating the values of speed, and torque. As part of the health and safety, making sure that there is *isolation*, such as using MCB's, fuses and isolation transformers due to high voltage and current. Filters for the three-phase input must be checked to minimize spiking errors and for smoothing waveforms.

Good points included

3. Research

3.1 Design Features and Control Techniques

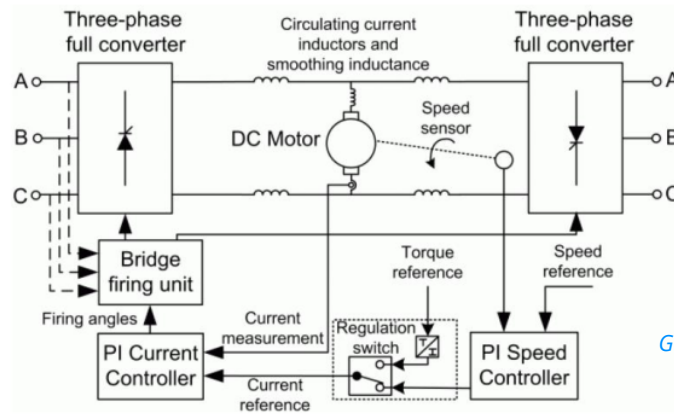


Figure 1 - Four-Quadrant Three-Phase Rectifier DC Drive Diagram

Good supporting diagram

In Three-phase, four quadrant DC drives are integral components in various industrial applications due to their ability to control the speed and direction of DC motors efficiently. These drives contain several design features and control techniques to achieve precise control and optimal performance. By looking at figure 1, it shows a closed-loop speed control with two anti-parallel three-phase thyristor rectifiers. These rectifiers form a circulating current flow *Good point here* including the help of current inductors. A speed control loop then connects to the armature current feeding the PI current controller. By using the controller, the two thyristor firing angles for the rectifiers are used to gather gate signals through a thyristor bridge unit.

Good point

(MathWorks, 2024)

Good explanation that includes good key points

3.1.1 Design Features

With this system there are a few different stages that are implemented into the design. These are listed below:

The DC drive includes a power conversion stage that converts AC input power into DC power. This stage typically consists of rectifiers to convert AC to DC. *Good key point*

In a four-quadrant DC drive, an inverter stage is employed to control the direction of rotation of the DC motor. This stage utilizes power electronic switches such as Insulated Gate Bipolar Transistors (IGBTs) or MOSFETs to regulate the voltage and current supplied to the motor. *Also thyristors*

These drives incorporate feedback control systems utilising sensors such as encoders or tachometers to measure motor speed and position. This feedback is used to adjust the control signals sent to the inverter stage, giving accurate speed and torque control. *Good point*

To ensure safe operation, DC drives include protection mechanisms such as overcurrent protection, overvoltage protection, and thermal protection to prevent damage to the motor and drive components. (rvstcc, 2024)

3.1.2 Control Techniques

In this system there are also control techniques needed for the system to operate efficiently, these are listed below:

Pulse Width Modulation (PWM) control is commonly used in DC drives to regulate the average voltage supplied to the motor. By modulating the width of the pulse, the effective voltage across the motor terminals can be controlled, giving accurate speed and torque regulation.

(Media, 2024) *Good key point included*

Field-Oriented Control techniques are employed in advanced DC drives to control both the speed and torque of the motor independently. By aligning the field vector with the rotor flux, FOC ensures optimal performance and efficiency. (Lewin, 2024)

DC drives use current control loops to regulate the armature and field currents of the motor. By maintaining the desired current levels, the drive can achieve smooth and stable motor operation across varying load conditions. (Torres, 2024) *Good technical information
Dual converter functions for 4 quadrant operation should be included*

3.2 Details of a Suitable DC Drive

One suitable DC drive is the Siemens SIMOREG DC MASTER. This drive offers precise control and flexibility for various industrial applications.



Good supporting image

There is probably an accompanying circuit diagram available for this driver.

Rated Voltage	Up to 690V
Power Range	6 kW to 1900 kW

Control Modes	Armature Voltage Control, Field Voltage Control
Feedback Options	Analog and Digital Feedback
Communication Interfaces	Profibus, Profinet, Ethernet/IP
Protection Features	Overcurrent Protection, Overvoltage Protection, Thermal Protection
Advanced Controls	FOC, PWM Control <i>Field Orientated Control</i>
Manufacturer	Siemens AG

There could be more details such as connections and key parameters

(Siemens, 2024)

3.3 Typical Applications and Comparisons

3.3.1 Applications

These drives find applications in industries requiring precise speed and torque control, such as steel rolling mills, paper mills, and cranes. They offer both forward and reverse operation with regenerative braking capabilities. (McTaggart, 2024) *Applications are identified*

3.3.2 Comparisons

Unlike single-phase converters, four-quadrant DC drives offer bidirectional control and regenerative braking, making them suitable for applications requiring dynamic speed and torque control. *Good point included*

While chopper drives also offer bidirectional control, they are limited in power handling capacity compared to four-quadrant drives. Additionally, chopper drives are typically used in low to medium-power applications. *Chopper fed drives application is identified*

AC drives have higher efficiency and improved control algorithms. However, DC drives still hold advantages in certain applications requiring precise speed and torque control, especially in industries with existing DC motor infrastructure. (Danfoss, 2024) *Good key points here*

Research Conclusion

Three-phase, four quadrant DC drives offer control and flexibility for various industrial applications. By employing advanced design features and control techniques, these drives ensure better performance and efficiency rates. Even though modern AC drives are improving, DC drives remain relevant in industries requiring speed and torque control. The choice between different drive types depends on factors such as application requirements, existing infrastructure, and cost considerations. *Good points in conclusion for research content.*

4. Simulation and Design Adaption

4.1 Three-Phase Full Wave Fully Controlled Rectifier

Firstly, Multisim was used to create a simulated circuit consisting of many components that are listed in the figure below. Once the circuit was designed and built, it could then be simulated.

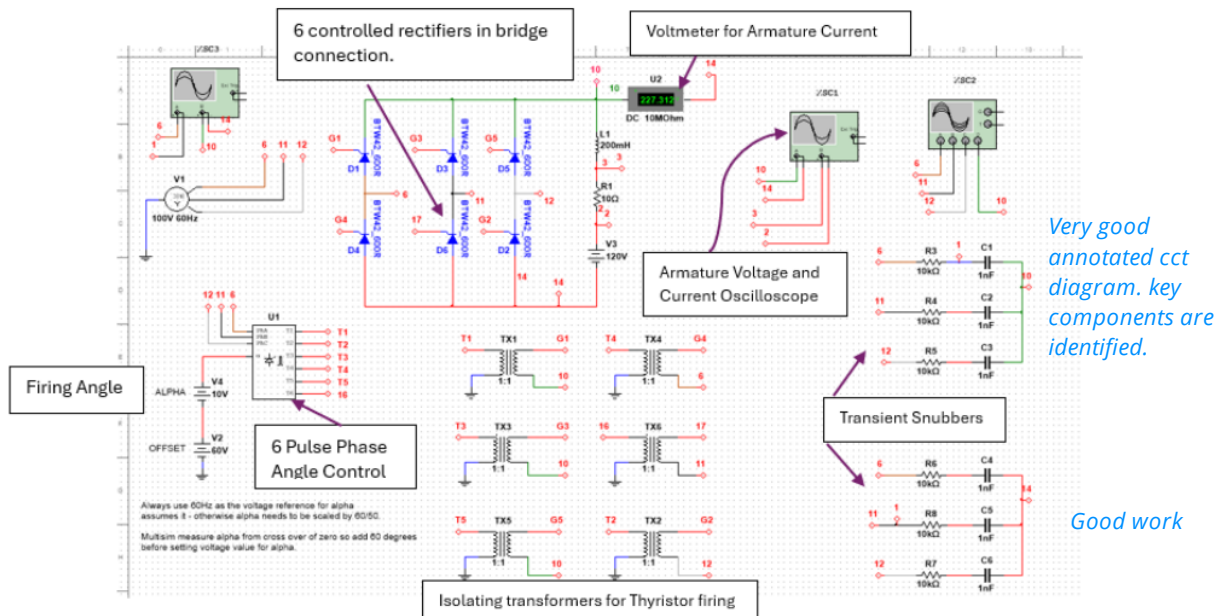


Figure 2 - Three-Phase Full Wave Fully Controlled Rectifier

Point of key components should be explained

For simulating the circuit, a battery formed voltage source is connected directly to the phase angle controller. This will then determine the firing angle as the voltage is directly proportional to it.

The reason for the offset should be explained

By using the equation below, five different firing angles were then used to work out the average voltage for each angle.

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

Formula is identified

Good point

$V_{max} = 242V$ (had to deduct 2V for the volt drop thyristor firing). This figure can be shown in Figure ??? in the appendix.

Number should be shown

Next, by using the equation given and knowing the Vmax, the five different firing angles were then used to calculate each average voltage.

$$\begin{aligned}\alpha = 10 & \quad \frac{3 \times 242}{\pi} (\cos 10) = 227.6v \\ \alpha = 20 & \quad \frac{3 \times 242}{\pi} (\cos 20) = 217.1v \\ \alpha = 30 & \quad \frac{3 \times 242}{\pi} (\cos 30) = 200.1v \\ \alpha = 40 & \quad \frac{3 \times 242}{\pi} (\cos 40) = 177v \\ \alpha = 50 & \quad \frac{3 \times 242}{\pi} (\cos 50) = 148.5v \quad \text{Excellent work here}\end{aligned}$$

After calculating the different firing angles, each angle was used in Multisim and a simulation was done by recording each angles waveform and also seeing what readings the armature current voltmeter had. This can be seen in figures 27-31 in the appendix. *Good ref to appendix*

After calculating and simulating the five different firing angles, a table of results was then created to see if all the tests and calculations matched and were successful. This can be shown in the table below.

Table 1 - Table of Results for Firing angles Calculated and Simulated

Alpha α	Armature Mean Voltage (V)		Error	Evidence
	Simulated Voltage	Calculated Voltage		
10	227.3v	227.6v	0.3v	Figure 27
20	217v	217.1v	0.1v	Figure 28
30	199.9v	200.1v	0.2v	Figure 29
40	176.7v	177v	0.3v	Figure 30
50	148.3v	148.5v	0.2v	Figure 31

Good explanation and use of table for test results. Good ref to fig numbers in appendix.

By looking at the table above its clear to see that there is very little errors between the calculated and simulated average armature voltage. This indicates that the tests and simulations were a success as they almost marched the calculated results. *Good point highlighting the minimal error values*

4.2 Dual Converter

4.2.1 Multisim Circuit

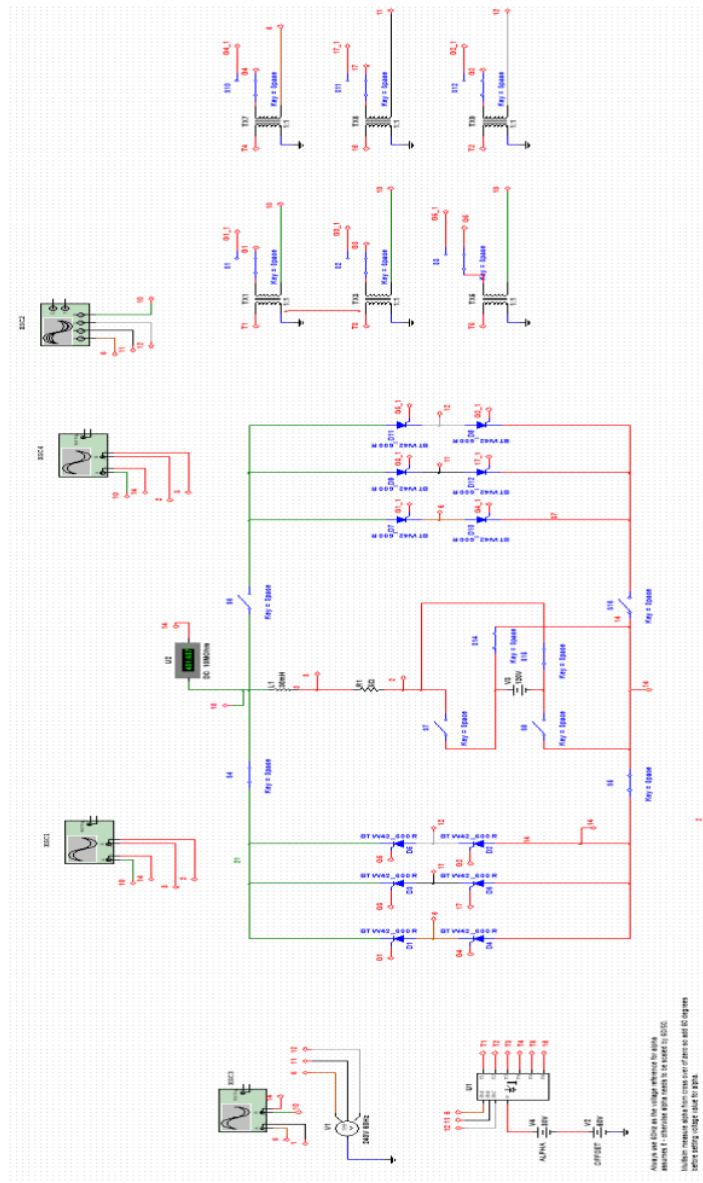


Figure 3 - Dual Converter Multisim Circuit

Next was to create a modified circuit on Multisim to create a dual converter, this can be shown in the image above. While building this circuit a modification was made to the three-phase full wave fully controlled rectifier circuit that had already been created. *Good point*

The modification was to add an additional 6 thyristors and reversing their polarity to the original bridge 1, these would then identify as bridge 2. By running the simulation on the Multisim software, there were 4 waveforms gathered with each waveform representing each quadrant. *Good work*

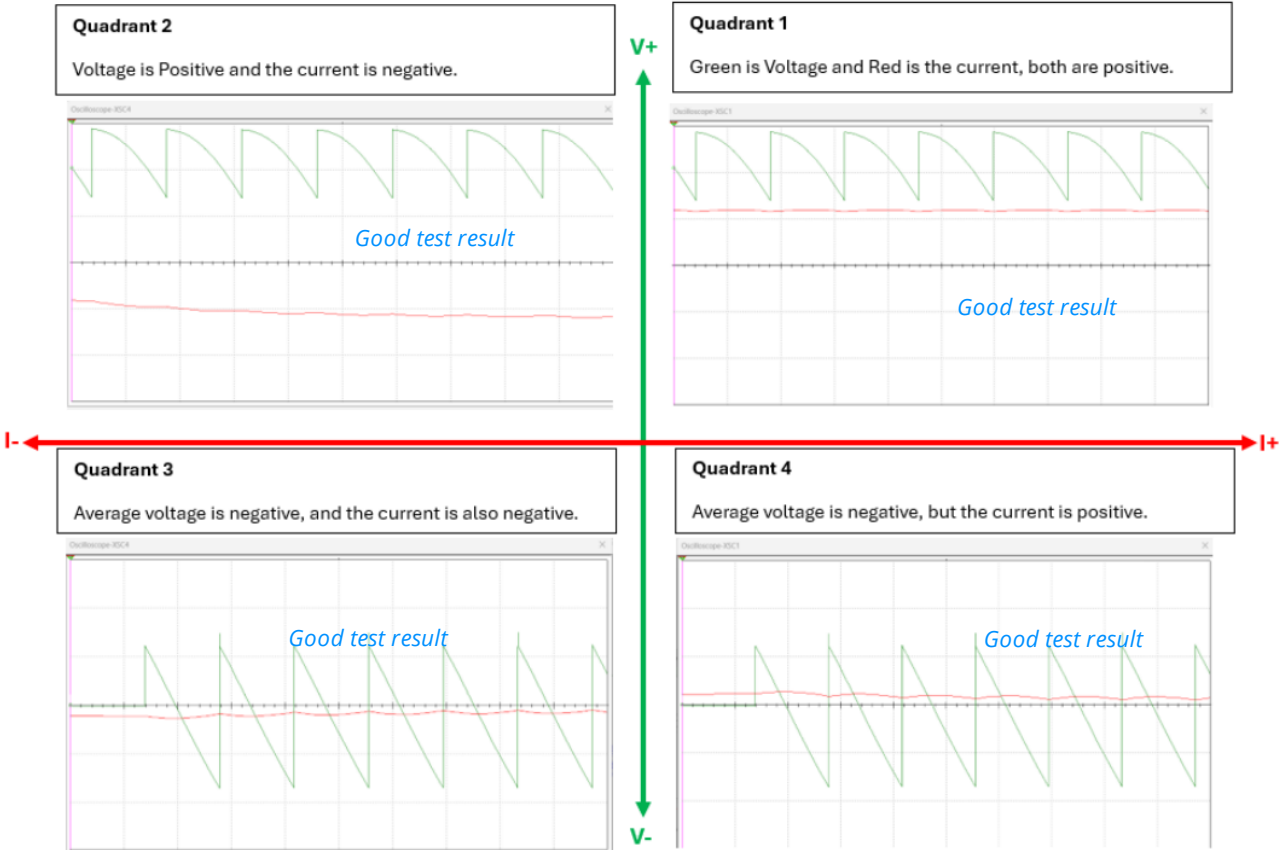


Figure 4 - 4 Quadrant Waveforms for Dual Converter

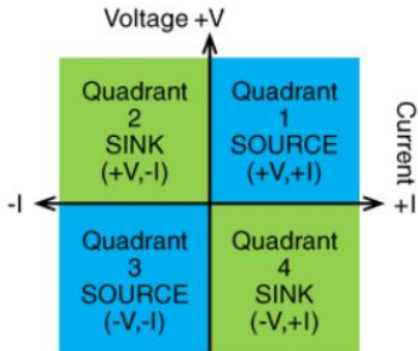


Figure 5 - 4 Quadrant by Matsusada

This is excellent work here comparing with theory

As shown by Matsusada's theory the waveform with a positive current and voltage represents quadrant 1, a positive voltage and negative current represents quadrant 2, a negative voltage and current represents quadrant 3 and a negative voltage and a positive current represents quadrant 4.

(Matsusada, 2024)

Table 2 - 4 Quadrant Comparison

Four Quadrant Comparison		
Quadrant	Simulated Results	Expected Results
1	+V, +I	+V, +I
2	+V, -I	+V, -I
3	-V, -I	-V, -I
4	-V, +I	-V, +I

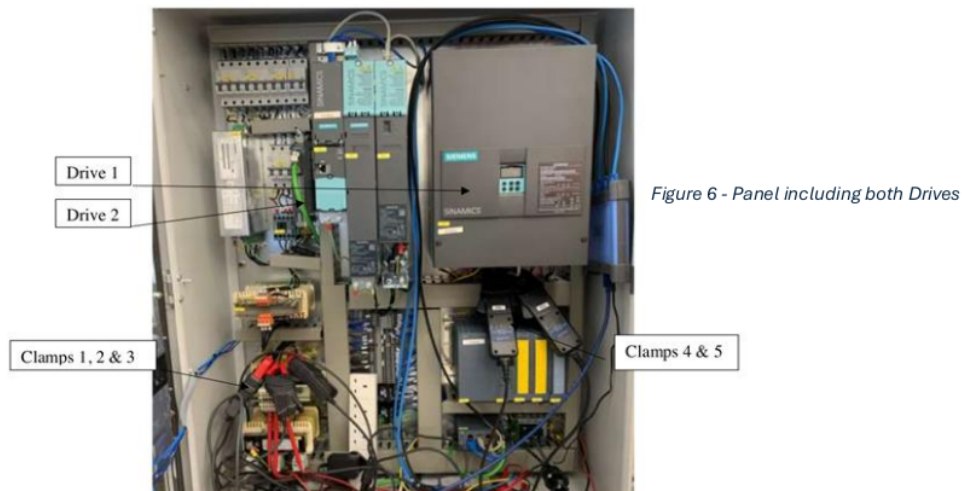
*Good useful
table for
operation*

By looking at the comparison table above, the simulated results were the exact same as the expected results. Therefore, the tests that has been completed were successful as it proved the theory correct.

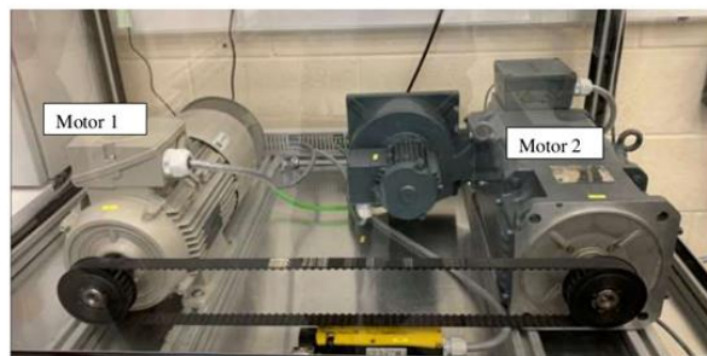
Excellent work with this section

5. Practical Investigations

5.1 Practical Setup



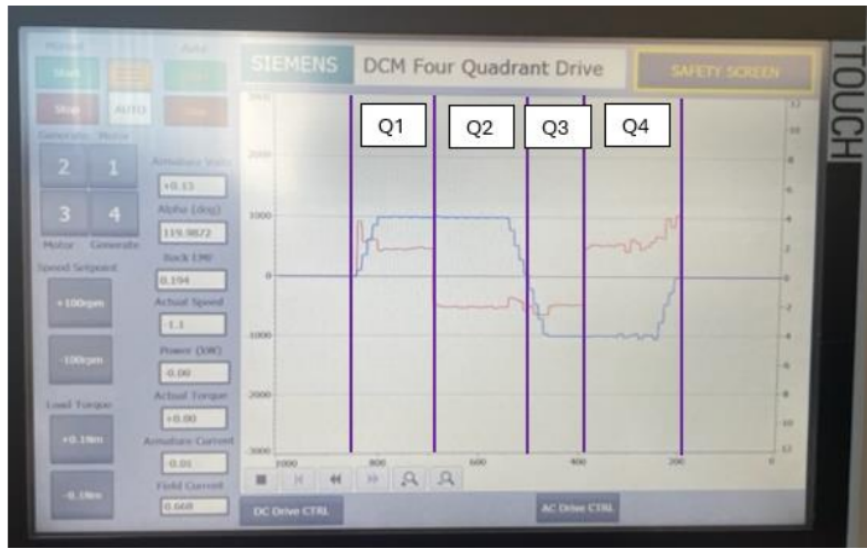
Very good annotated images of test setup



By looking at the figures above, the practical was focused on an AC – DC motor system. The AC motor is controlled by a Siemens S120 Drive while the DC motor is controlled by a Siemens Three-phase Sinamics DCM DC converter. The AC motor is acts as a variable load to the other motor and the two are mechanically connected by a drive belt and pulley. *Good key points identified*

During the practical, there were waveforms taking by a Pico scope as well as the waveforms off the HMI screen of each quadrant.

5.2 Four Quadrant Operation



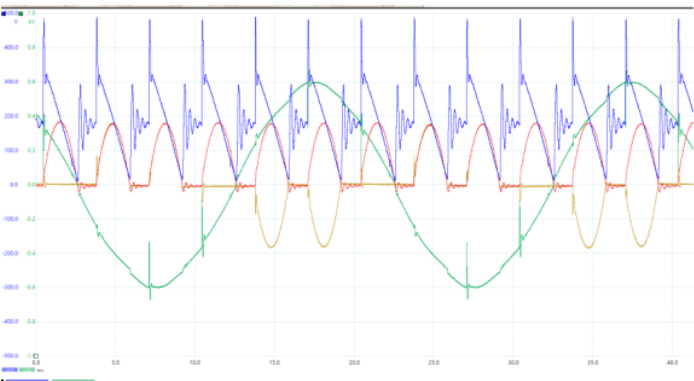
Excellent annotated image of test result for all 4 quadrants

Figure 8 - Four Quadrants HMI Practical

Next was to capture the waveforms of all four quadrants in one image, this was done by running the simulation of the two motors and examining the characteristic of each quadrant to see the outcome of the results gathered. By looking at the image above each quadrant has been separated into its own category to show its characteristics. The blue line represents the voltage and the red line represents the current. *Key parameters identified*

Next was to gather the results of each of the four quadrants from the Pico scope. These results can be shown below.

Quadrant 1



Good test result

Channel	Name	Value	Min	Max	Average	σ	Capture Count	Span
A	DC Average	185.4 V	185 V	185.9 V	185.4 V	254.4 mV	20	Whole trace
B	DC Average	1.502 A	1.494 A	1.513 A	1.505 A	6.169 mA	20	Whole trace
C	AC RMS	413.2 V	409.3 V	417.2 V	413.8 V	2.552 V	20	Whole trace
D	AC RMS	1.705 A	1.699 A	1.731 A	1.713 A	9.318 mA	20	Whole trace

Figure 9 – Quadrant 1 Pico scope Waveform

Quadrant 2

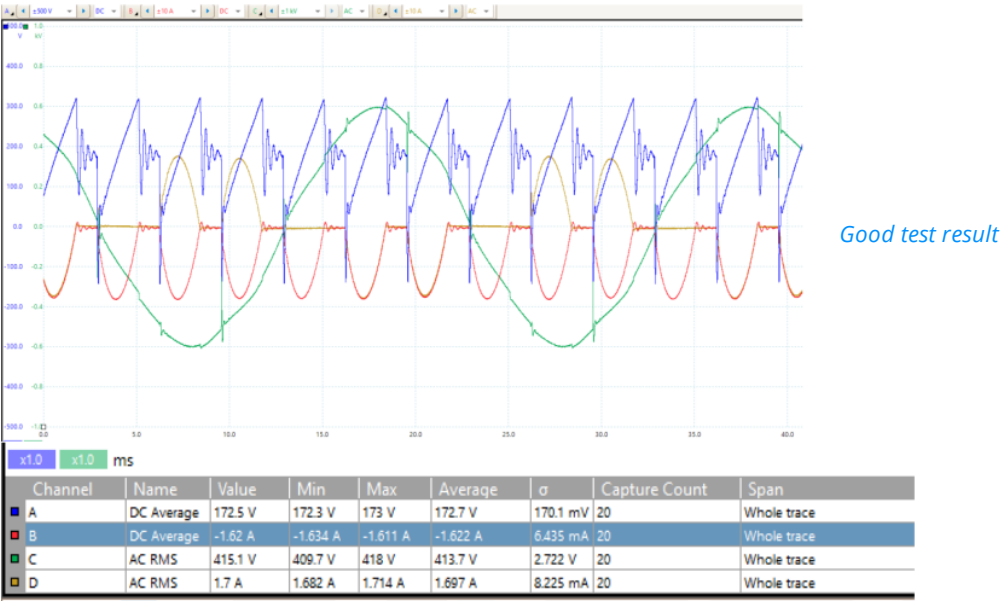


Figure 10 - Quadrant 2 Pico scope Waveform

Quadrant 3

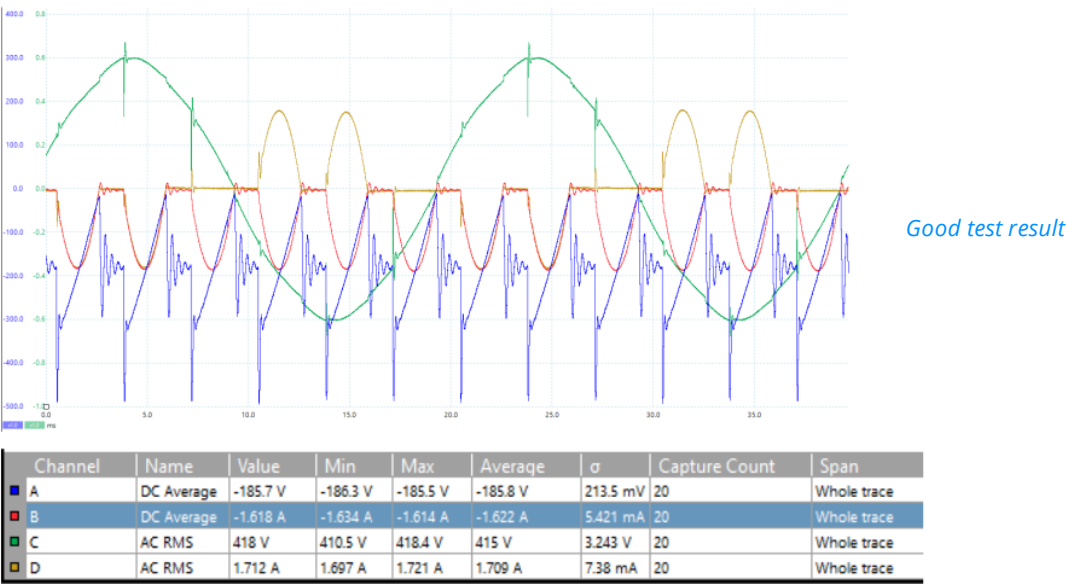


Figure 11 - Quadrant 3 Pico scope Waveform

Quadrant 4

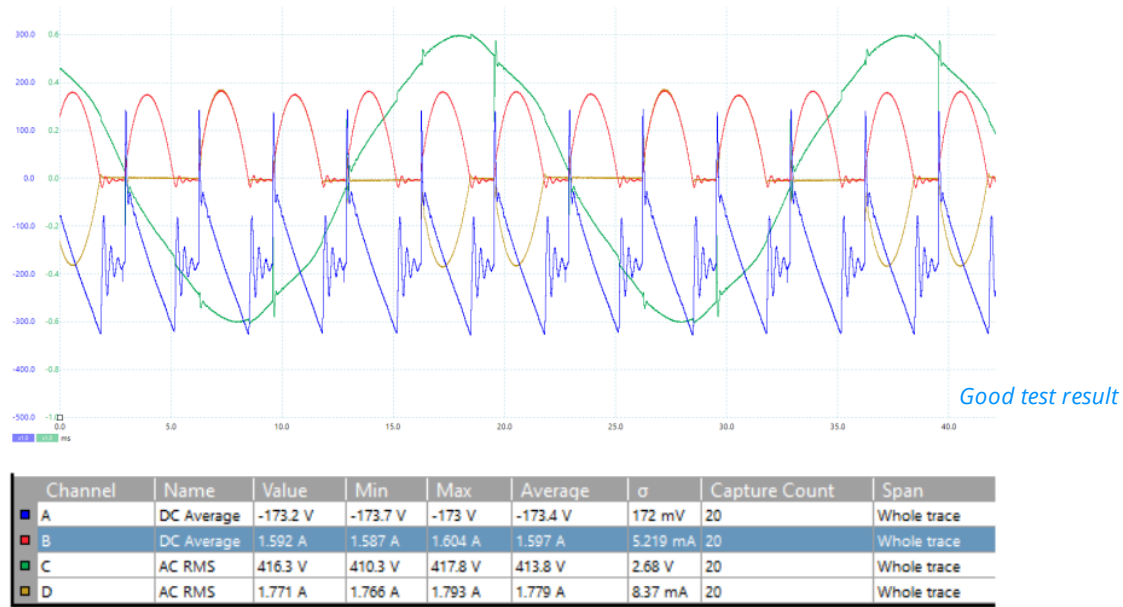


Figure 12 - Quadrant 4 Pico scope Waveform

Excellent set of test results that clearly show the values changing polarity for each quadrant.

After gathering all the waveforms for each quadrant during the practical, each result from the Pico scope, HMI and the expected results were then put into a table of comparison. This table can be seen below. Although the Pico scope doesn't measure torque and speed, in this case, the speed of the motor is proportional to the voltage and the torque is proportional to the current.

Good work here. The proportional parameters in the system are identified

Table 3 - Four Quadrant Operation - Practical Results Comparison

Four Quadrant Practical Comparison Table			
Quadrant	HMI Result	Expected Result	Pico scope Result
1	Positive Speed and Torque	Positive Speed and Torque	Positive Voltage and Current
2	Positive Speed, Negative Torque	Positive Speed, Negative Torque	Positive Voltage, Negative Current
3	Negative Speed and Torque	Negative Speed and Torque	Negative Voltage and Current
4	Negative Speed, Positive Torque	Negative Speed, Positive Torque	Negative Voltage, Positive Current

Good use of table for evaluation of results

5.3 Various speed setpoint with constant torque (Discontinuous)

Next was to run three simulations by using 3 different speed setpoints but each simulation would have the same torque setpoint. The Waveforms and the HMI screens for each speed setpoint test can be shown below.

Speed Setpoint at 1100 rpm



Figure 13 - Waveform at 1100rpm

Good test result

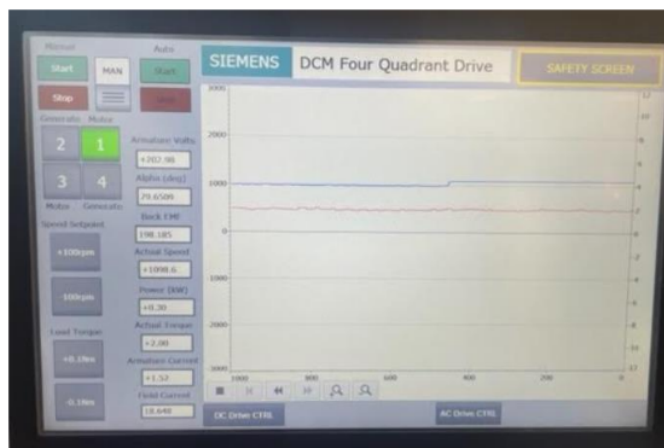


Figure 14 - HMI at 1100rpm

Speed Setpoint at 1500rpm

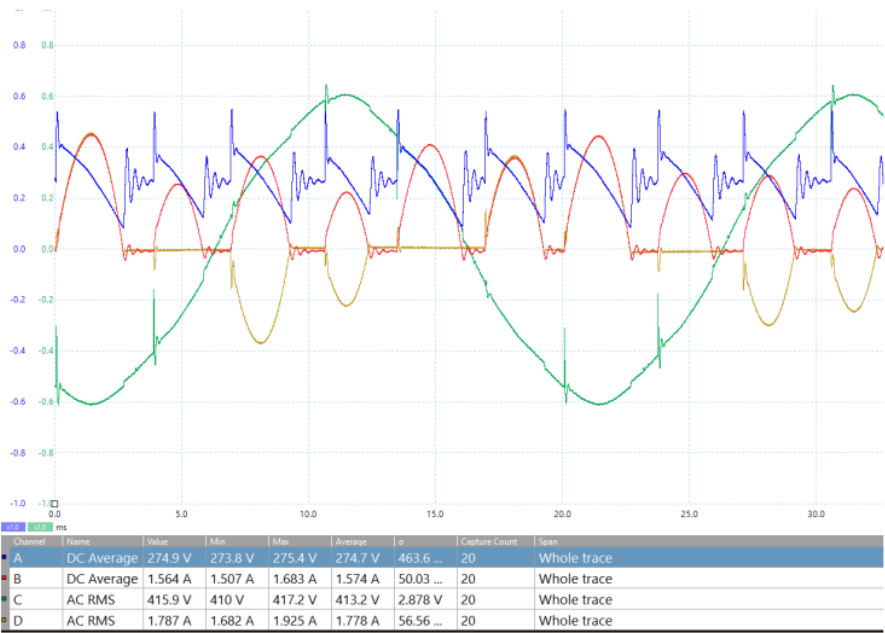


Figure 15 - Waveform at 1500rpm

Good test result



Figure 16 - HMI at 1500rpm

Speed Setpoint at 1900rpm

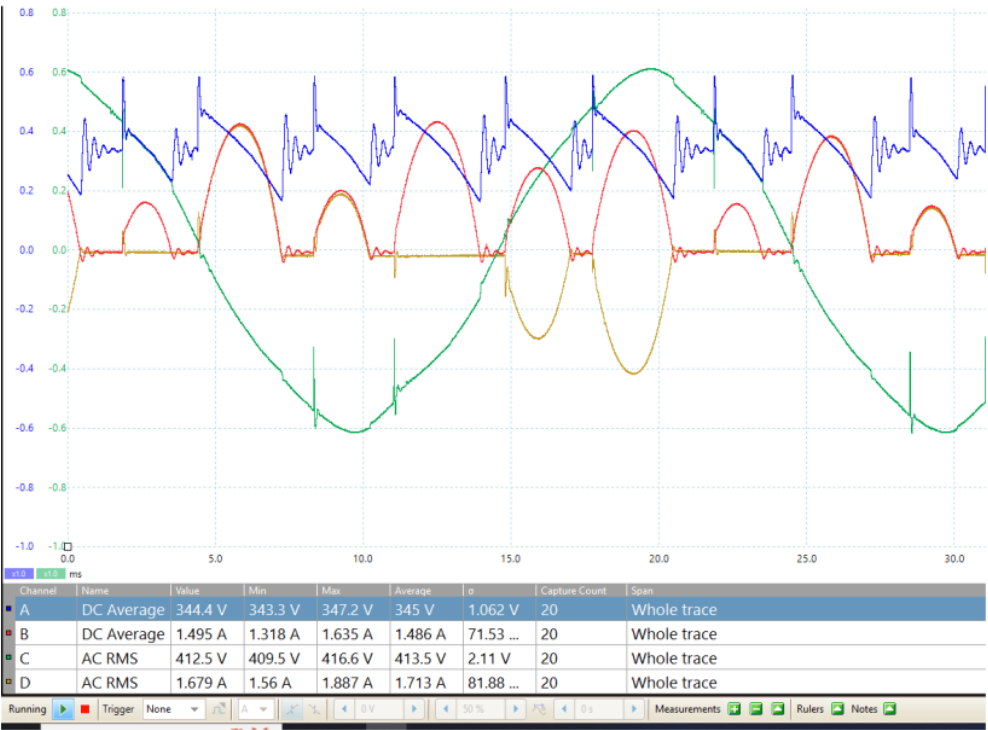


Figure 17 - Waveform at 1900rpm

Good test result



Figure 18 - HMI at 1900rpm

These results were gathered from the waveform on the Pico scope and the HMI vales and put into a table of results. This can be shown below.

Table 4 - 3 Speed Setpoints with a Constant Torque

3 Speed Setpoints with a Constant Torque						
Motor Parameters	Speed at 1100rpm		Speed at 1500rpm		Speed at 1900rpm	
Test Recorder	HMI	Pico Scope	HMI	Pico Scope	HMI	Pico Scope
Armature Voltage (VA)	202.98v	203.1v	277.02v	274.7v	345.40v	344.7v
Firing Angle (Deg)	79.65		75.86		58.42	
Back EMF	198.185		270.28		339.711	
Speed (RPM)	1098.6		1499.9		1900.0	
Power (kW)	0.30		0.43		0.38	
Actual Torque (Nm)	2.0		2.15		1.87	
Armature Current (Ia)	1.52A	1.524A	1.56A	1.564A	1.58A	1.495A
Field Current (If)	18.648		18.671		18.699	

Excellent table of results

By looking at the HMI and the Pico scope results for each test set point, the values are very similar this proves that the simulations were successful as we can see clear pattern in the change of speed. The difference in current is due to the characteristics of a DC motor.

Good point

Next was to calculate the derived formula for V_{mean} . This can be shown in the calculations below.

$$V_{mean} = \frac{Area A + Area B}{\frac{\pi}{3}} \quad \text{Formula is identified}$$

$$Area A = E \times Y = \left[\alpha - \frac{\pi}{3} \right]$$

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

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

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

$$\text{Use the rule } \cos(A + B) = \cos A \cdot \cos B - \sin A \cdot \sin B$$

$$\text{If, } \cos \pi = -1$$

$$\sin \pi = 0$$

$$\cos \frac{\pi}{3} = \frac{1}{2}$$

$$\sin \frac{\pi}{3} = \frac{\sqrt{3}}{2}$$

$$\text{Therefore : } \cos\left(\frac{\pi}{3} + \alpha\right) = \cos\left(\frac{\pi}{3}\right) \cdot \cos \alpha - \sin\left(\frac{\pi}{3}\right) \sin \alpha$$

$$= \frac{1}{2} \cos \alpha - \frac{\sqrt{3}}{2} \sin \alpha$$

$$V_{max} [(-1) - (-\frac{1}{2} \cos \alpha - \frac{\sqrt{3}}{2} \sin \alpha)]$$

$$Area B = V_{max} [1 + \frac{1}{2} \cos \alpha - \frac{\sqrt{3}}{2} \sin \alpha]$$

$$V_{mean} = \frac{E \cdot \left(\alpha - \frac{\pi}{3}\right) + V_{max} [1 + \frac{1}{2} \cos \alpha - \frac{\sqrt{3}}{2} \sin \alpha]}{\frac{\pi}{3}}$$

$$V_{mean} = \frac{3}{\pi} \{E \cdot (\alpha - \frac{\pi}{3}) + V_{max} [1 + \frac{1}{2} \cos \alpha - \frac{\sqrt{3}}{2} \sin \alpha]\}$$

Good work here

After calculating the derived formula, the calculations for speed setpoint at 1100rpm can be done. This is shown in the equation below. The Vmax value is shown by the cursor table on the Pico scope shown in the appendix in figure 32.

Speed Setpoint at 1100rpm

$$HMI > E = 198.185v$$

$$\alpha = 79.65^\circ (1.39)$$

$$Pico\ Scope\ Waveform > V_{max} = 591v$$

$$\therefore V_{mean} = \frac{3}{\pi} \{198.185 \times (1.39 - \frac{\pi}{3})\} + 591[1 + \frac{1}{2}\cos(1.39) - \frac{\sqrt{3}}{2}\sin(1.39)]$$

$$V_{mean} = 205.53v$$

Good work

The calculations for speed setpoint at 1500rpm can be shown below.

Speed Setpoint at 1500rpm

$$HMI > E = 270.28v$$

$$\alpha = 75.86^\circ (1.324)$$

$$Pico\ Scope\ Waveform > V_{max} = 591v$$

$$\therefore V_{mean} = \frac{3}{\pi} \{270.28 \times (1.324 - \frac{\pi}{3})\} + 591[1 + \frac{1}{2}\cos(1.324) - \frac{\sqrt{3}}{2}\sin(1.324)]$$

$$V_{mean} = 238.32v$$

Good work

The calculations for speed setpoint at 1900rpm can be shown below.

Speed Setpoint at 1900rpm

$$HMI > E = 339.711v$$

$$\alpha = 58.42^\circ (1.02)$$

$$Pico\ Scope\ Waveform > V_{max} = 591v$$

$$\therefore V_{mean} = \frac{3}{\pi} \{339.711 \times (1.02 - \frac{\pi}{3})\} + 591[1 + \frac{1}{2}\cos(1.02) - \frac{\sqrt{3}}{2}\sin(1.02)]$$

$$V_{mean} = 300.7v$$

Good work

The results from the calculations were then put into a table of results which can be shown below.

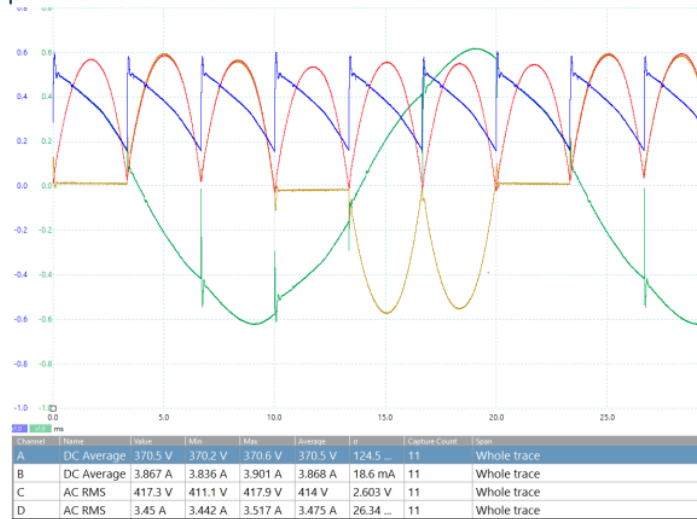
Calculations for Different Speed Setpoints Results			
Calculation	Speed at 1100rpm	Speed at 1500rpm	Speed at 1900rpm
Vmean	205.53v	238.32v	300.7v

Good table of results

5.4 Various Torque Setpoints with Constant Speed (Continuous)

Next was to run similar simulation test as previous but with a various torque set points and a constant speed setpoint. These simulations can be shown in the waveforms from the Pico scope and the HMI screen values below.

Torque Setpoint at 5Nm



Good test result

Figure 19 - Waveform for Torque set at 5Nm



Figure 20 - HMI for Torque set at 5Nm

Torque Setpoint at 3.5Nm

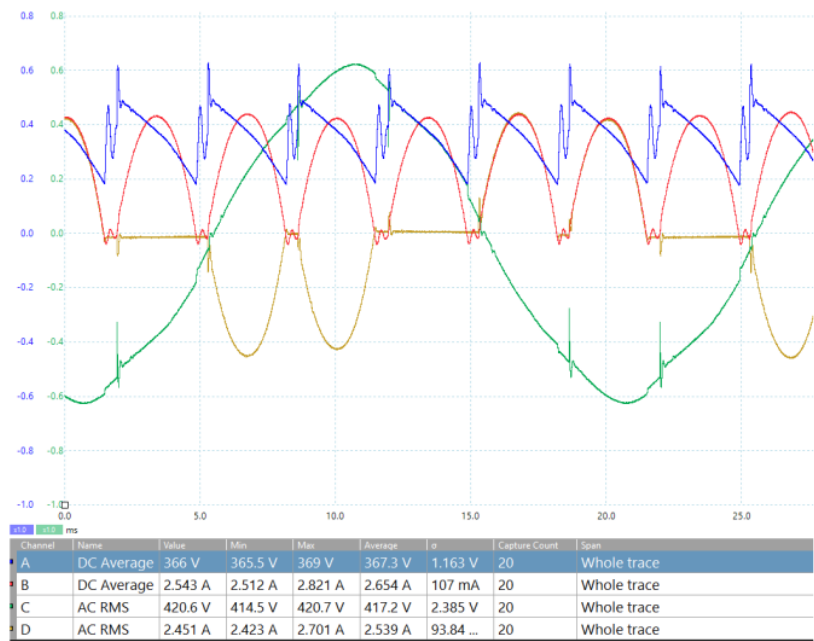


Figure 21 - Waveform for Torque set at 3.5Nm

Good test result



Figure 22 -HMI for Torque set at 3.5Nm

Torque Setpoint set at 2Nm

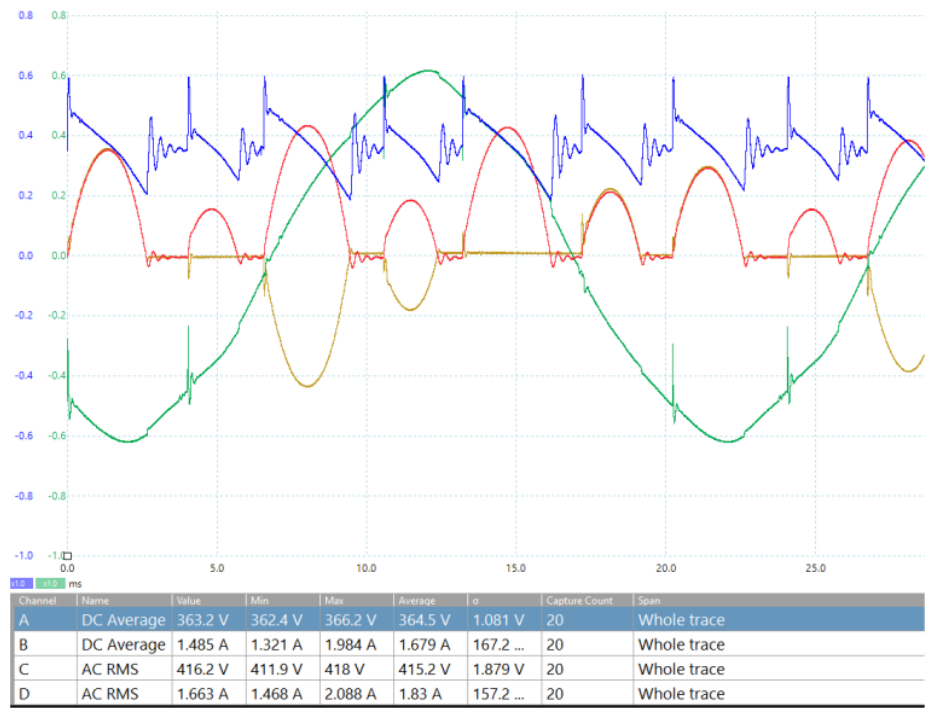


Figure 23 -Waveform for Torque set at 2Nm

Good test result

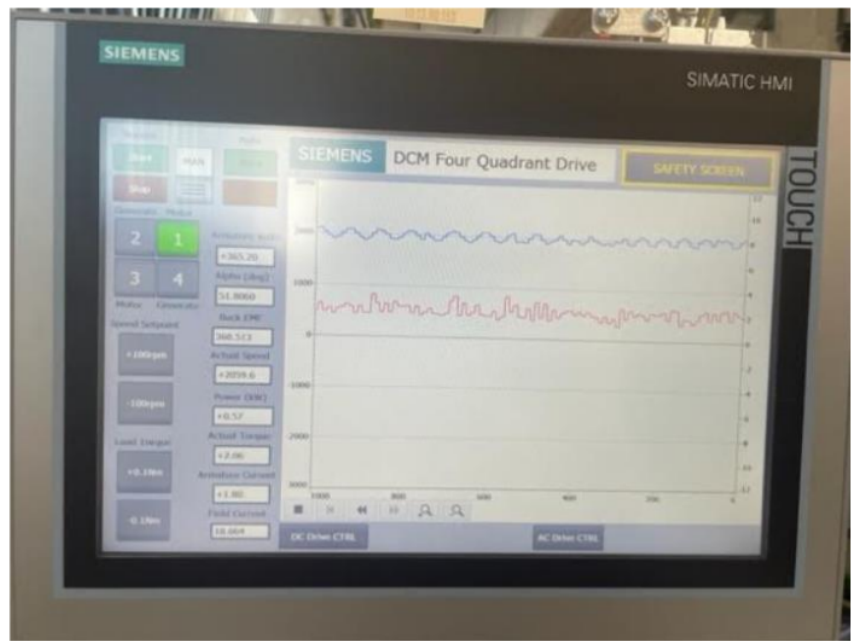


Figure 24 - HMI for Torque set at 2Nm

After gathering all the results from the simulation tests, these were then put into a table of results which can be shown below.

Table 5 - 3 Torque Setpoints with a Constant Speed

3 Torque Setpoints with a Constant Speed						
Motor Parameters	Torque at 5Nm		Torque at 3.5Nm		Torque at 2Nm	
Test Recorder	HMI	Pico Scope	HMI	Pico Scope	HMI	Pico Scope
Armature Voltage (VA)	370.61v	370.5v	370.60v	366v	365.20v	363.2v
Firing Angle (Deg)	47.35		51.31		51.80	
Back EMF	353.74		356.907		360.513	
Speed (RPM)	1994.7		1995.3		2059.6	
Power (kW)	1.40		0.93		0.57	
Actual Torque (Nm)	5.06		3.49		2.06	
Armature Current (Ia)	3.74A	3.867A	2.61A	2.543A	1.80A	1.485A
Field Current (If)	18.647		18.665		18.664	

Good table of results

By looking at the table of results the comparison between the Armature Voltage and Current for the HMI and Pico scope for the three torque set points were similar. The characteristics of the results show that when the torque is increased the current decreases. Due to these results being similar for both test recorders this indicates that the simulations were successful as the correct results were obtained.

*Good test results and very good method of presentation using tables.
Excellent level of detail in the tables.*

The explanations could have been more detailed

5.5 Motor Constant

practical

Next was to run a simulation for the motor constant values. The waveform for this can be shown below with the cursor table included.



Figure 25 - Motor Constant Pico Scope Waveform and Cursor Tables

After running the simulation, the calculations for the motor constant could be done using the values from the HMI. This can be shown below.

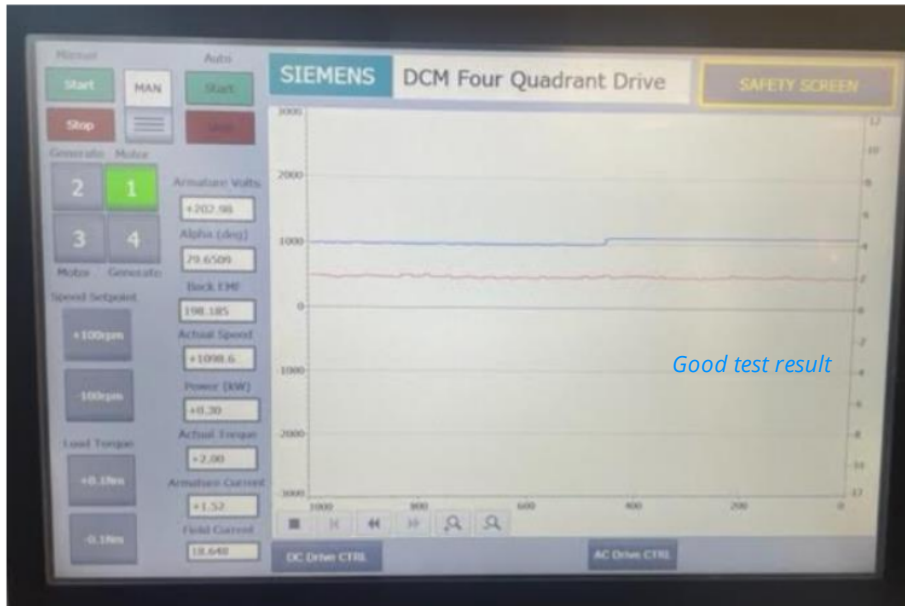


Figure 26 - Motor Constant HMI

Dynamic Resistance:

$$V_a = E + I_a R_a + L \frac{di}{dt} \quad \text{Formula is identified}$$

$$\text{Using Peak Current, } L \frac{di}{dt} = 0$$

Re-arranged equation for armature resistance:

$$R_a = \frac{V_a - E}{I_a} = \frac{202.98 - 198.185}{1.52} = 3.15 \text{ Ohms} \quad \text{Ra value is identified through calc}$$

Then by substituting R_a into the original equation, this can confirm the value for the armature voltage.

$$V_a = 198.185 + (1.52 \times 3.15) = 202.973 \quad \text{Good work}$$

Motor torque constant:

$$K_t = \frac{T}{I_a} = \frac{2.06}{1.52} = 1.36$$

Motor Back EMF:

$$K_e = \frac{E_a}{w}$$

Where w:

$$w = \frac{Rpm}{2\pi} = \frac{1100}{2\pi} = 175.07$$

Therefore K_e :

$$K_e = \frac{E_a}{w} = \frac{1100}{175.07} = 6.283v/Krpm$$

Good work here

6. Conclusions and Recommendations

In this report the research was carried out about the four quadrants for a DC drive based on the Siemens DCM DC converter that was using in the practical. The control techniques and the different loop stages were mentioned and understood. Applications for the system was given to show what the system could be used for in domestic and industrial purposes.

During the design of the four-quadrant on Multisim this circuit was made up of many components such as controlled rectifiers, phase angle controllers, oscilloscopes, supply, transient snubbers, isolating transformers and a firing angle. The simulation for this four-quadrant design was proven to be successful as the expected results matched the test results proving the theory. *Good key points from tasks*
Good point

The dual converter circuit was then designed by adding 6 more thyristors and reversing the polarity to create two bridges. The simulation that was carried out for this was also successful as the expected results matched the test results also proving the theory. *Good point that underpins the understanding why the dual converter is needed*

After the practical test was complete for the four-quadrant operation, waveforms were gathered from the Pico Scope and then HMI screens were compared, and table of results was made. The simulation and results gathered for this was a success as the expected results matched the test results for the simulation.

practical
After running the simulation tests with various speed set points the values from the waveforms were gathered and then put into a table of results. By comparing the HMI and Pico Scope results for the VA and IA, the tests are deemed successful as they were similar. Next was to calculate the Vmean for each speed setpoint and put the final values into a table of results. The pattern with is was as the speed increases the so does the average voltage. *Good key point identified*

Next a similar test was done by changing the setpoints for the torque but keeping a constant speed. No calculations were done for this, but a table of results was made. The simulation tests for the Pico scope and HMI were similar, the patter was as the torque would decrease then so would the armature current, therefore these simulations proved to be successful. *Good point identified*
practical

Finally, a simulation test was conducted to obtain the motor constant for the results gathered from the HMI and Pico scope with the speed at 1100rpm. After calculating the results, the VA calculation was similar to the HMI results proving that the test was a success.

There are a few recommendations that could be made to improve this method of testing and the report. One improvement would be to compare the torque setpoint values as was done for the speed setpoints. Another improvement would be to measure for power attributes using power meters, to obtain power factors, reactive power and real power. Also, more use of the field current to test motor speed by altering the field resistance. Finally, further testing data from the above to create characteristic graphs. *Good valid recommendation*
This is also a good recommendation

7. Citation List

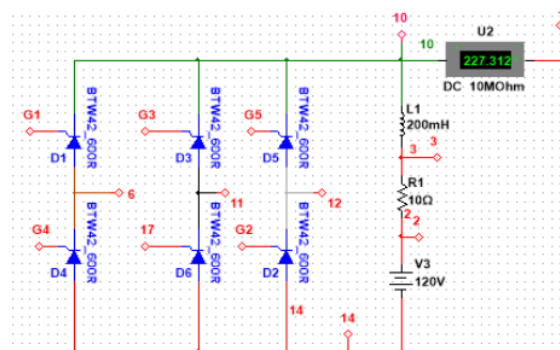
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Good number of ref sources used

8. Appendix

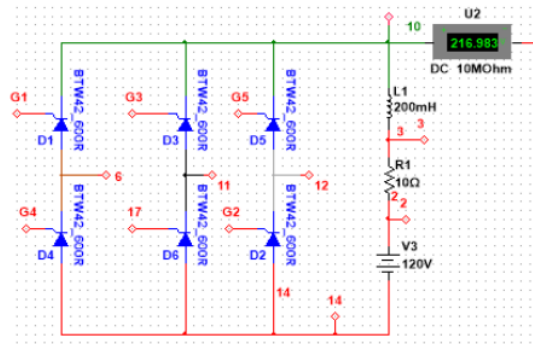
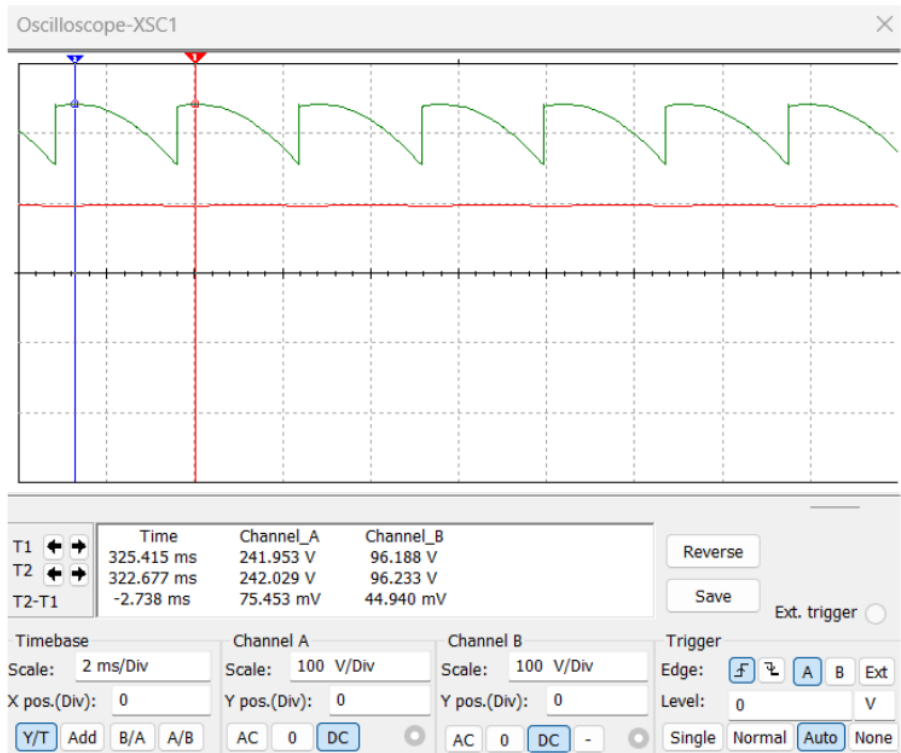
Alpha = 10°



Good test result

Figure 27 - Alpha = 10°

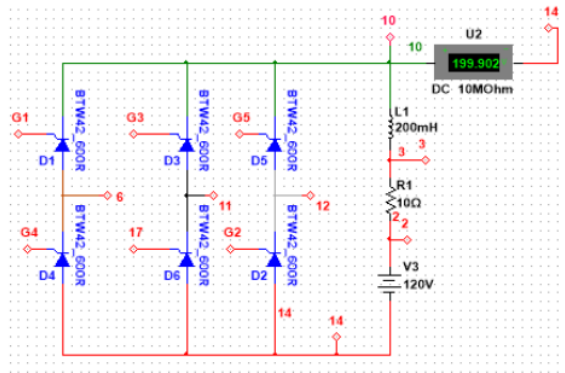
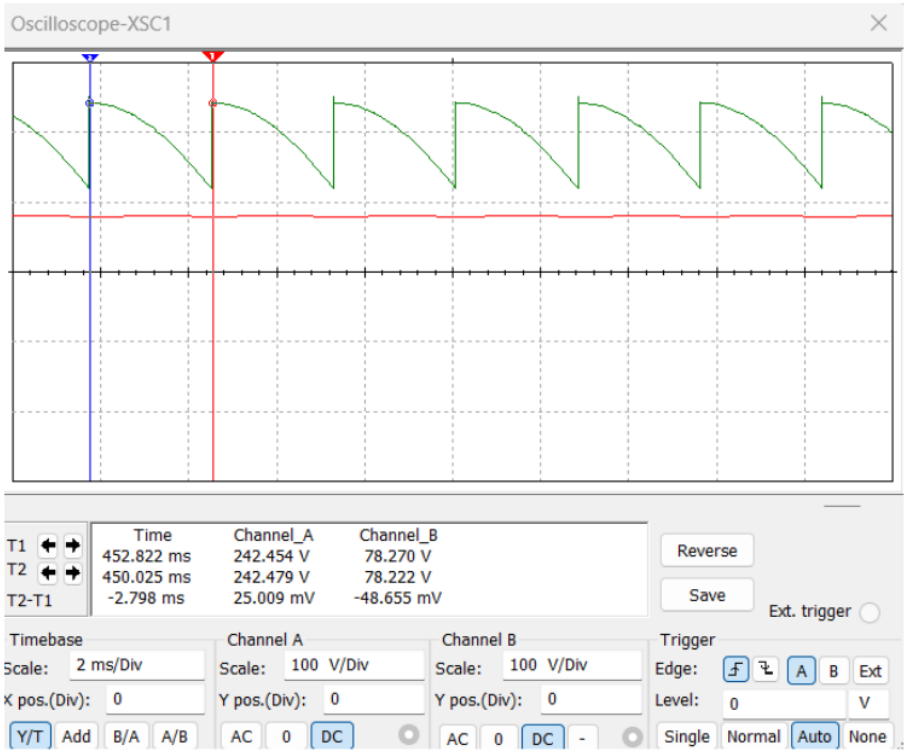
Alpha = 20°



Good test result

Figure 28 - Alpha = 20°

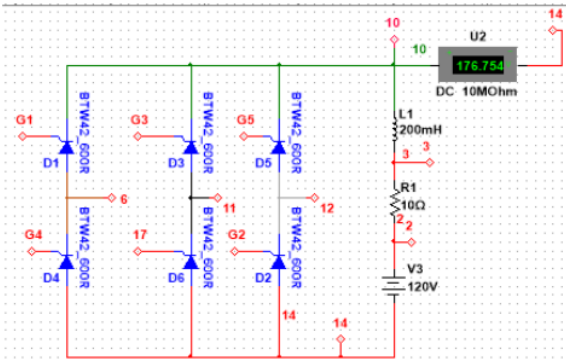
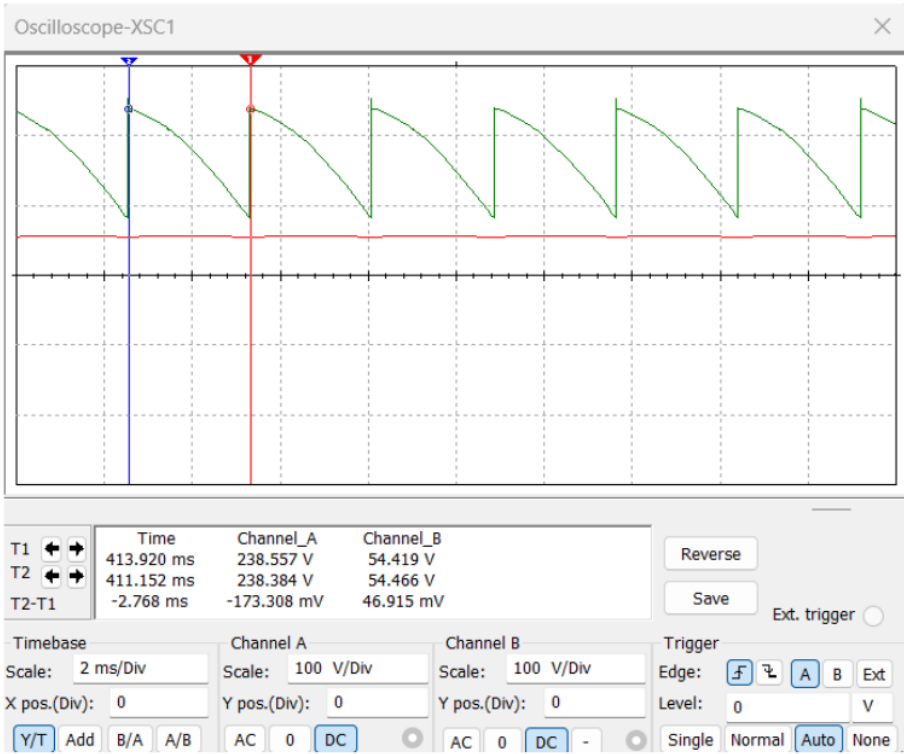
Alpha = 30°



Good test result

Figure 29 - Alpha = 30°

Alpha = 40°



Good test result

Figure 30 - Alpha = 40°

Alpha = 50°

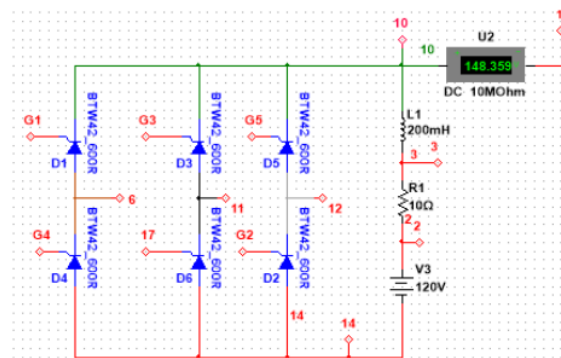
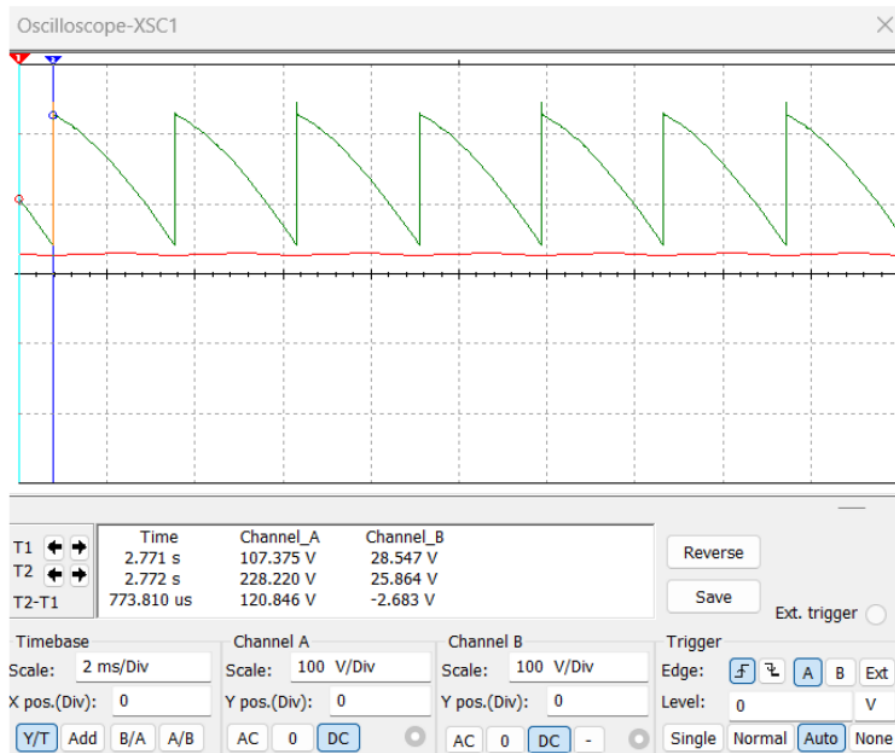


Figure 31 - Alpha = 50°

Good test result

Vmax = 591V

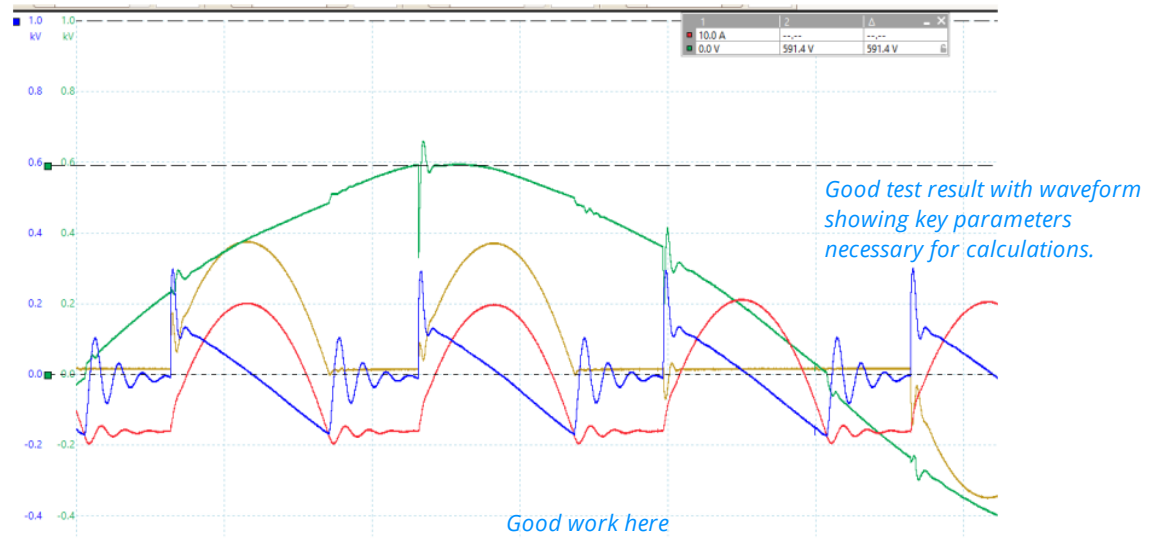


Figure 32 - Vmax Waveform

71 /100

PAGE 1

PAGE 2

Text Comment. Good detailed table of contents

PAGE 3

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Text Comment. Good use of tables

PAGE 4

Text Comment. Tasks identified

Text Comment. Summary includes key points

PAGE 5

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PAGE 6

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PAGE 7

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Text Comment. Good technical information

Text Comment. Dual converter functions for 4 quadrant operation should be included

Text Comment. Good supporting image

Text Comment. There is probably an accompanying circuit diagram available for this driver.

PAGE 8

Text Comment. Field Orientated Control

Text Comment. There could be more details such as connections and key parameters

Text Comment. Applications are identified

Text Comment. Good point included

Text Comment. Chopper fed drives application is identified

Text Comment. Good key points here

Text Comment. Good points in conclusion for research content.

Text Comment. Very good annotated cct diagram. key components are identified.

Text Comment. Good work

Text Comment. Point of key components should be explained

Text Comment. The reason for the offset should be explained

Text Comment. Formula is identified

Text Comment. Good point

Text Comment. Number should be shown

Text Comment. Excellent work here

Text Comment. Good ref to appendix

Text Comment. Good explanation and use of table for test results. Good ref to fig numbers in appendix.

Text Comment. Good point highlighting the minimal error values

Text Comment. Good work here

Text Comment. Good point

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Text Comment. Good test result

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Text Comment. This is excellent work here comparing with theory

PAGE 13

Text Comment. Good useful table for operation

Text Comment. Excellent work with this section

PAGE 14

Text Comment. Very good annotated images of test setup

Text Comment. Good key points identified

PAGE 15

Text Comment. Excellent annotated image of test result for all 4 quadrants

Text Comment. Not simulated

Text Comment. Key parameters identified

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PAGE 16

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PAGE 17

Text Comment. Good test result

Text Comment. Excellent set of test results that clearly show the values changing polarity for each quadrant.

Text Comment. Good work here. The proportional parameters in the system are identified

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PAGE 18

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PAGE 19

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PAGE 20

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PAGE 21

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PAGE 22

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PAGE 23

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PAGE 24

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Text Comment. Good test results and very good method of presentation using tables. Excellent level of detail in the tables.

Text Comment. The explanations could have been more detailed

Text Comment. practical

Text Comment. Good test result showing parameter values needed for calcs

Text Comment. Good test result

Text Comment. Formula is identified

Text Comment. Ra value is identified through calc

Text Comment. Good work

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Text Comment. Good point that underpins the understanding why the dual converter is needed

Text Comment. practical

Text Comment. Good key point identified

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Text Comment. Good valid recommendation

Text Comment. This is also a good recommendation

PAGE 32

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PAGE 33

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PAGE 34

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PAGE 35

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PAGE 36

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PAGE 37

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PAGE 38

Text Comment. Good test result with waveform showing key parameters necessary for calculations.

Text Comment. Good work here

GRADING FORM: NEW CSG-RUBRIC

JACK ROGERS

0

1. ENGAGEMENT WITH LITERATURE



Research includes good relevant points. There are parts that are too brief and there should be more details.

Key features are identified and explained clearly.

The comparison section should be expanded further.

Good number of relevant sources used.

12/20

2. KNOWLEDGE AND UNDERSTANDING



There is evidence of comparison to theory, however, there should have been more of this.

Some key components should be explained.

Good comparison methods using tables are used for evaluation purposes. Simulated methods have been carried out successfully with explanations.

Practical tasks have been carried out methodically and using detailed tables of results for evaluation.

This was a very good area.

Thorough testing has been carried out with an abundance of well presented evidence that is

14/20

clearly referenced in appendix. Only one minor error where figure number s not specified in report.

A very good level of understanding has been demonstrated.

3. COGNITIVE AND INTELLECTUAL



Simulation of full wave controlled rectification has been achieved and tests have been carried out. Tables of results have been presented in good order and results have been evaluated. Test evidence in the appendix was accurate and supported the report content.

Adapted sim cct test for 4 quadrant operation has been carried out and results evaluated against research findings.

All practical test requirements have been carried out, constant speed with discontinuous current and constant torque with continuous current. The practical should not be referred to as simulated in report.

Conclusion points out key features of the tasks carried out and the results. Good relevant recommendations are included.

Results for sim and prac were compared to calculated values and tables used to present findings.

16/20

4. PRACTICAL APPLICATION



Practical application of simulated ccts has been carried out using very good methods and real problems solved during implementation with good

15/20

results.

Practical application showed initiative and evidence included demonstrates the initiatives with the tasks.

Explanations could have been more detailed.

Results were taken from a wide range of tests carried out for speed and torque.

5. TRANSFERABLE SKILLS



A very good report with quality content. There some minor errors and some grammatical errors. However, the report has a good logical order and demonstrates a good level of understanding for the tasks.

14/20