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by Robbie Herbert

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Power electronics and drives ACDA6004

Assignment 1- Drives and rectifiers

By

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Submission Date:

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Abstract

Within this assignment, there has been research into various drive systems. The drive systems have been compared and contrasted between each other to ensure that the choice of drive system is correct for the motor. The systems that have been compared and contrasted are VFDs and DOLs. soft starters, Star Delta starters and autotransformer starters have not been chosen due to the types of motors and their capabilities needed to complete their task correctly. Through the comparisons most of the motors have been chosen with specific VFDs and DOLs as these are appropriate in their use cases.

Within the second task, there has been a comparison of the types of rectifier systems used in VFDs. These systems components include SCRs (Thyristors), Diodes & IGBTs. These three components are used in VFDs most commonly. What has been found is that these components all rectify, but the way that the rectification is completed is different. The SCR uses specific firing angles (which can be changed) to rectify the AC, the SCR induces harmonics during this which are undesirable for the VFD. The IGBT also switches quickly inducing harmonics into the system, these are usually at higher frequencies which are easier to filter out. When looking at the system, the suggested component to use is the diode the harmonics are much lower in amplitude and appear at much higher frequencies than the simulated circuits.

Contents

Abstract	2
List of Figures	4
List of Tables	4
Acronyms, Abbreviations and Units	6
1 Introduction to Motor drive technology	7
2 Motor A- Rolling Mill	8
2.1. ABB ACS880.....	8
2.2. Siemens G120X	9
2.3. Siemens S120.....	10
2.4. Comparison Table & Choice	11
3 Motor B - Crane	13
4 Motor C- Conveyor.....	14
4.1. ABB ACS355.....	14
4.2. ABB ACS580.....	16
4.3. Siemens G120C	18
4.4. Comparison Table & Choice	19
5 Motor D- Cutting machine.....	21
5.1. Crompton Controls Reversing DOL	21
5.2. Lovato DOLR5 Reversing Starter	23
5.3. Choice and Excel comparison of reversible DOL	25
6 Motor E- Pumps/ Fans	27
6.1. Crompton 1.1kW DOL	27
6.2. Hylec DMS1-12D DOL starter	28
6.3. Choice and Excel comparison.....	29
7 Rectification Introduction	31
8 Harmonic noise mitigation & effects of harmonics on power factor.....	31
9 Rectification methods	32
9.1. Thyristors	32
9.2. Diodes	40
9.3. Insulated Gate Bipolar Transistor	47
10 Choice of Rectifier.....	50
11 References.....	51

List of Figures

Figure 1 ABB drive system [4].....	8
Figure 2 Siemens G120X [5].	9
Figure 3 Siemens S120 [18].....	10
Figure 4 ABB ACS355 [19].	15
Figure 5 ABB ACS580 [20]	17
Figure 6 Siemens G120C [21]	18
Figure 7 Crompton Control Reversing DOL [22].....	22
Figure 8 Lovato DOLR5.5400 [23]	24
Figure 9 Crompton DOL [24]	27
Figure 10 Hylec DOL [25].....	28
Figure 11 SCR Half Wave	34
Figure 12 SCR Half wave analogue graph.	35
Figure 13 SCR Fourier Graph.....	36
Figure 14 SCR full wave rectifier.	37
Figure 15 SCR Full wave Rectifier Analogue Graph	38
Figure 16 SCR Full Wave Fourier Graph	39
Figure 17 6 Pulse Diode Rectifier.....	41
Figure 18 6 Pulse Analogue graph.....	42
Figure 19 6 Pulse Fourier Graph.....	43
Figure 20 12 Pulse diode rectifier.	44
Figure 21 12 Pulse analogue graph.....	45
Figure 22 12 Pulse Fourier Graph.....	46
Figure 23 IGBT Rectifier [11].	48
Figure 24 Analogue Analysis of IGBT with smoothing capacitors [11].....	49

List of Tables

Table 2-1 Drive system Rolling Mill	12
Table 4-1 Motor C Comparison Table.....	20
Table 5-1 Reversible DOL comparison	26
Table 6-1 DOL Comparison	30

Table 8-1 Mitigation & Power factor explanation 31

Table 9-1 SCR Harmonics Half wave 32

Table 9-2 Harmonic Frequencies SCR full wave 32

Table 9-3 Harmonic frequencies 6 pulse 40

Table 9-4 Harmonic Frequencies 12 Pulse 40

Acronyms, Abbreviations and Units

Ω	Ohms
%	Percent
μ	Micro
V	Volts
AC	Alternating Current
$^{\circ}\text{C}$	Celsius
pk	Peak
DC	Direct Current
ms	Milli-seconds
Hz	Hertz
I/O	Input/Output

1 Introduction to Motor drive technology

In recent times motor drive technology has been improving and high attention has been given because of increasing need for electric cars, aircraft and ships [1]. Improving motor drive technologies improves the motors in areas such as the efficiency and the size of the system [1].

Silicon technologies have been implemented into the use of motor drive systems; this has been done because of the need for operation at higher frequencies for the systems capabilities [2]. The higher frequencies multi-phase electric technologies can be used to drive the systems to increase the degrees of freedom and reduce the common mode voltage [2].

There are many different types of drive systems which are used depending on the type of motor, seen below is comparisons between best fit drive systems for each specific motor..

2 Motor A- Rolling Mill

The choices made for this motor are to suggest only Variable frequency drives, this is because Direct online starters, Star-Delta starters and soft starters are not reliable for this type of motor because other types of starters are lacking in speed control and limited reversing capability. Due to the systems also being VFD they also all have a common DC bus internally.

2.1. ABB ACS880

The first starter found is the ABB ACS880 the system is regenerative and ultra-low harmonics, this starter is more frequently used in heavy duty applications such as a rolling mill [4, 8]. This starter has a large range for voltage and power so selecting the correct components is easy, the starter is also IP rated [4, 8]. There is also support for the forward/reverse operation, variable speed and overload capability for safety [4, 8].

ABB industrial drives ACS880, single drives 0.55 to 6000 kW



Figure 1 ABB drive system [4].

2.2. Siemens G120X

The second drive system is the Siemens G120X, this motor has the same ratings as the motor. This drive system is usually used in pump/fan applications which may make the system slightly more unreliable [5, 7]. The system is easily integrated and installed with low complexity [5, 7]. The driving system can perform in many environments, which makes it a reasonable choice for a rolling mill [5, 7]. Two issues with this drive system include the ability to manage high inertia is moderate so it is not an optimized choice for the rolling mill, secondly during a braking phase of the rolling mill the system will create heat rather than regenerative braking [5, 7].

The SINAMICS G120X is the rugged frequency converter specially optimized for pump and fan applications in water, wastewater, and HVAC systems.



Figure 2 Siemens G120X [5].

2.3. Siemens S120

The final drive system which has been found and is more optimal, similarly to the ABB ACS880 is the Siemens S120. The S120 is used frequently in heavy industrial applications with high performance and reliability with use of different variants for different applications [6]. The system efficiency is easily accessible using a PC, Modifications to this system can be made on the fly using the siemens TIA portal [6]. This drive system is also available to reverse the motors, control the torque, high inertia handling, and regenerative braking [6].

SINAMICS S120

SINAMICS S120 is the modular drive system for high-performance motion control. Quickly and simply configure a flexible system that perfectly fits your requirements.

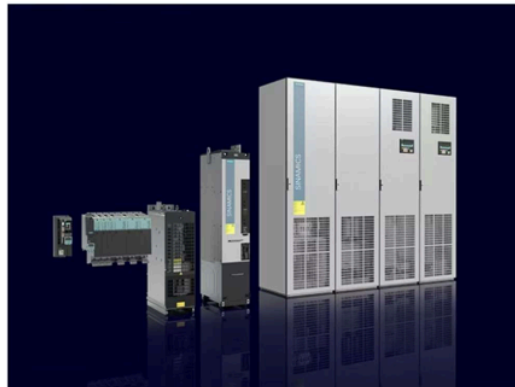


Figure 3 Siemens S120 [18]

2.4. Comparison Table & Choice

As seen in Table 2-1 the three systems have been compared and two of the three VFDs are extremely similar. Firstly, the G120X can be removed from the discussion, as its usual applications are for pumps and this makes it less than adequate for this system [6]. Another reason as to why the system can be removed is since it does not have regenerative braking as standard and only moderate capability for reversing, this makes the system much less cost effective [6].

The other two starters are within their domain of usual application with all the safety and diagnostic capability, the ABB drive is slightly lacking in comparison for this motor, as it has regenerative braking as an optional extra and does not come as standard [8]. For Motor A the best-in-class drive system is the S120, this is because of the regeneration, reversing performance, overall control of the motor, safety features, and system flexibility [7]. As siemens is also extensively used in the UK/Europe the maintenance is easily accessible in comparison to the ABB system [7].

Table 2-1 Drive system Rolling Mill

Drive System	Typical Cost	Information Gathering Ability	Flexibility	Starter Type	Protection Features	Use of DC Bus
ABB ACS880	£25k-£75k (variant dependent) £28k-£35k	full feedback and diagnostics	Very High (complex industrial processes)	VFD with Active Front End	Comprehensive protections + grid interaction control	Yes
Siemens G120X (General VFD)	(variant dependent) £25k-£75k	High (industrial monitoring, comms)	High (multi-application)	VFD (soft start built-in)	thermal, short-circuit, voltage faults	Yes
Siemens S120 (AFE Drive)	(variant dependent)	full feedback and diagnostics	Very High (complex industrial processes)	VFD with Active Front End	Comprehensive protections + grid interaction control	Yes

3 Motor B - Crane

This drive system can also use the same drive systems as the previous motor due to the variants and voltages used as well as the motors requirements such as reversibility and speed variation. As the kilowatts can be reduced in variants the previous VFDs can be used within comparisons.

As the application for a crane the cranes operation must be specified for the best type of VFD to use. is the crane is not used constantly and is occasionally lifting, regenerative braking is not needed, low cycling of the cranes use will allow for the ABB ACS880 to be used within this application [8]. If the crane is high duty and has long operating hours then the S120 is the best option as the power can be restored to increase efficiency and reduce heat created from the systems [7]. – all previous comparisons in Motor A- Rolling Mill apply.

4 Motor C- Conveyor

For this Application a VFD is also used, this VFD is not as advanced as the previous motors VFDs because of the lack of a need for reversibility. The conveyor is likely used for production, the need for a VFD to control the speed is, if there are issues with the product on the conveyor, the conveyor can slow and people can work on the product without fully stopping the conveyor. Three different types of VFD have been found, two are ABB and the third is Siemens.

4.1. ABB ACS355

This first conveyor VFD is used in conveyor applications, this VFS has relatively high diagnostics and basic communication [9]. The flexibility of the VFD is also relatively high for a basic VFD, as there are many applications and not only conveyors (mixers, packaging, winders) [9]. The protection features include safe torque off and under/overvoltage over current and overload [9]. One of the issues with this is that the drive system has less networking capability than the siemens VFD, depending on the conveyors loads and the products the VFD may not be capable.

 LOW VOLTAGE AC • LEGACY

ACS355 DRIVES

Maximize your machine's availability with drives that are easy to install and setup.

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Figure 4 ABB ACS355 [19].

4.2. ABB ACS580

This is the second ABB VFD found which can be used. This is similar to the previous VFD, although includes slight differences. The VFD uses high level diagnostics and communication for the engineers working on the system. the flexibility is also high with general purpose industrial use including fans, pumps, conveyors, compressors and more [12]. Protection for this system includes, advanced motor protection, thermal, current, voltage and fault protection [12]. This VFD is over specification and large for the application [12].

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GoSelect your drive



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Figure 5 ABB ACS580 [20]

4.3. Siemens G120C

The final VFD for the conveyor is the siemens G120C, this VFD is used in many applications because of its package and design [10]. The G120C has high diagnostics because of the Siemens TIA portal. The module is also small so it can be fitted in many areas. the torques that are produced within this system are high allowing for heavier loads to be moved with the conveyor [10]. All protection features are the same as the previous VFDs (overvoltage/current, STO, Thermal) [10]. Some issues with this include a slightly more complex setup than the other VFDs, this is also slightly more expensive [10].

SINAMICS G120c

The SINAMICS G120C combines an extremely compact design with an integrated safety function and a wide range of functions for diverse applications up to 132 kW.



Figure 6 Siemens G120C [21]

4.4. Comparison Table & Choice

Between the three VFDs which have been found for this application, the ACS355 is small and easy to set up and easy to maintain, it is usually used for smaller conveyors and because the supplication of this task and the previous applications for the VFDs these are likely to be in a steel rolling factory meaning that the ACS355 is likely to be too small for the application [9].

The second system, ACS580, is a good choice for this application as it is flexible and has high diagnostics, the issues with this include a higher cost and a larger footprint than the other VFDs [12]. To keep with simplicity and standardisation of the motor drive systems, the VFD which is recommended is the Siemens VFD, because of the higher communication and diagnostics protocols, also the fact that the VFD is slightly cheaper [10].

Table 4-1 Motor C Comparison Table

Drive System	Estimated Cost (£)	Information Gathering Ability	Flexibility machinery / conveyor focused	Starter Type	Protection Features	Use of DC Bus
ABB ACS355	£900–£1,600	diagnostics, basic comms		VFD with built-in soft start	Overcurrent, overload, STO, undervoltage/overvoltage	Yes
Siemens SINAMICS G120C	£1,100–£2,000	good diagnostics, PROFINET/fieldbus options	strong automation integration	VFD with built-in soft start	Overcurrent, overload, STO, voltage and thermal protection	Yes
ABB ACS580	£1,400–£2,400	industrial diagnostics and comms	general-purpose industrial use	VFD with built-in soft start	Advanced motor, thermal, current, voltage, and fault protection	Yes

5 Motor D- Cutting machine

For this application, a VFD is not required, this is because of the lack of a need for variable speed management. the VFD is excessive for the cutting machine [13]. Other applications can be used such as a reversible DOL [13]. A regular DOL and a soft starter are not inherently reversible, so they are not good for this application.

5.1. Crompton Controls Reversing DOL

This reversing DOL has low information gathering as there are no screens and there are only buttons to operate the system. the flexibility of this DOL is reasonable, this can be used for other applications such as process machinery or HVAC systems [13]. Protection features of this include thermal overload and interlocking [13]. This DOL is robust as it uses an IP55 rated enclosure but is slightly higher cost [22].



Crompton 5.5kW 400V DOL Reversing Starter with 10-13A Overload

Part Code: 3DRIELS Stock Code: 1033-3198

★★★★★ No reviews

£254.47 For 1

£305.36 Inc VAT



— 1 +

Delivery

Reserve & Collect

● 4 in stock for delivery

[Select Collection Store](#)

Free delivery on orders over £50

£5.95 Delivery on orders under £50

Figure 7 Crompton Control Reversing DOL [22].

5.2. Lovato DOLR5 Reversing Starter

This reversing starter is almost the exact same but a different brand than the previous DOL, the Lovato DOL has minimal information gathering, no screen. Only buttons for forwards reverse and stop.

The flexibility is also the same as the Lovato is rated for 5.5kW, this includes similar applications four use in industrial and HVAC systems [13]. The protection features of this starter include overload relay and interlocking. One of the advantages of this starter is that the enclosure is IP65 rated which helps in heavy industrial areas such as the cutting machine application [23].

DOLR5.5400 - Lovato L-Starter Reversing DOL Starter 5.5kW Forward/Stop/Reverse 12A 400V Coil IP65
Insulated Enclosure 225H x 110W x 148mmD





List price:

£162.60 ex. VAT

£195.12 inc. VAT

Prices per 1 (each)

1 In Stock

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Figure 8 Lovato DOLR5.5400 [23]

5.3. Choice and Excel comparison of reversible DOL

The two starters are inherently the same, the choice for this DOL is ease of maintenance and support from the manufacturers. Whilst both are eligible for the motor's application, the Crompton DOL is more easily maintainable and found more often within the UK. Although it is higher cost, the quality of the Lovato is poorer and less recognized in the UK so maintenance from OEM can be difficult to procure. The Crompton DOL should be used for this application.

Table 5-1 Reversible DOL comparison

Drive System	Estimated Cost (£)	Information Gathering Ability	Flexibility	Starter Type	Protection Features
Crompton Controls Reversing DOL (5.5kW)	£250–£350	Low	Medium	Reversing DOL	Thermal overload + interlocking
Lovato DOL RS.5400 Reversing Starter	£120–£180	Low	Medium	Reversing DOL	Overload relay + interlocking

6 Motor E- Pumps/ Fans

This motor uses 230V 1kW and is not required to be reversible or variable speed. The drive systems which can be used are, DOL, Reversible DOL, soft starter and VFD. The chosen system for this motor is a regular DOL [13]. Similarly to the previous motor the VFD is too much/too expensive for this application, the reversible section and motor speed variation is unnecessary, which is also why a reversible DOL is unnecessary [13]. A soft starter can be used. Fans and pumps can often be used for safety applications which may need to be started intensely [13].

6.1. Crompton 1.1kW DOL

The Crompton DOL has a low information gathering ability, because the system does not need to have much information gathered as the only thing needed is visible information, the DOL has a low flexibility so there are not many applications to use this DOL on. This DOL has basic protection features and also thermal overload.



The image shows a product listing for a Crompton 1.1kW 230V DOL Starter with 7-10A Overload. On the left is a photograph of the white, rectangular device with a red emergency stop button and a green start button. The Crompton logo and 'SERIES 3000' are visible on the front. To the right of the image is the product title and details. The title is 'Crompton 1.1kW 230V DOL Starter with 7-10A Overload'. Below the title are the part code '3DLICKS10' and stock code '1033-3003'. There is a section for reviews showing 'No reviews'. The price is listed as '£120.49 For 1' with a note '£144.99 inc VAT'. There is a 'Compare' button. Below the price is a quantity selector set to '1'. There are two buttons: 'Delivery' (highlighted in green) and 'Reserve & Collect'. Below these buttons, it says '11 in stock for delivery' and 'Select Collection Store'. At the bottom, it states 'Free delivery on orders over £50' and '£5.95 Delivery on orders under £50'.

Crompton
controls

Crompton 1.1kW 230V DOL Starter with 7-10A Overload

Part Code: 3DLICKS10 Stock Code: 1033-3003

No reviews

£120.49 For 1
£144.99 inc VAT

Compare

1

Delivery Reserve & Collect

11 in stock for delivery Select Collection Store

Free delivery on orders over £50
£5.95 Delivery on orders under £50

Figure 9 Crompton DOL [24]

6.2. Hylec DMS1-12D DOL starter

Similarly to the previous starter the information gathering of this DOL is low, it also has a low flexibility, and basic overload protection. three DOL starters that have been found this is the cheapest. This DOL also has low flexibility with a small number of applications that can be used.

DIRECT ONLINE STARTERS (DOL) - DMS1-12D/240V



Figure 10 Hylec DOL [25].

6.3. Choice and Excel comparison

The Hylec DOL starter is the cheaper out of the two, these two starters are the same, both have low flexibility, low information gathering and basic protections. As previous motors have a starter with the Crompton DOL, the recommendation should be the Crompton DOL because it is more reliable, maintenance choices in the UK are better and more suitable for heavier applications if the starter needs to be changed to another application.

Table 6-1 DOL Comparison

Drive System	Estimated Cost (£)	Information Gathering Ability	Flexibility	Starter Type	Protection Features	Use of DC Bus	Pros	Cons
Crompton 1.1kW 230V DOL Starter	£120–£150	Low	Low	DOL Starter	Thermal overload + basic protection	No	Very robust, industrial-grade, reliable	More expensive than basic options
Hylec DMS1-12D/S DOL Starter	£30–£50	Very Low	Low	DOL Starter	Basic overload protection	No	Very cheap, simple, easy to install	Lower durability, not ideal for heavy use

7 Rectification Introduction

The second section of this paper there is a comparison task between three different types of rectification, the types of rectification used are Diodes, Thyristors and finally Insulated Gate Bipolar Transistors (IGBT). The rectification methods have been used to create designs to show how noise can be minimised. With the use of the designs there has been considerations on the effects of the noise and evidence is shown on efficiency and effectivity for the rectification methods.

8 Harmonic noise mitigation & effects of harmonics on power factor

Common methods to mitigate harmonics within VFDs are and how power factor correction can be mitigated and how it occurs:

Table 8-1 Mitigation & Power factor explanation

Method	Description of how it works
Line Reactors	This protection/ mitigation device is a way to reduce noise by creating a magnetic field to limit the rate of current change to smooth wave forms which mitigates the harmonics and improve power factors.
Active Harmonic Filters	The active harmonic filters are usually devices used in parallel to the VFD, the active harmonic filter uses equal and opposite frequencies to be able to filter the harmonics out for a clean current in phase.
Passive Harmonic Filters	There are many different types of passive harmonic filters, however the working principle is the same/similar for each, to remove/mitigate harmonics the filter is created using capacitors inductors and resistors to choose what frequencies to remove whilst also being simple and cost effective.
Power Factor Correction	This process works by using capacitors to reduce the amount of distortion to compensate for high harmonics or phase difference from the voltage and current.

9 Rectification methods

9.1. Thyristors

Thyristors or Silicone controlled rectifier (SCR) is used to rectify the AC power to DC variable voltage [14]. Thyristors induce significant harmonics as seen in Figure 13 SCR Fourier Graph & Figure 16 SCR Full Wave Fourier Graph. The harmonics are created because of non-linear switching of the SCR as a result of the specific angles of the SCR being switched on [14].

As shown in Figure 13 SCR Fourier Graph the harmonics and the analogue graph match up, where the phase angle is turning on the SCR [14]. The same frequency is showing in the Fourier graph. Seen in the table below is the frequency of the phase angle and the order of harmonic [14]. The magnitude of the harmonic is higher at 50Hz than at 200 because of the energy concentrated at the supply frequency. As the frequency increases there is less distortion impact [14].

Table 9-1 SCR Harmonics Half wave

Frequency (Hz)	Amps	Harmonic (Order)
50	150	Fundamental
100	90	3 rd
150	30	5 th
200	20	7 th

As seen in Figure 16 SCR Full Wave Fourier Graph, the harmonics are similar to the half wave rectifier. The fundamental harmonic is at 50Hz also, at a slightly higher magnitude than the half wave rectifier. The frequency of the harmonics is also slightly further apart as shown in the table below for the 5th and 7th harmonic. As this is a full wave, the frequency of the firing angle to activate the SCR increases so that the rectification doubles and odd harmonics are cancelled out [14].

Table 9-2 Harmonic Frequencies SCR full wave

Frequency (Hz)	Current	Harmonic (Order)
50	162 A	Fundamental
100	112 A	3 rd
200	40 A	5 th
300	25 A	7 th

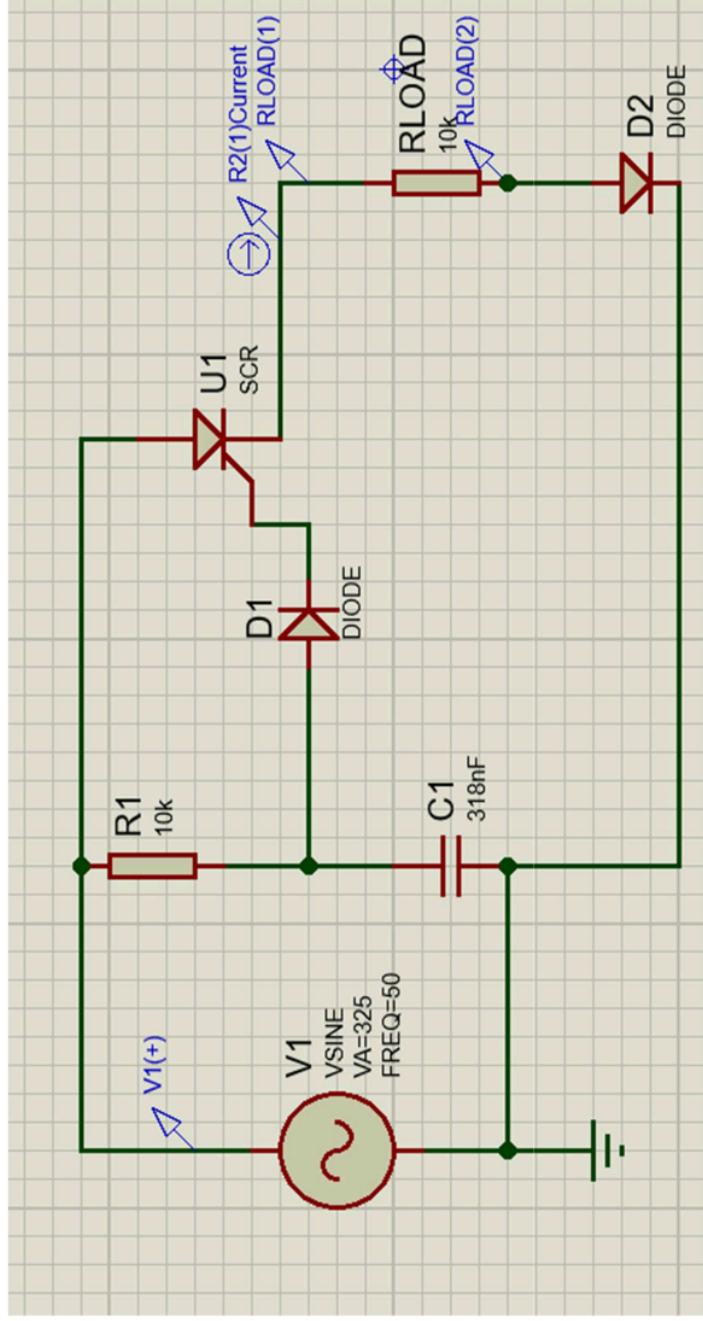


Figure 11 SCR Half Wave

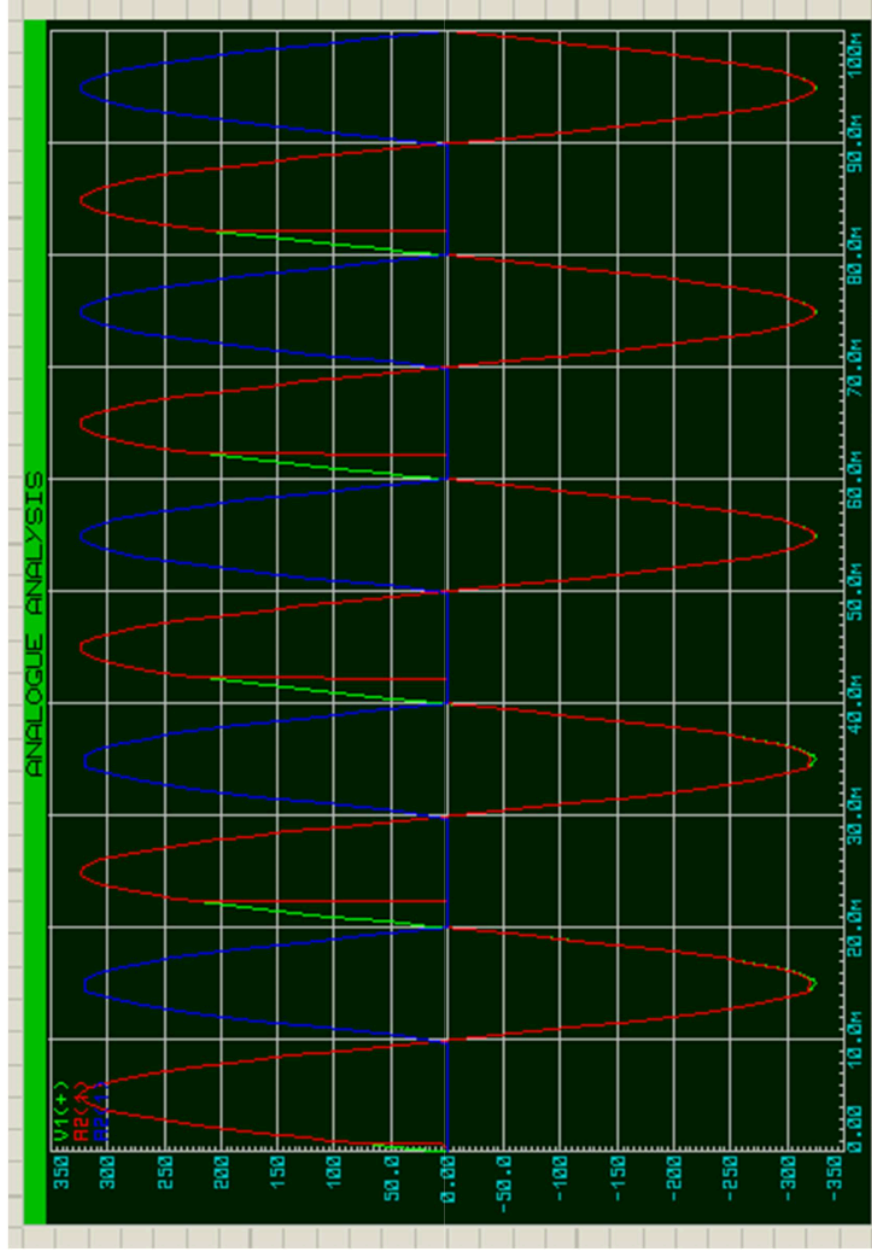


Figure 12 SCR Half wave analogue graph.

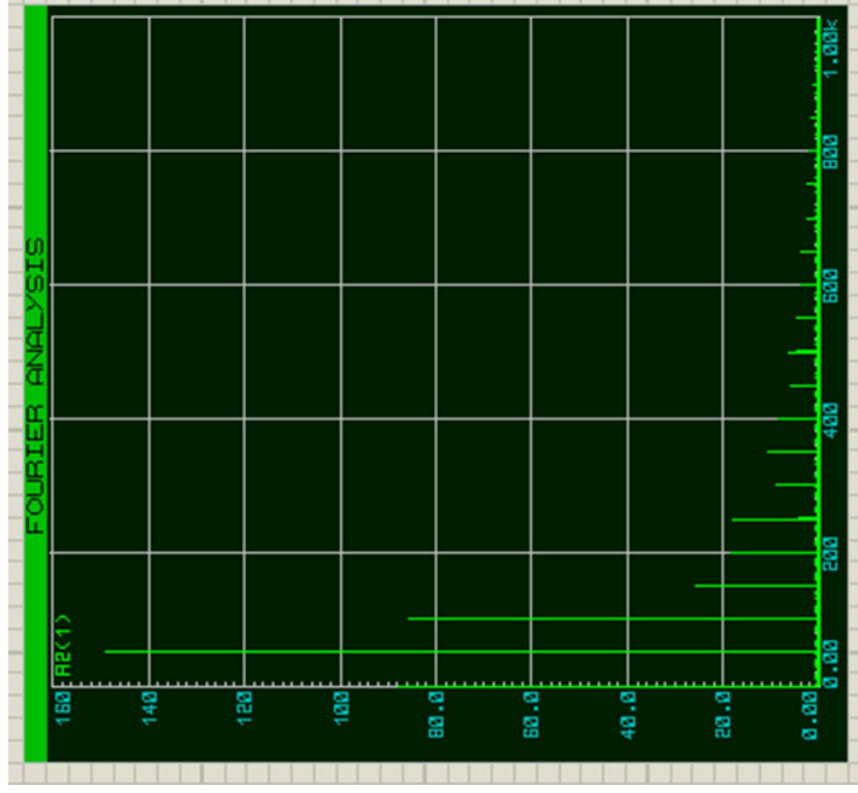


Figure 13 SCR Fourier Graph

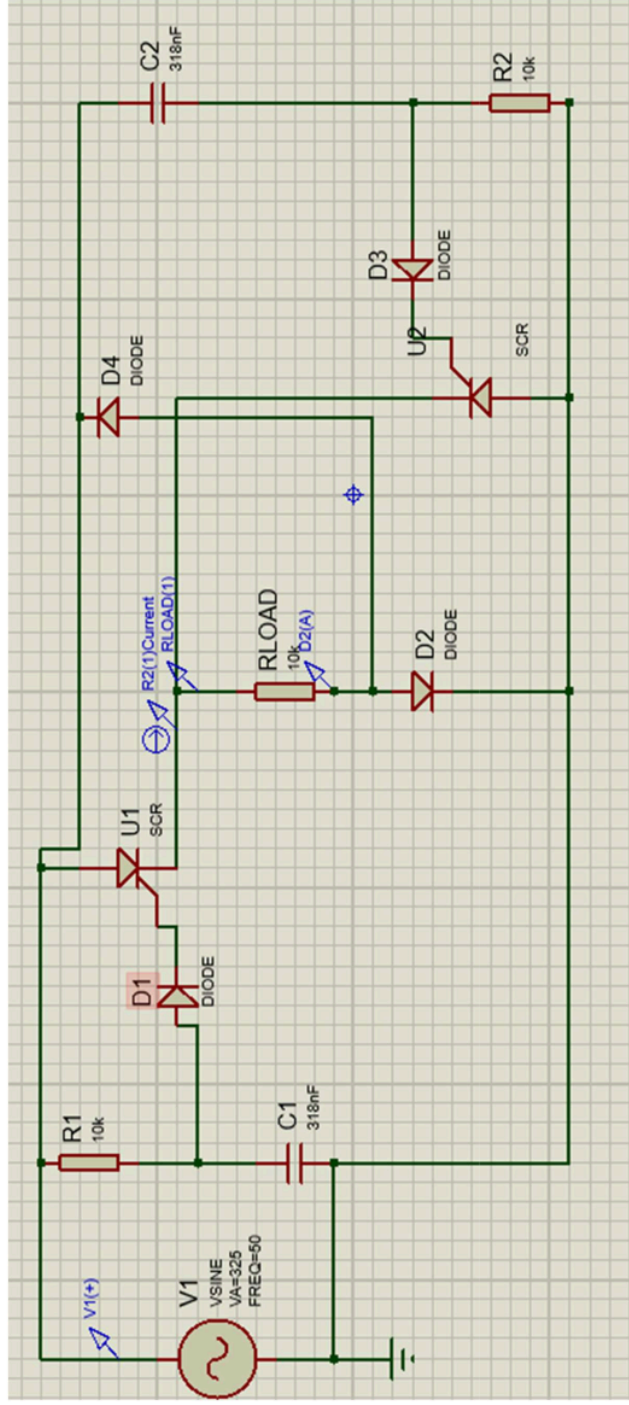


Figure 14 SCR full wave rectifier.

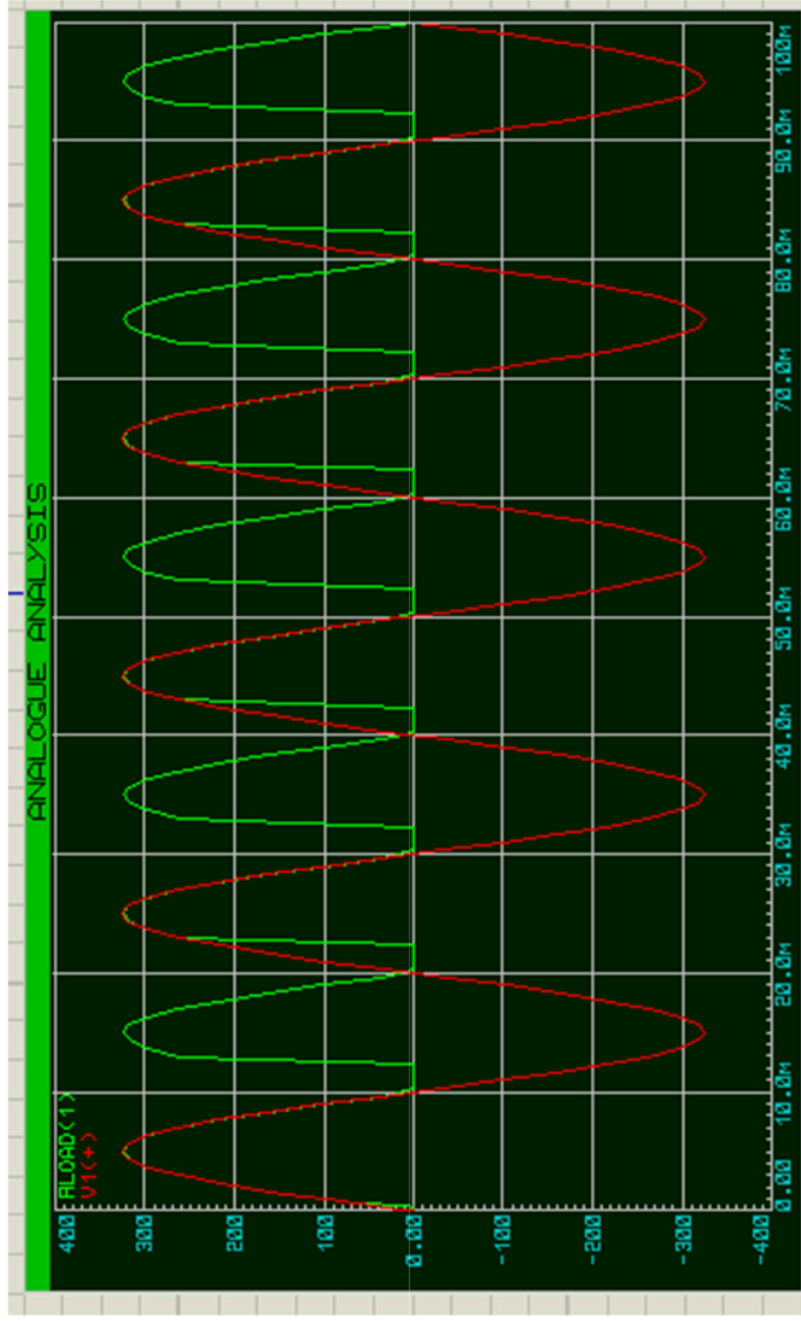


Figure 15 SCR Full wave Rectifier Analogue Graph

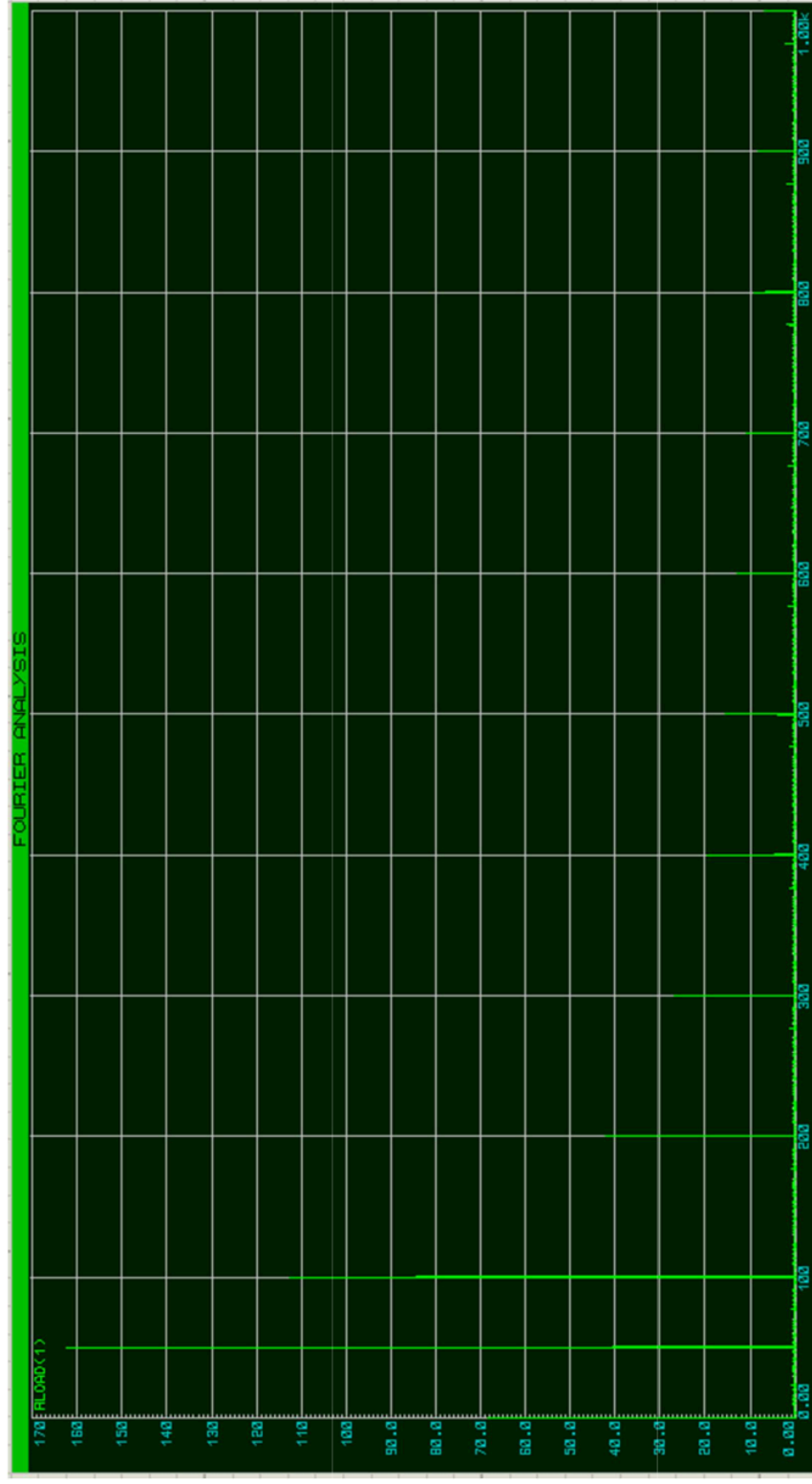


Figure 16 SCR Full Wave Fourier Graph

9.2. Diodes

The first circuit is the 6 pulse three phase rectifier; this circuit uses diodes to rectify the AC sine waves [15]. The diodes will smooth out the AC by only allowing the sine wave to pass through on the positive half cycle [15]. The load voltage shows that the most voltage from each phase is taken at any point [15]. The harmonics within the Fourier graph show that at 150Hz is the fundamental, the 3rd 5th and 7th, are decreasing in magnitude which is similar to the SCR graphs. Shown in the table below is the harmonics and the frequency at which they occur [15].

Table 9-3 Harmonic frequencies 6 pulse

Frequency (Hz)	Current (A)	Harmonic (Order)
150	70	Fundamental
300	 1	3 rd
450	5	5 th
600	2.5	7 th

This second circuit shows the three phase 12 pulse diode rectifier. This circuit is similar to the previous is much more advanced in its rectification [16]. The rectifier uses two separate starter methods, star-star and star-delta, to create a phase shift between the two rectification stages [16]. These stages are two separate 6 pulse rectifiers, hence the name 12 pulse wherever. The 12 pulse rectifier is used to remove/reduce 5th and 7th order harmonics effectively and reduce the ripple in the DC waveform created from rectification [16]. All of the harmonics are much lower in current than any of the previous harmonic tables shown. By using the diodes in this configuration, the total harmonic distortion is reduced [16].

Table 9-4 Harmonic Frequencies 12 Pulse

Frequency (Hz)	Current(A)	Harmonic (Order)
900	175m	Fundamental
1175	625m	3 rd
1500	275m	5 th
1750	40m	7 th

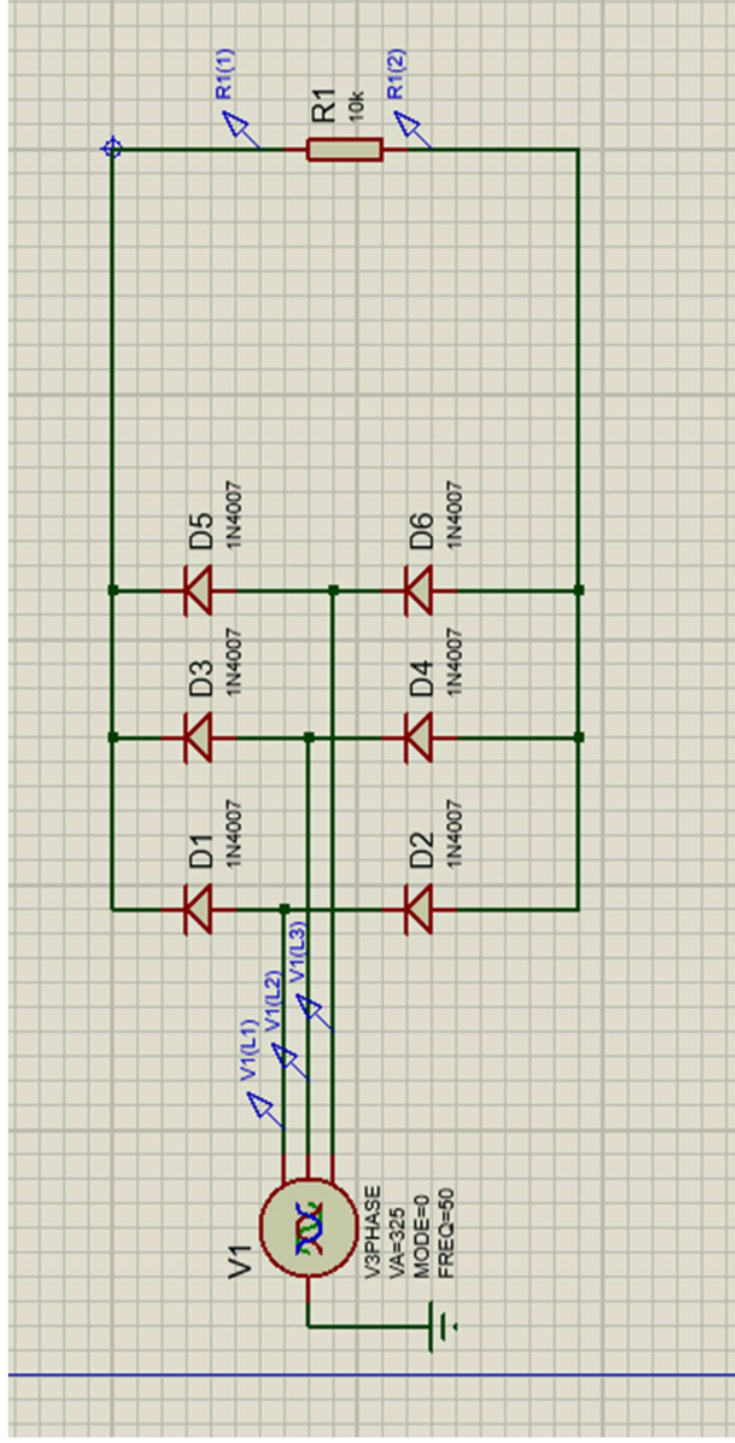


Figure 17 6 Pulse Diode Rectifier

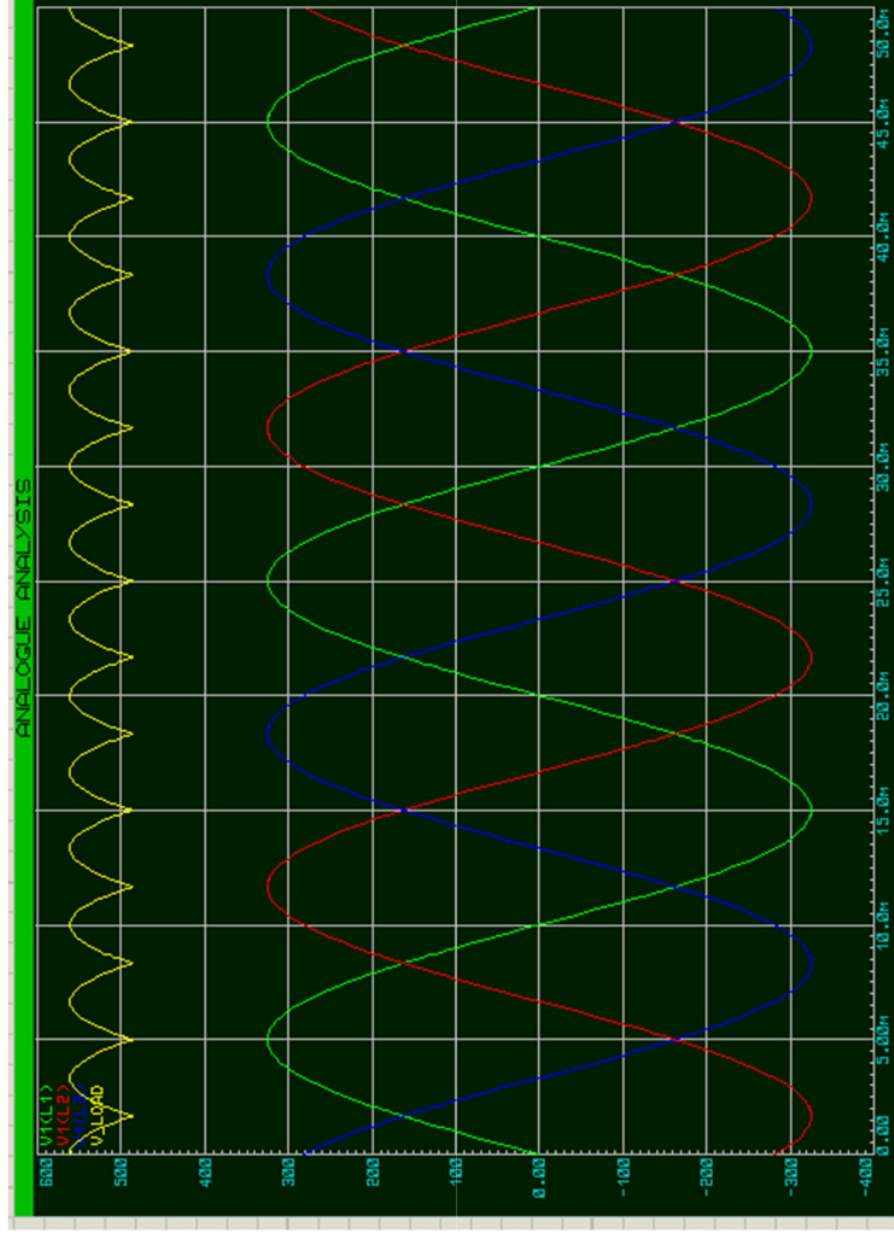


Figure 18 6 Pulse Analogue graph.

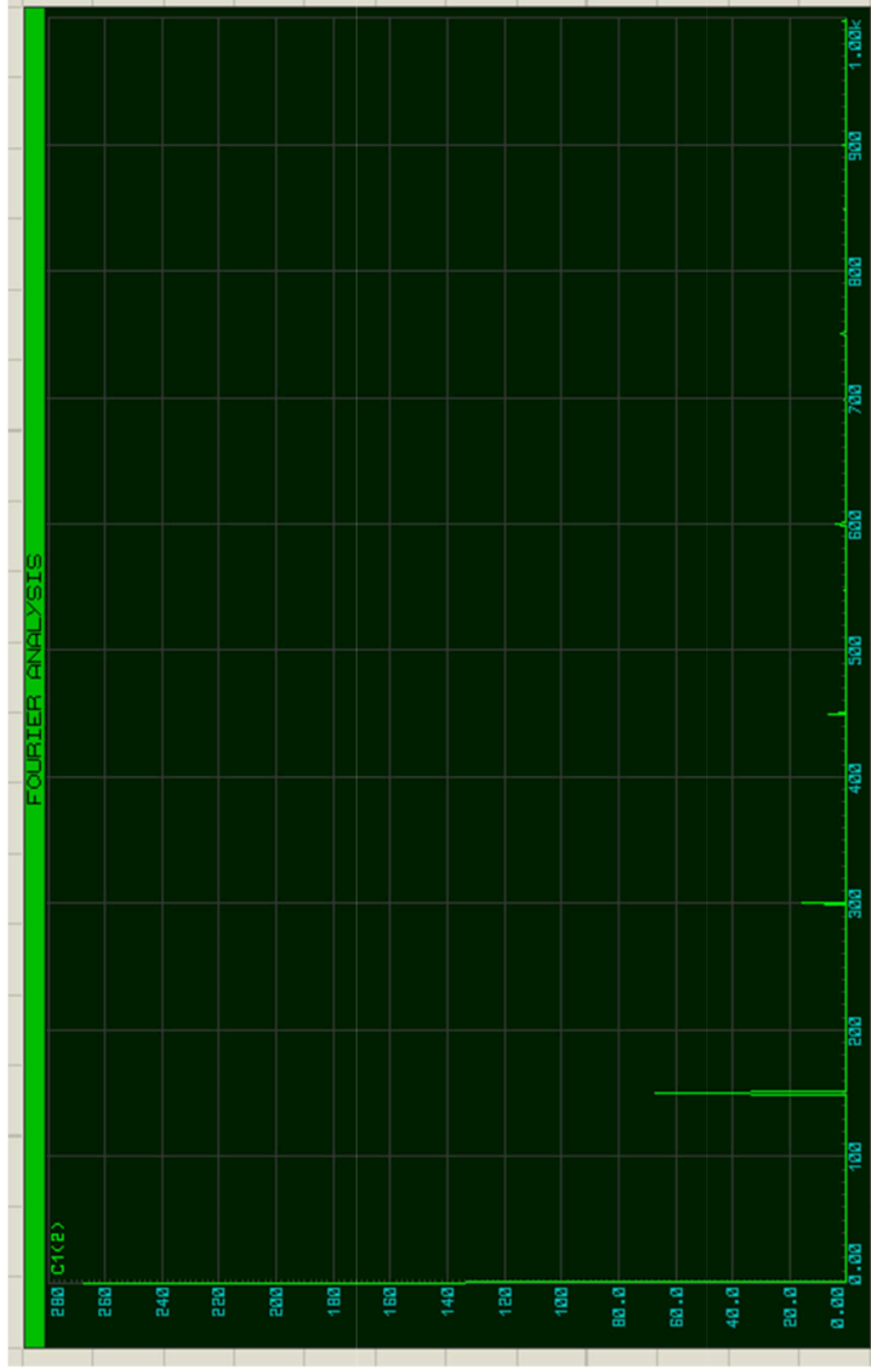


Figure 19 6 Pulse Fourier Graph

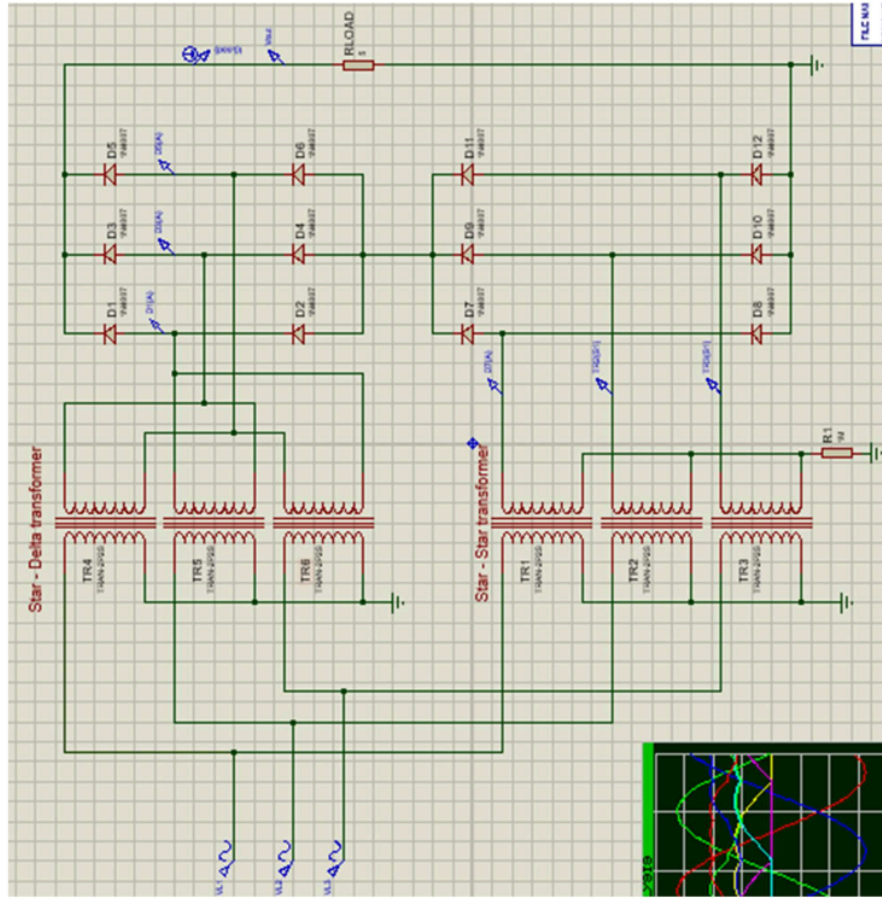


Figure 20 12 Pulse diode rectifier.

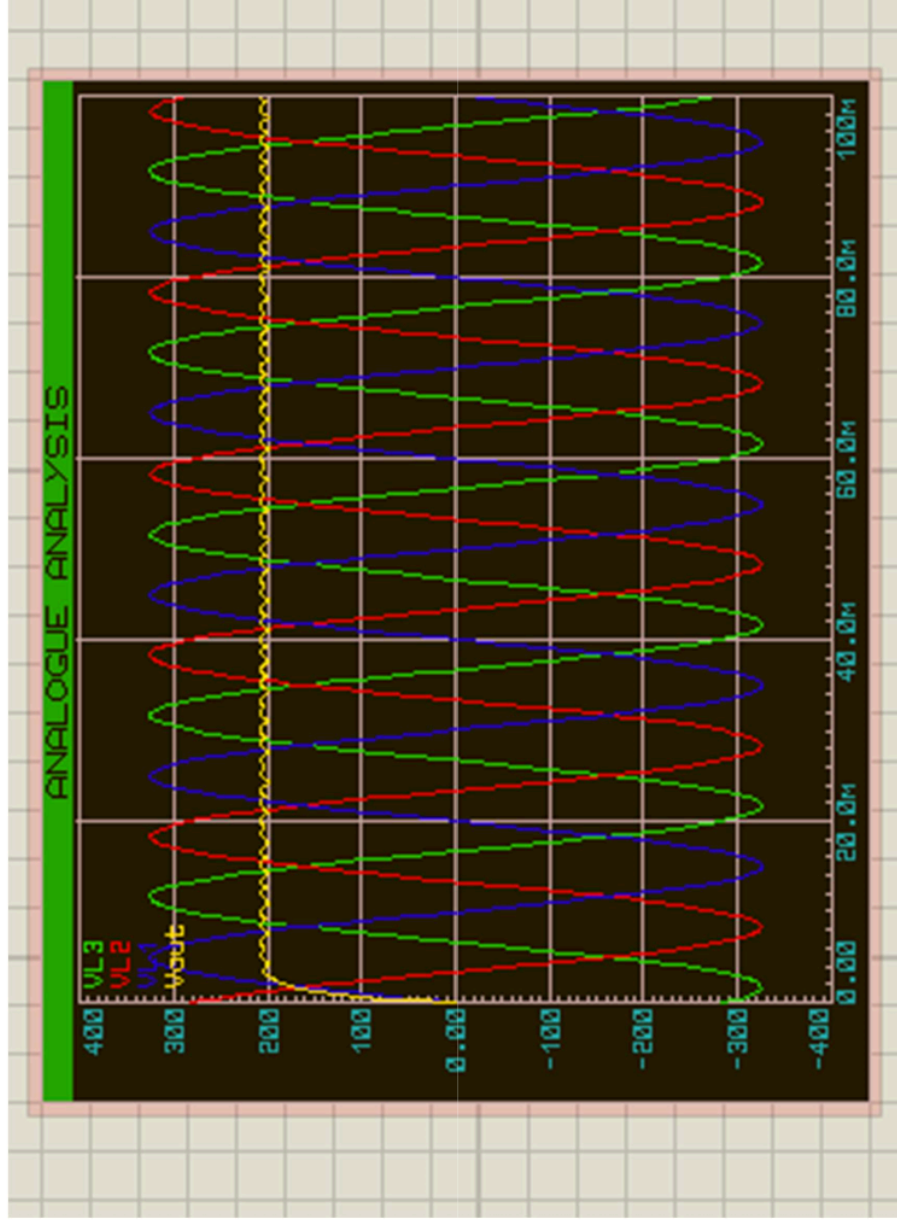


Figure 21 12 Pulse analogue graph.

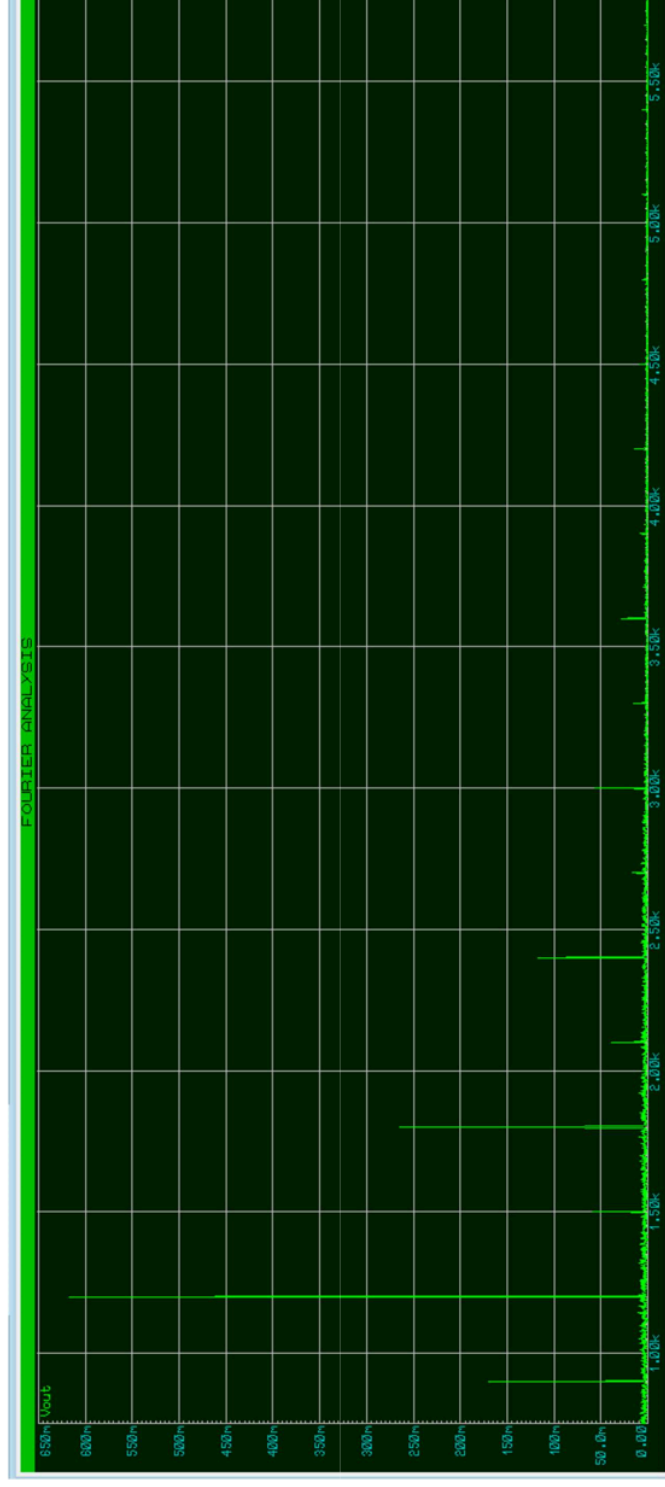


Figure 22 12 Pulse Fourier Graph

9.3. Insulated Gate Bipolar Transistor

For the IGBT, the working principle is to switch (turn on and off) during high speed voltage switching [11]. When voltage is applied to the gate, the current is allowed to flow through the collector and emitter [11]. By using an AC source, the IGBT is activated at specific times throughout the rectification process [11].

As shown in the figure below, the graph shows the rectification it does include the smoothing as this paper [11] includes smoothing components. The grey line is showing the rapid switching of the IGBT also known as pulse width modulation. The width of the pulses from the IGBT controls the amount of voltage [11]. The black line in the graph shows the rectified smoothed waveform at roughly 12V with small ripples [11]. Using an IGBT there are usually higher frequency harmonics because of switching speeds of the transistor [17].

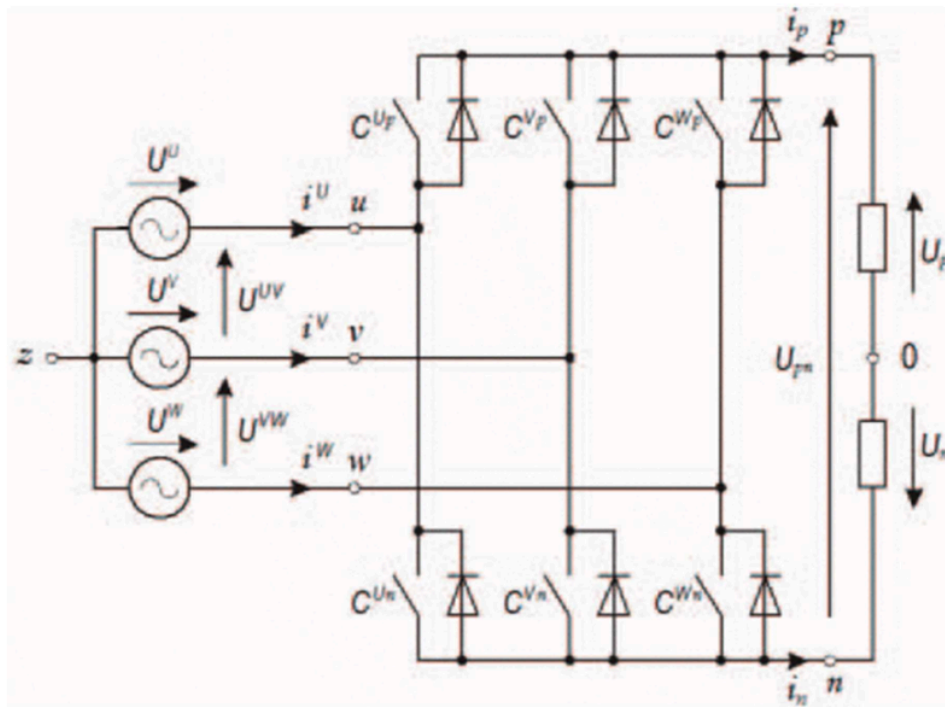


Figure 23 IGBT Rectifier [11].

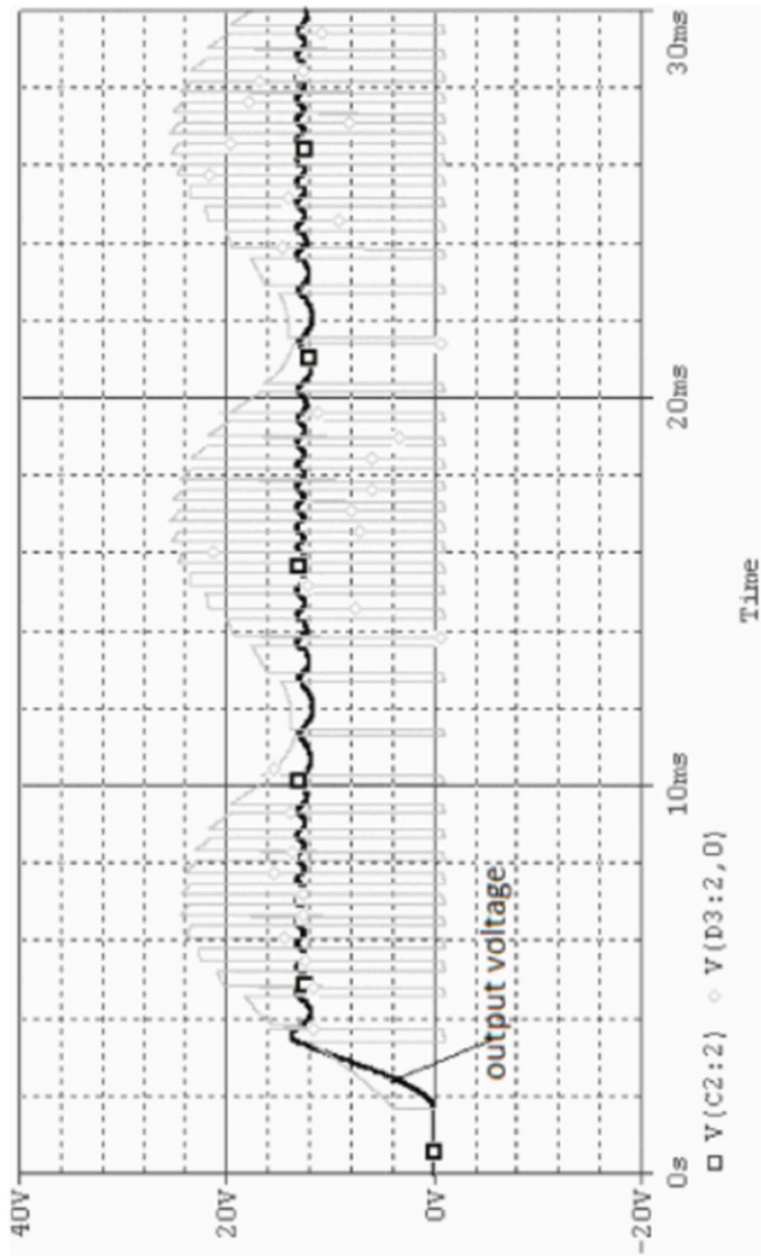


Figure 24 Analogue Analysis of IGBT with smoothing capacitors [11].

10 Choice of Rectifier

For VFDs, the choice of rectifier should be Diodes. There are many reasons for this including the fact that Thyristors and IGBTs introduce harmonics into the system [11, 13]. although they can be reduced/removed, to do this effectively can be expensive, rather than using IGBTs and SCRs generating harmonics they should be greatly reduced or removed entirely which is why a diode should be used although they do introduce harmonics, the amplitude and frequency of the harmonics is much less [11, 13, 15, 16].

Secondly there are the 6 pulse and 12 pulse rectifiers, the choice of which to use entirely depends on the system application. If this is referred to in the previous task Motor A would likely use a 12 pulse rectifier and Motor C would likely use a 6 pulse rectifier for their respective applications [15, 16].

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

70/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

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

PAGE 40



Comment 1

It would have been nice to see a table with results from all rectification methods in

PAGE 41

PAGE 42

PAGE 43

PAGE 44

PAGE 45

PAGE 46

PAGE 47

PAGE 48

PAGE 49

PAGE 50

PAGE 51

PAGE 52

PAGE 53

PAGE 54

GRADING FORM: SMU GENERIC_SMOSEY

ROBBIE HERBERT

69.90

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty

-  Exceptional engagement with an extensive range of relevant and credible literature. You have used relevant and credible sources. Generally sound referencing, with no/very few inaccuracies or inconsistencies. Sources used are informed by the latest research.

15

KNOWLEDGE & UNDERSTANDING

Knowledge of the basic underlying concepts and principles of a subject.

-  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.

18.6

COGNITIVE & INTELLECTUAL

Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.

-  Sound critical thinking, analysis, synthesis and evaluation demonstrating critical thinking. Ability to devise and sustain persuasive arguments, and to review the reliability, validity and significance of

23.8

evidence (that may be incomplete) to make mostly appropriate and valid judgements.

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



A good and appropriate application of standard methods, materials, tools and/or techniques. Clear appreciation of the context of the application. Mainly consistent, accurate and logical application of theory to practice, making appropriate links between the two. Can identify problems and propose mostly appropriate solutions in complex and unpredictable contexts.

5.5

TRANSFERABLE SKILLS

Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.



Can communicate professionally confidently and consistently in a suitable format. Work is coherent, very fluent and is presented professionally. Demonstrates excellent graduate employment skills and an appetite for further development.

7