

Power Electronics and Drives Assignment 1.docx

by Ethan Reynolds

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Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

University of Wales Trinity Saint David, Swansea

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Ethan Reynolds

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Task 1

1.1. Introduction

The selection of motor drive systems within an industrial environment requires careful consideration of both technical requirements and overall system performance. Induction motors are widely used due to their reliability and relatively simple construction, but their effectiveness depends on how well the chosen drive system matches the application. Factors such as power rating, speed control, and the need for reversible operation must be considered alongside broader issues including efficiency, protection, and system integration [2], [3].

In addition to these technical aspects, practical considerations such as installation scale, operational cost, and long-term efficiency also influence system design decisions. The following section evaluates suitable drive technologies for five motors used in a factory environment, ensuring that each selection aligns with both the technical requirements and the practical constraints of the application.

1.2. Drive Selection and Evaluation

The selection of motor drive systems must reflect the specific operational requirements of each application, including power rating, need for speed control, and direction of operation. Based on the given specifications, different drive technologies are more suitable depending on the duty.

1.2.1 Motor A – Rolling Mill

For this application, a suitable drive system for Motor A is the ABB ACS880-17 regenerative drive, configured for 500 kW at 400 V. The motor is used in a rolling mill, where both variable speed and frequent reversal are required. In this type of process, the drive must respond quickly to changes in load while maintaining consistent torque output. The ACS880-17 supports four quadrant operation, allowing controlled motoring and braking in both directions, which is essential where continuous operation and rapid direction changes are expected [4].

This level of control is achieved through inverter-based operation using pulse width modulation, allowing precise adjustment of both voltage and frequency supplied to the motor. Advanced control strategies, such as vector control, further improve dynamic performance and reduce harmonic distortion [13].

Another important factor is the regenerative capability of the drive. Rather than dissipating braking energy as heat, the system can return energy to the supply, improving efficiency during repeated deceleration cycles [3], [9]. In larger installations, this also enables the use of a common DC bus, allowing energy to be shared between drives and reducing overall power demand [5]. Compared with simpler solutions such as soft starters, which only limit starting current, a regenerative VFD provides continuous control, improved protection, and enhanced operational flexibility [2].

1.2.2 Motor B – Gantry Crane

For Motor B, used in a gantry crane, the ABB ACS880-01 industrial drive is a suitable choice for an 80 kW, 400 V system. From the given specifications, both variable speed and reversible operation are required. In crane applications, smooth control of acceleration and deceleration is important to prevent load swing and reduce mechanical stress. A variable frequency drive enables this by continuously adjusting motor speed and torque throughout operation [1], [3].

In practice, this is achieved through inverter-based control, where switching devices regulate the output waveform to maintain stable motor performance under varying load conditions. This allows precise positioning and improved operational safety during lifting tasks.

The ACS880-01 supports controlled braking and rapid directional changes, making it well suited to this type of application. Simpler alternatives such as direct-on-line starting would result in high inrush current and abrupt motion, while soft starters would only control startup behaviour without providing continuous speed adjustment [2]. Although a VFD introduces higher initial cost, this is justified by the improved control, safety, and reliability required in crane systems [6].

1.2.3 Motor C – Conveyor

For Motor C, a 10-kW conveyor motor, the Schneider Electric Altivar 320 Variable Frequency Drive provides an appropriate solution. The specifications indicate that variable speed is required, although reversing is not necessary. In conveyor systems, speed adjustment is often used to regulate material flow and match production demand. A VFD enables this by controlling both frequency and voltage, allowing efficient operation across a range of speeds [2], [3].

This is achieved through electronic control of the inverter output, allowing smooth speed variation without the mechanical stress associated with traditional starting methods. As a result, system wear is reduced and process control is improved.

The Altivar 320 is designed for machine-level applications and offers a practical balance between performance and cost. Direct-on-line starting or soft starters would not provide the required speed control during operation [2]. At the same time, more advanced regenerative systems would introduce unnecessary complexity for this type of application. The selected drive therefore represents a suitable compromise between flexibility and simplicity.

1.2.4 Motor D – Cutting Machine

For Motor D, used in a cutting machine, the Schneider Electric TeSys LE2D12N7 reversing starter is more appropriate than a variable speed drive. The motor requires reversible operation but does not need variable speed control. In this case, a reversing direct-on-line starter provides a straightforward and reliable method of operation by switching the phase sequence to change direction [2].

This approach avoids the additional cost and complexity associated with VFD systems while still meeting the functional requirements. Reversing starters also incorporate electrical and mechanical interlocking to prevent unsafe switching between directions, improving operational safety [8].

For applications where the motor operates at a fixed speed, this type of system is generally more practical, easier to maintain, and more cost-effective than a full variable speed drive.

1.2.5 Motor E – Pumps/Fans

For Motor E, a 1 kW single-phase fan motor, the Schneider Electric Altivar 12 Variable Frequency Drive is a suitable option. Although reversing is not required, variable speed control is necessary to regulate airflow. In fan systems, reducing speed can significantly reduce power consumption, making efficient control particularly important [3], [10].

The use of inverter-based control ensures that the motor operates efficiently across a range of speeds, maintaining an appropriate voltage-to-frequency ratio and reducing energy losses. Compared to simple voltage control methods, this approach provides improved performance and more stable operation [2].

Given the relatively large number of Motor E units installed, even small efficiency improvements per motor can result in significant overall energy savings when considered across the entire system.

1.3. System Level Considerations

Beyond individual motor requirements, several wider system factors influence the overall design. One of the most important is the use of a common DC bus, particularly in systems involving high-power drives such as Motors A and B. In these arrangements, energy recovered during braking can be redistributed to other drives, improving overall system efficiency and reducing peak power demand [5].

Protection is another key consideration. Modern drive systems typically include overload protection, thermal monitoring, and fault detection, which help prevent damage under abnormal operating conditions [2]. These features are essential in industrial environments where reliability is critical.

Cost must also be considered alongside performance. While advanced drive systems offer improved control and efficiency, they should only be implemented where the application justifies their use. For example, regenerative drives are appropriate for high-power systems such as Motor A, whereas simpler solutions are more suitable for lower power applications such as Motor D.

In addition, modern drives provide monitoring and communication capabilities, allowing performance data to be collected and analysed. This supports predictive maintenance strategies and reduces long-term operational costs.

The increasing use of power electronic converters in industrial systems has also led to greater emphasis on harmonic control, as these devices represent a significant source of non-linear load behaviour [14].

Installation and maintenance considerations must also be considered. While advanced drive systems offer improved performance, they require more complex commissioning and may involve higher maintenance requirements due to the presence of electronic components. Simpler systems are generally easier to maintain but offer less flexibility.

1.4. Evaluation

The selected drive systems reflect the differing requirements of each application. Motors A and B require advanced control due to their high power and demanding operational conditions, while Motor C benefits from standard variable speed control without unnecessary complexity. Motor D demonstrates that simpler technologies remain appropriate where speed control is not required, reducing both cost and maintenance requirements. Motor E highlights the advantage of applying variable speed control in lower power applications to improve energy efficiency across multiple units.

However, it is important to recognise the limitations of these systems. Variable frequency drives can introduce harmonic distortion into the supply due to their non-linear switching behaviour, resulting in non-sinusoidal current draw and reduced power quality [13], [14]. This can lead to increased losses, overheating, and interference with other equipment connected to the same system [13]. As a result, standards such as IEEE 519 place limits on acceptable harmonic levels, often requiring additional mitigation measures such as filtering in larger installations [15].

In addition, VFD systems typically involve higher initial cost and increased system complexity compared to conventional starters. While these systems provide improved control and efficiency, their use must be justified by the operational requirements of the application.

1.5. Conclusion

The selection of motor drive systems must be based on both technical requirements and practical considerations. By matching each motor to an appropriate drive technology, it is possible to achieve efficient and reliable operation while avoiding unnecessary complexity. The selected solutions demonstrate how different drive technologies can be effectively applied across a range of industrial applications.

Task 2

2.1. Rectifiers & Harmonics Introduction

Variable frequency drives (VFDs) are widely used in industrial systems to provide efficient and flexible control of induction motors. These systems typically consist of a rectifier stage, a DC link, and an inverter stage. The rectifier converts the incoming AC supply into DC, and its design has a significant influence on system performance, particularly in terms of harmonic distortion and power quality [3], [10].

Different rectifier technologies, including diode rectifiers, thyristor-based controlled rectifiers, and IGBT-based active rectifiers, exhibit varying levels of control and impact on the supply waveform. The switching behaviour of these devices results in non-linear current draw, which introduces harmonic distortion into the electrical system [11]. This can reduce efficiency, affect power factor, and interfere with other equipment connected to the same supply network [12], [15].

In recent work, increased attention has been given to the impact of power electronic converters on grid performance, particularly in relation to harmonic mitigation and compliance with international standards [13], [14]. This section compares the performance of different rectifier types through simulation, examining their impact on harmonic generation, power factor, and overall system behaviour.

2.2 SCR Half-Wave Rectifier

2.2.1 Circuit Configuration

Figure 1 below shows the SCR half-wave rectifier circuit used in the simulation. The circuit consists of an AC supply, a diode, a silicon-controlled rectifier (SCR), and a resistive load. The SCR is triggered at a specific firing angle, which determines when conduction begins during the positive half-cycle. This provides a basic level of control over the output voltage, although it also affects the shape of the current waveform [3].

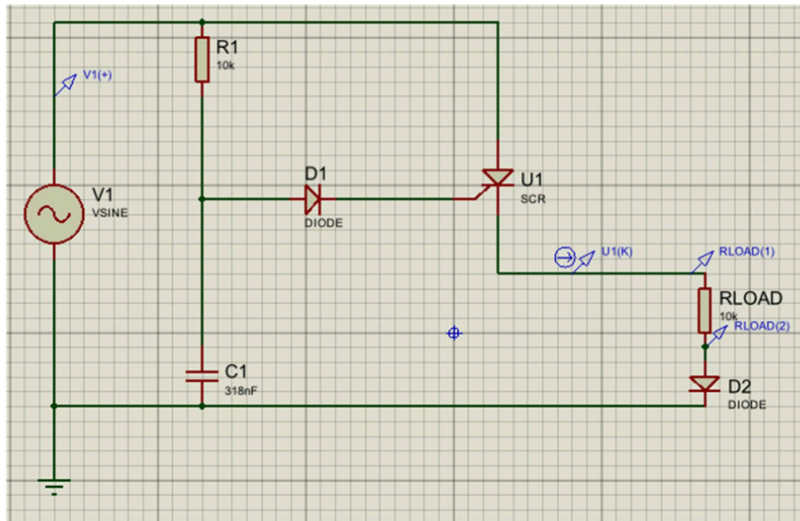


Figure 1 - SCR Half-Wave Circuit Design

2.2.2 Waveform Analysis

The simulated input voltage and load current are shown in Figure 2. The supply voltage follows a sinusoidal waveform, while the load current is clearly non-sinusoidal and discontinuous. Current only flows during part of the positive half-cycle, and no conduction occurs during the negative half-cycle.

This behaviour is a direct result of the SCR firing angle. The device remains in the off state until it is triggered, after which it conducts for the remainder of the cycle. As a result, the conduction period is reduced, producing narrow pulses of current rather than a continuous waveform. This type of operation is characteristic of controlled rectifiers and leads to non-linear current draw [10].

From the waveform, it can be seen that the current does not follow the voltage, indicating both distortion and phase-related effects. This confirms that the rectifier introduces significant deviation from ideal sinusoidal operation.

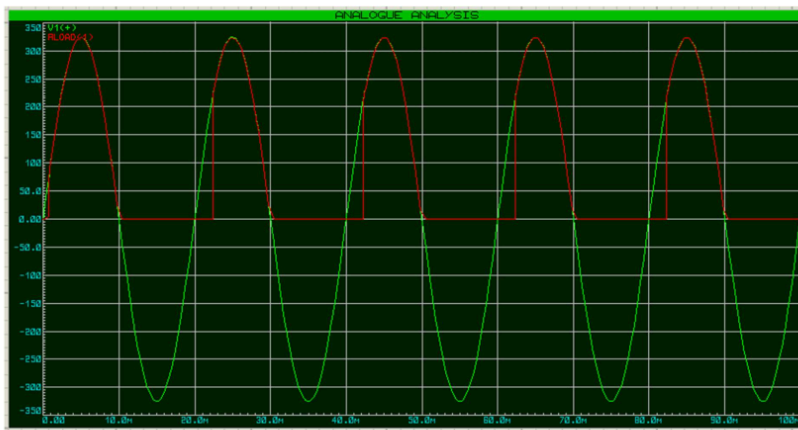


Figure 2 - Input Voltage and Load Current Waveform

2.2.3. Harmonic Analysis

Figure 3 presents the harmonic spectrum obtained from the simulation. The presence of multiple frequency components beyond the fundamental frequency indicates that the waveform contains significant harmonic distortion. These harmonics arise due to the discontinuous conduction of the SCR and the non-linear relationship between voltage and current [11].

The dominant harmonic components are concentrated at lower frequencies, which are typically the most problematic in power systems. These harmonics contribute to increased losses, heating, and reduced efficiency in electrical equipment. In addition, they can affect overall power quality and may require mitigation to meet industry standards such as IEEE 519 [15].

2.2.4 Discussion

The SCR half-wave rectifier shows the weakest performance of all configurations analysed. The discontinuous conduction and use of only one half of the supply cycle result in poor utilisation of the input and a highly distorted current waveform. This leads to high harmonic content and reduced power quality. While the circuit provides simple control over output voltage, its limitations make it unsuitable for most industrial applications where efficiency and waveform quality are important [10], [11].

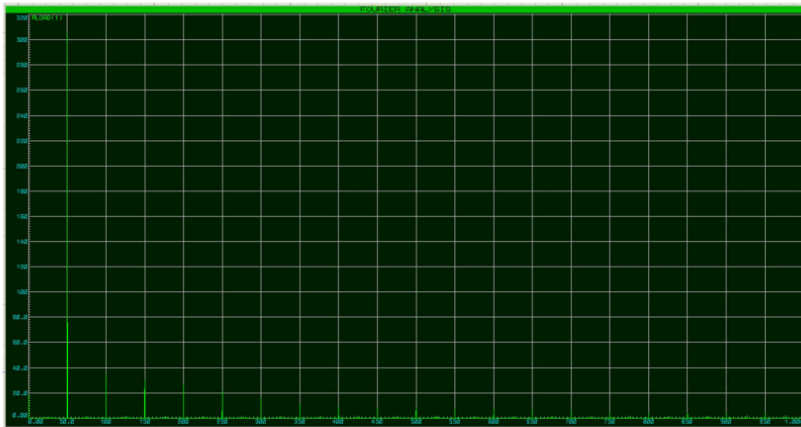


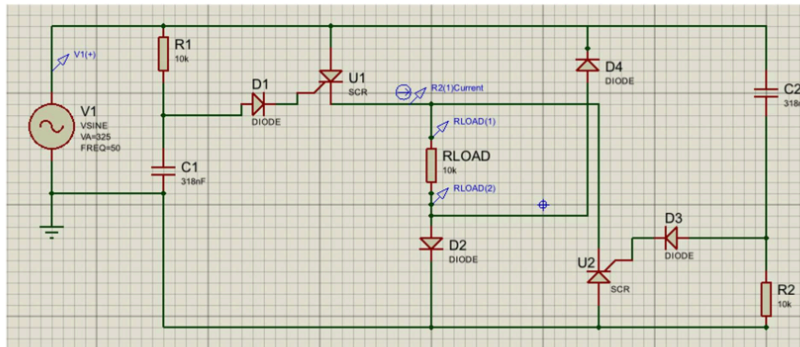
Figure 3 - Harmonic Fourier Analysis

2.3 SCR Full-Wave Rectifier

2.3.1. Circuit Configuration

Figure 4 shows the SCR full-wave rectifier circuit used in the simulation. In this arrangement, two SCR devices are used with supporting diodes to allow controlled conduction during both halves of the AC supply cycle. Compared with the half-wave circuit, this configuration makes use of the full input waveform and therefore provides a higher average DC output across the load [3], [10].

The firing of each SCR determines when conduction begins in its respective half-cycle. This gives a degree of control over the rectified output, although the switching action also affects the shape of the input current waveform and the harmonic content of the



system.

Figure 4 - SCR Full-Wave Circuit Design

2.3.2. Waveform Analysis

The simulated input voltage and load current are shown in Figure 5. The supply voltage remains sinusoidal, while the load current is present during both the positive and negative half-cycles. This confirms that the full-wave configuration makes better use of the available AC supply than the half-wave rectifier.

Although conduction occurs in both halves of the cycle, the current waveform is still discontinuous and does not follow a smooth sinusoidal shape. A firing delay is visible before current begins to rise in each half-cycle, indicating that the SCRs do not conduct immediately at the zero-crossing point. This delayed conduction is characteristic of controlled rectifiers and reflects the effect of the firing angle on output control [3].

Compared with the half-wave SCR rectifier, the full-wave arrangement produces a more continuous output and improved utilisation of the supply. Even so, the waveform remains clearly distorted, showing that non-linear current draw is still present.

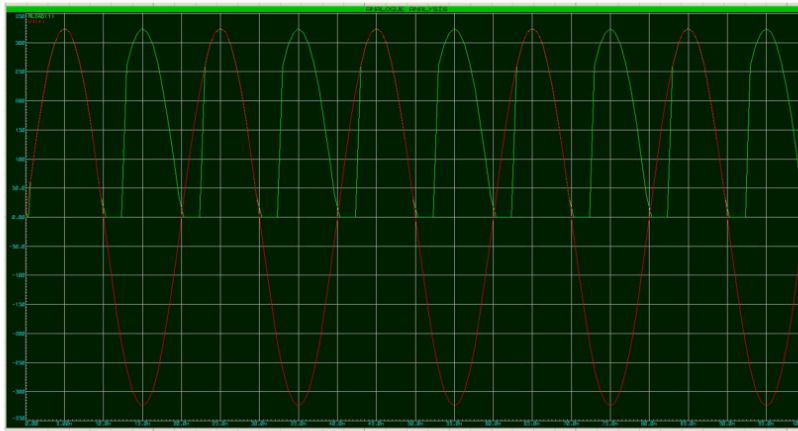


Figure 5 - Input Voltage and Load Current Waveform

2.3.3. Harmonic Analysis

Figure 6 shows the harmonic spectrum for the SCR full-wave rectifier. The spectrum confirms the presence of significant harmonic components in addition to the fundamental frequency. These harmonics are produced by the discontinuous nature of SCR conduction and the delayed triggering of the devices [11].

From the spectrum, it can be seen that the fundamental component remains dominant, but several lower-order harmonic components are still present at noticeable amplitude. These lower-order harmonics are particularly important because they contribute strongly to waveform distortion, additional heating, and reduced system efficiency. In practical systems, this can lead to greater losses in transformers, cables, and other connected equipment [11], [15].

The full-wave configuration improves waveform quality compared with the SCR half-wave rectifier, but the harmonic content remains high enough to affect overall power quality.

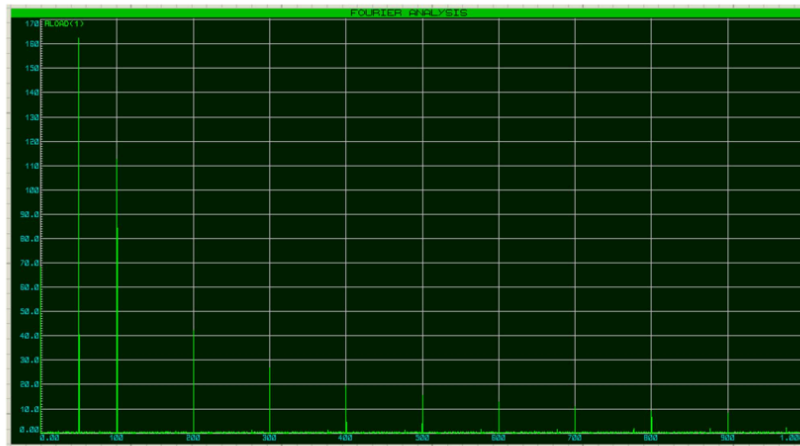


Figure 6 - Harmonic Fourier Analysis

2.3.4. Discussion

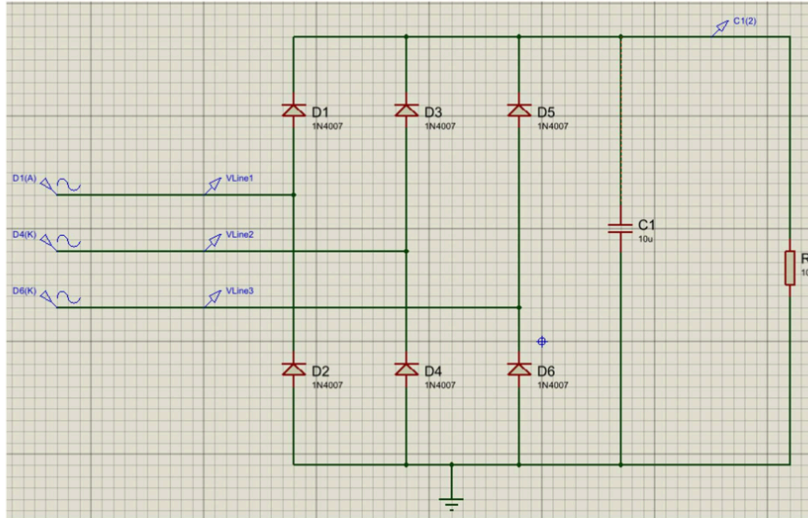
The SCR full-wave rectifier improves upon the half-wave configuration by utilising both halves of the AC supply, resulting in a higher average output and more continuous conduction. However, the delayed firing of the SCRs still introduces distortion and phase displacement between voltage and current. As a result, harmonic distortion remains significant, and overall power quality is still limited when compared to diode-based or active rectifier systems [3], [12].

2.4. 3-Phase 6-Pulse Diode Rectifier

2.4.1. Circuit Configuration

Figure 7 shows the 3-phase 6-pulse diode rectifier circuit used in the simulation. The circuit consists of six diodes arranged in a bridge configuration, supplied by a 3-phase AC source. This type of rectifier is widely used in industrial variable frequency drives due to its simplicity, robustness, and relatively low cost [3], [10].

In operation, pairs of diodes conduct sequentially, allowing current to flow from the phase with the highest instantaneous voltage to the phase with the lowest. This results in a stepped DC output voltage and a characteristic pulsed current drawn from the



supply.

Figure 7 - 3-Phase 6-Pulse Diode Rectifier Circuit Design

2.4.2. Waveform Analysis

The 3-phase input voltages and resulting load behaviour are shown in Figure 8. The phase voltages are balanced and sinusoidal, as expected from the supply. However, the current drawn by the rectifier does not follow a sinusoidal shape. Instead, current is drawn in distinct pulses corresponding to diode conduction intervals.

Each diode conducts for a portion of the cycle, typically 120° , resulting in a six-step conduction pattern over one complete cycle. This produces a more continuous DC output compared to single-phase rectifiers, but the input current remains clearly non-linear.

The waveform indicates that the rectifier draws current only when the instantaneous phase voltage exceeds the DC link voltage. This behaviour leads to sharp transitions in current, which are responsible for the distortion observed in the waveform.



Figure 8 - 3-Phase Input Voltage and Load Behaviour

2.4.3. Harmonic Analysis

Figure 9 shows the harmonic spectrum of the line current obtained from the 6-pulse rectifier simulation. The fundamental component is clearly dominant, however several additional frequency components are visible, indicating the presence of harmonic distortion.

From the plot, distinct peaks can be observed at frequencies corresponding to approximately five and seven times the fundamental frequency. These represent the 5th and 7th harmonics, which are characteristic of 6-pulse rectifier operation. Additional smaller peaks are also present at higher frequencies, although their magnitudes are noticeably lower.

The distribution of harmonic components shown in Figure 9 reflects the pulsed nature of the current drawn by the diode bridge. Current is only drawn during specific conduction intervals, resulting in a non-sinusoidal waveform and the introduction of multiple frequency components.

Although the harmonic levels are lower than those observed in the SCR-based rectifiers analysed earlier, they are still significant enough to affect system performance. In practical systems, these harmonics can lead to increased losses, additional heating,

and reduced power quality. As a result, mitigation techniques are often required to meet standards such as IEEE 519 [11], [15].

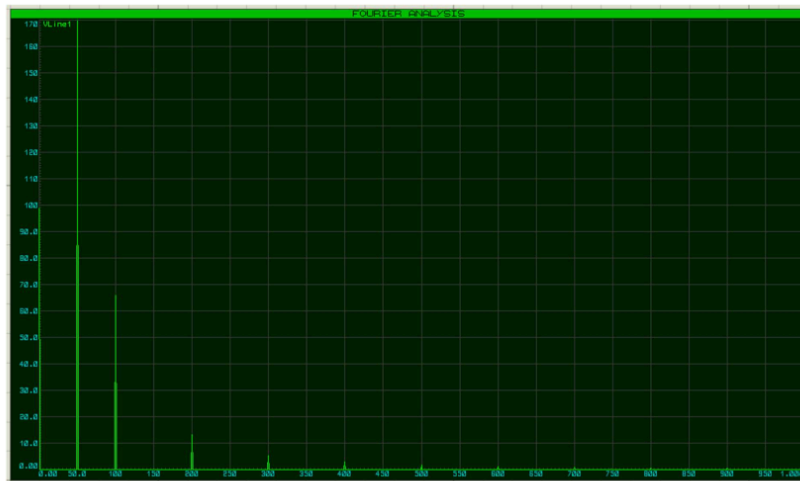


Figure 9 - Harmonic Fourier Analysis

2.4.4. Discussion

The 6-pulse diode rectifier provides a clear improvement over SCR-based systems, offering a more stable DC output and better utilisation of a three-phase supply. The absence of firing delay improves the displacement power factor, and the system is widely used due to its simplicity and reliability. However, the presence of characteristic harmonics means that distortion is still present, and additional filtering or mitigation may be required in practical installations to meet harmonic standards [11], [15].

2.5. 3-Phase 12-Pulse Diode Rectifier

2.5.1. Circuit Configuration

Figure 10 shows the 12-pulse diode rectifier used in the simulation. The system consists of two 6-pulse diode bridge rectifiers supplied through two transformers: one configured as star-star and the other as star-delta. This arrangement introduces a phase shift between the two sets of supply voltages.

The phase shift between the transformer outputs allows the two rectifier bridges to operate with offset conduction intervals. As a result, certain harmonic components produced by each bridge are partially cancelled when combined at the output. This is a well-established method for reducing harmonic distortion in high-power industrial systems [3], [10].

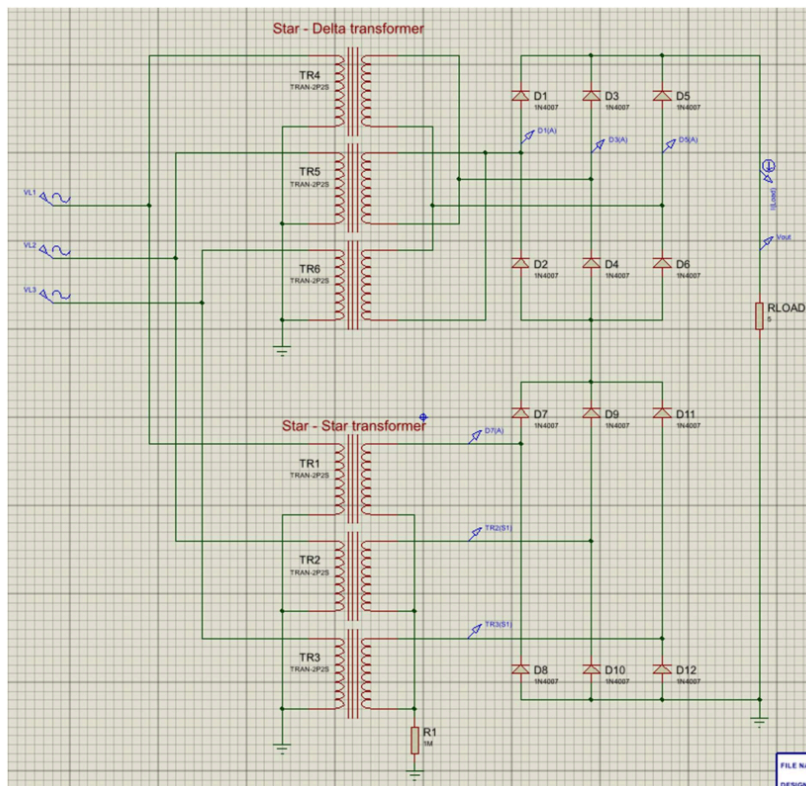


Figure 10 - 12-Pulse Rectifier Circuit with Star-Star and Star-Delta Transformers

2.5.2. Waveform Analysis

The input phase voltages shown in Figure 11 are balanced and sinusoidal, confirming that the supply is ideal and that any distortion observed is introduced by the rectifier itself.

The output behaviour, shown in Figures 12 and 13, demonstrates a relatively smooth DC waveform with only small ripple components present. Compared to the 6-pulse rectifier, the ripple is noticeably reduced, and the output appears more stable over time. This indicates improved utilisation of the AC supply and better overall conversion performance.

The multi-trace waveform shown in Figure 12 represents the combined conduction of multiple diodes across both rectifier bridges. The overlapping conduction intervals result in a more continuous transfer of energy to the load, which contributes to the smoother DC output observed.

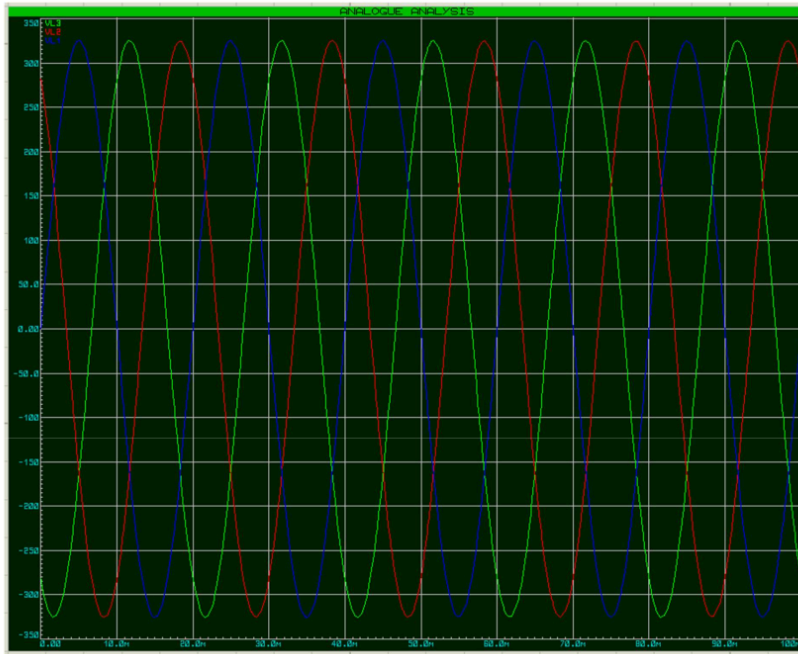
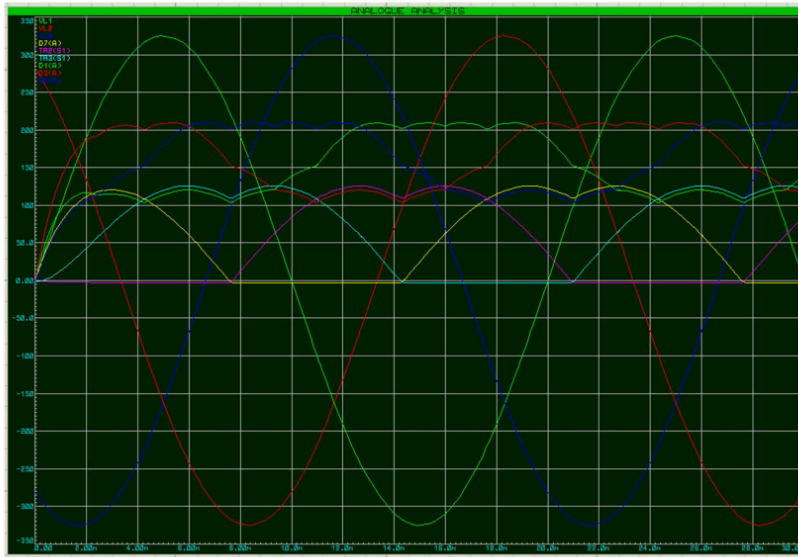


Figure 11 - 3-Phase Input Voltage Waveforms



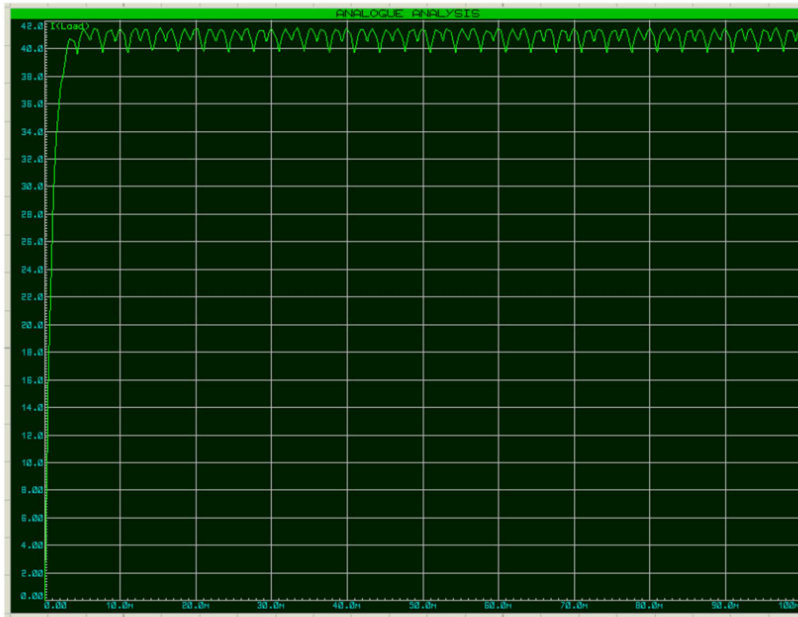


Figure 13 - Output DC Waveform

2.5.3. Harmonic Analysis

Figure 14 shows the harmonic spectrum of the rectifier output. Compared to the 6-pulse rectifier, the harmonic content is more evenly distributed, and the magnitude of dominant components is reduced. There are no strong, isolated peaks of the same prominence as those seen in earlier simulations, indicating that lower-order harmonics have been significantly reduced.

This reduction occurs because the phase-shifted operation of the two bridges causes partial cancellation of harmonic components. In particular, harmonics that were dominant in the 6-pulse system are suppressed, resulting in improved waveform quality.

Although harmonic distortion is still present, its overall impact is reduced. This leads to improved power quality, lower losses, and reduced stress on connected equipment. In practical systems, this makes the 12-pulse rectifier more suitable for applications where compliance with harmonic standards such as IEEE 519 is required [11], [15].

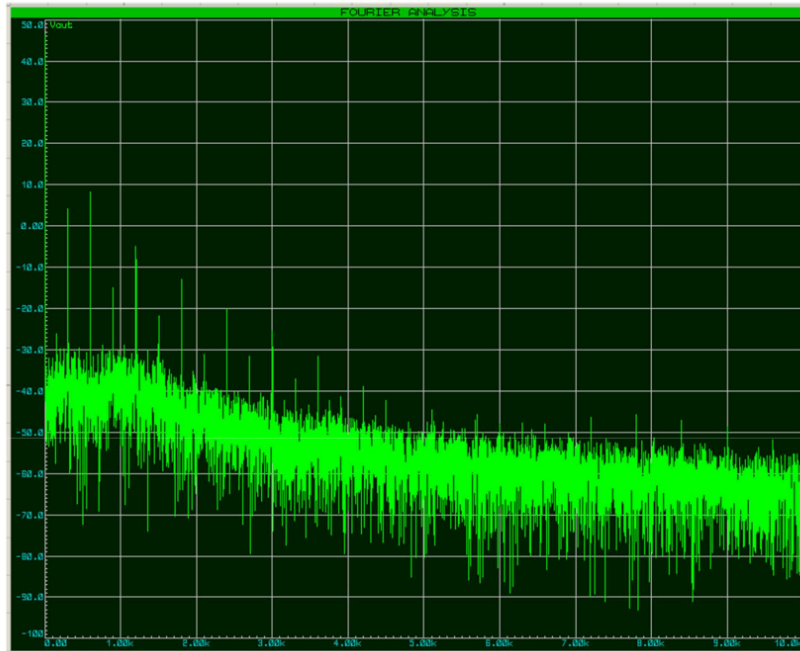


Figure 14 - Harmonic Spectrum of the Rectifier Output

2.5.4. Discussion

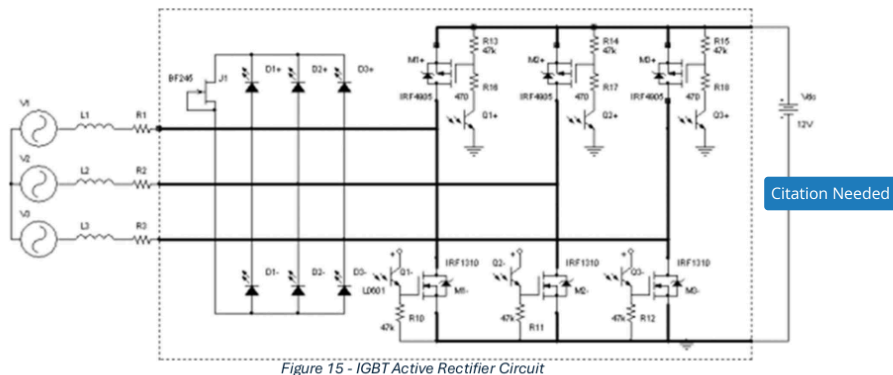
The 12-pulse rectifier demonstrates a significant reduction in harmonic distortion compared to the 6-pulse configuration. The use of phase-shifted transformer supplies enables partial cancellation of lower-order harmonics, resulting in improved waveform quality and reduced ripple in the DC output. This makes the system well suited to higher power applications where harmonic performance is critical. However, the increased complexity and cost associated with the transformer arrangement must be considered when selecting this approach [3], [12].

2.6 IGBT Active Rectifiers

2.6.1. Circuit Configuration

Figure 15 shows the IGBT-based active rectifier circuit used in the simulation. The system consists of a three-phase AC supply followed by a diode bridge and a controlled switching stage implemented using IGBT devices. The switching devices are arranged to regulate the DC output voltage through controlled operation, rather than relying solely on passive rectification.

Unlike diode or SCR rectifiers, the active rectifier uses switching control to shape the current and voltage waveforms. This allows greater flexibility in operation and enables improved performance in terms of power quality and output regulation [10]. Similar transistor-based rectifier configurations have been studied to enhance AC–DC conversion performance through controlled switching techniques [16].



2.6.2. Waveform Analysis

The output voltage waveform is shown in Figure 16. The waveform initially rises from zero before stabilising at a steady DC level with only small ripple present. The ripple that remains is relatively low compared to the diode rectifier systems analysed earlier.

Superimposed on the waveform are high-frequency switching components, which are a result of pulse-width modulation (PWM) used to control the IGBT devices. These switching actions allow the rectifier to regulate the output voltage more effectively and maintain a stable DC level under varying conditions.

Compared to the 6-pulse and 12-pulse rectifiers, the output is more tightly controlled, demonstrating improved regulation and reduced low-frequency ripple.

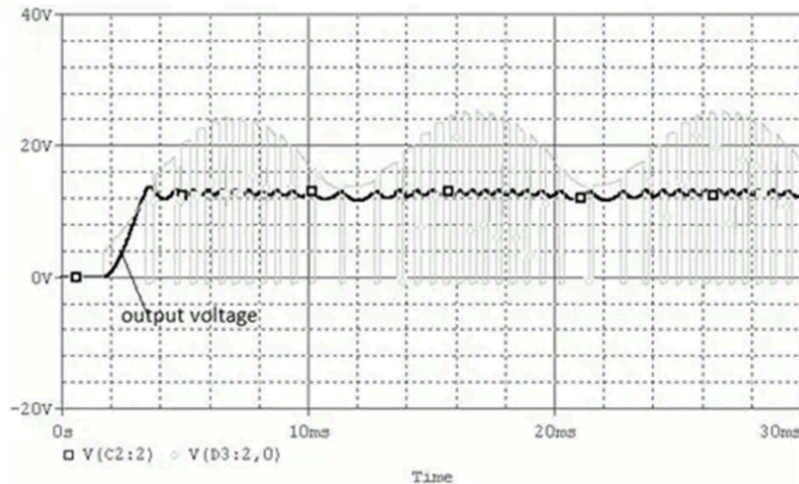


Figure 16 - Output Voltage Waveform of the Active Rectifier

2.6.3. Harmonic and Performance Analysis

The use of controlled switching in the active rectifier significantly changes the harmonic behaviour of the system. Instead of producing strong low-order harmonics, as seen in diode and SCR rectifiers, the harmonic content is shifted towards higher frequencies due to the switching process.

This results in a reduction in dominant low-frequency harmonics, which are typically the most harmful in power systems. As a result, the overall power quality is improved, and the impact on the supply network is reduced.

In addition, active rectifiers can operate with near unity power factor and allow bidirectional power flow, enabling regenerative operation. This makes them particularly suitable for applications where energy efficiency and control flexibility are important [3], [11].

2.6.4. Discussion

The IGBT active rectifier provides the highest level of performance among the systems analysed. The use of controlled switching allows the output voltage to be regulated effectively while reducing low-order harmonic distortion. In addition, the ability to operate with near unity power factor and support bidirectional power flow makes it highly suitable for modern industrial applications. Despite these advantages, the increased complexity, cost, and control requirements mean that active rectifiers are typically reserved for applications where performance and efficiency are prioritised [10], [16].

2.7 Final Comparison & Conclusion

The simulation results demonstrate a clear progression in performance across the different rectifier topologies. Starting with the SCR half-wave rectifier, the system shows poor utilisation of the AC supply and highly distorted current waveforms. The limited conduction period leads to significant harmonic content and reduced efficiency, making it unsuitable for most industrial applications.

The SCR full-wave rectifier improves performance by utilising both halves of the supply waveform. However, the presence of firing delay continues to introduce distortion and phase displacement, meaning that harmonic content and power quality issues are still evident. While it offers better output than the half-wave configuration, it remains limited when compared to more modern rectifier systems.

A significant improvement is observed with the 6-pulse diode rectifier. The use of a three-phase supply results in a more continuous DC output and improved system efficiency. Despite this, characteristic harmonics such as the 5th and 7th remain present, indicating that further harmonic mitigation would be required in practical applications to meet standards such as IEEE 519 [15].

The 12-pulse rectifier demonstrates a further step forward by reducing harmonic distortion through the use of phase-shifted transformer supplies. The simulation results show a smoother output waveform and reduced ripple, along with a more distributed harmonic spectrum. This confirms that harmonic cancellation techniques are effective in improving power quality, particularly in higher power systems where such configurations are commonly used [3].

The highest level of performance is achieved with the IGBT active rectifier. The use of controlled switching enables effective regulation of the DC output while significantly reducing low-order harmonic distortion. In addition, the ability to operate with near unity power factor and support bidirectional power flow provides a level of flexibility not available in passive rectifier systems. These characteristics make active rectifiers particularly suitable for modern industrial applications where efficiency, control, and power quality are critical [10], [16].

Overall, the results show a clear trade-off between system complexity and performance. Simpler rectifiers offer low cost and ease of implementation but suffer from poor waveform quality and higher harmonic distortion. In contrast, more advanced systems such as 12-pulse and active rectifiers provide improved performance at the expense of increased complexity and cost. This highlights the importance of selecting an appropriate rectifier topology based on the specific requirements of the application.

References

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

79/100

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Comment 1

Why have you not started with reference [1]? They are supposed to be in numerical order

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GRADING FORM: SMU GENERIC_SMOSEY

ETHAN REYNOLDS

78.60

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



Engagement with an extensive range of literature. You have used relevant and credible sources. Referencing may show minor inaccuracies or inconsistencies. Sources used are informed by the latest research.

12.75

KNOWLEDGE & UNDERSTANDING

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



Excellent coherent and detailed knowledge and systematic understanding of the principles and theories of current research and scholarship. Clear awareness of challenges to established views and the limitations of the knowledge base.

23.4

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.



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.

26.95

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



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.

7.5

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 with an exceptionally high level of professionalism. Work is exceptionally

coherent, very fluent and is presented professionally. Demonstrates exceptional graduate employment skills and an appetite for further development.

8