**Q2)**

**Part a)**

**Single Phase Rectifier Fully Controlled**

Input voltage is given as rms. So peak value of the input voltage is , which is equal to 324.3 V. After that, from the integral calculations, average output voltage is calculated, as . However, in addition topology has extra losses due to commutation, . From the equation loss due to commutation is 4 \* 50 \* 2 \* 0.01 = 4 V. So, total voltage is 203.7 \* cos(a). For getting 40 A, output average voltage should be 160 V. For getting 160 V DC output, a value calculated as, a = arccos(160/203.7) = 38.2359 degree.

metin, diyagram, çizgi, öykü gelişim çizgisi; kumpas; grafiğini çıkarma içeren bir resim

Açıklama otomatik olarak oluşturuldu

*Figure 1. Voltage Waveform of RL Load Single Phase Fully Controlled Rectifier*

*Full Wave Thyristor Rectifier*

Then, design of topology is implemented.

diyagram, teknik çizim, plan, şematik içeren bir resim

Açıklama otomatik olarak oluşturuldu

*Figure 2. Matlab Simulink Schematic for Fully Controlled Rectifier*

After creating topology, pulse generator is adjusted according to our calculations. We found a degree as 38.2359 degree. So, we must create a delay for firing angle. We calculate firing angle from equation, , from the equation delay is found as 0.0021244 s. So, this delay is implemented to pulse generator 1 and 3. Then, delay on the pulse generators 2 and 4 are adjusted as (0.00212 + 0.01) s, because this current way is used second interval of one full period. So, extra 1/100 s coming from this inference.

metin, ekran görüntüsü, sayı, numara, yazı tipi içeren bir resim

Açıklama otomatik olarak oluşturuldu

*Figure 3. Pulse Generator Implementations for Fully Controlled Rectifier*

Then simulation was run, after adjusting.

taslak, çizgi, dikdörtgen, diyagram içeren bir resim

Açıklama otomatik olarak oluşturuldu

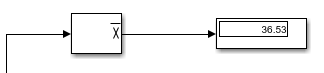
*Figure 4. Average Output Voltage of Fully Controlled Rectifier*

çizgi, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, ekran görüntüsü, diyagram içeren bir resim

Açıklama otomatik olarak oluşturuldu

*Figure 5. Output Voltage Waveform of Fully Controlled Rectifier*

Results are given in Figure 4 and 5. Output average voltage is measured as 146.1 V. It is very similar to our theoretical calculations. However, because of the losses in the thyristors and voltage drop on the load inductor, some voltage drops can be seen.



*Figure 6. Average Output Current of Fully Controlled Rectifier*

Resulted average output current can be seen in Figure 6. From the calculation, . So, our theoretical calculations match with simulation results. Again, some non-idealities in the rectifier and voltage drop on load inductance, we see some small differences.

**Single Phase Rectifier Half Controlled**

For single phase rectifier half controlled, used diodes are work like Free-Wheeling Diode. So, output voltage cannot go below 0 V. It will stay at 0 V when voltage is exactly zero and jump to voltage when thyristors are fired. With this information, we made calculations.

diyagram, çizgi, öykü gelişim çizgisi; kumpas; grafiğini çıkarma içeren bir resim

Açıklama otomatik olarak oluşturuldu

*Figure 7. Average Voltage Waveform of Half Controlled Rectifier*

From this waveform, we can do calculations for getting 40 A output current. As we did previous part, our expected average voltage should be 160 V again. From the equation, , we understand that firing angle should be degree, and commutation loss is taking into account. After these calculations, same pulse generator formulas are implemented to pulse generator.

metin, ekran görüntüsü, sayı, numara, yazı tipi içeren bir resim

Açıklama otomatik olarak oluşturuldu

*Figure 8. Pulse Generator Implementations for Half Controlled Rectifier*

diyagram, metin, çizgi, plan içeren bir resim

Açıklama otomatik olarak oluşturuldu

*Figure 9. Matlab Simulink Schematic for Half Controlled Rectifier*

Afterwards, the simulation results were saved.

*çizgi, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, diyagram, metin içeren bir resim

Açıklama otomatik olarak oluşturuldu*

*Figure 10. Output Voltage Waveform of Half Controlled Rectifier*

taslak, diyagram, çizgi, dikdörtgen içeren bir resim

Açıklama otomatik olarak oluşturuldu

*Figure 11. Average Output Current of Half Controlled Rectifier*

taslak, diyagram, çizgi, dikdörtgen içeren bir resim

Açıklama otomatik olarak oluşturuldu

*Figure 12. Average Output Voltage of Half Controlled Rectifier*

From the results, our theoretical expectations are very similar with simulation results. They have small deviations; these deviations may cause from many reasons. Diodes and thyristors are not ideal. They have forward voltages and leakage currents. In addition, they have internal resistances. In addition, expected output voltage is not exactly same, 12.5% deviation is available. When we calculate total resistance at output, which is , this value is not expected.

**Part b)**

**Single Phase Rectifier Half Controlled**

öykü gelişim çizgisi; kumpas; grafiğini çıkarma, çizgi, diyagram, ekran görüntüsü içeren bir resim

Açıklama otomatik olarak oluşturuldu

*Figure 13. Input Voltage and Current Waveform of Fully Controlled Rectifier*

metin, ekran görüntüsü, çizgi, yazı tipi içeren bir resim

Açıklama otomatik olarak oluşturuldu

*Figure 14. FFT Window of Fully Controlled Rectifier*

metin, ekran görüntüsü, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, yazı tipi içeren bir resim

Açıklama otomatik olarak oluşturuldu

*Figure 15. FFT Analysis of Fully Controlled Rectifier*

çizgi, diyagram, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, paralel içeren bir resim

Açıklama otomatik olarak oluşturuldu

*Figure 16. Input Voltage and Current Waveform of Half Controlled Rectifier*

metin, ekran görüntüsü, çizgi, yazı tipi içeren bir resim

Açıklama otomatik olarak oluşturuldu

*Figure 16. FFT Window of Half Controlled Rectifier*

metin, ekran görüntüsü, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, yazı tipi içeren bir resim

Açıklama otomatik olarak oluşturuldu

*Figure 17. FFT Analysis of Half Controlled Rectifier*

**Part c)**

***Single Phase Fully Controlled Rectifier***

Advantages:

* Enhanced Control: Manages the entire AC cycle, providing better regulation of output voltage and current.
* Reduced Harmonics: Offers improved control, leading to reduced harmonic distortion in the output waveform.
* Wider Applicability: Suitable for a broader range of applications due to its superior control capabilities.
* It performs two-quadrant operation i.e., forward motoring and reverse braking operation
* It has inversion mode

Disadvantages:

* Complexity: Requires additional control circuits and more components, increasing complexity and cost.
* Higher EMI: May produce higher electromagnetic interference due to the rapid switching of semiconductor devices.
* Higher Cost: Due to the additional components and complex control systems, it is generally more expensive.
* Low Power Factor

Applications:

* DC motor drives
* UPS: Utilized in UPS systems to ensure continuous power supply during outages
* Industrial Power Systems: Employed in industrial power systems where precise control and reduced harmonics are critical
* AC/DC converter

***Single Phase Half Controlled Rectifier***

Advantages:

* Simplicity: Requires fewer components and less complex control circuitry
* Cost-effectiveness: Due to its simpler design, it’s generally less expensive to implement
* Reliable for Resistive Loads
* High power factor
* Internal F.W.D. exist
* Low ripples, required filter circuit’s cost and complexity

Disadvantages:

* Limited Control: Controls only one half-cycle of the AC input, limiting its ability to regulate output voltage and current
* Harmonics: Generates more harmonic content in the output waveform due to abrupt transitions during diode switching
* It performs only one quadrant operation, forward motoring
* Limited control
* No inversion mode

Applications:

* Heating systems
* Basic Motor Drives
* Simple Power Supplies
* AC/DC converters

Their operational similarities and differences are commented in the advantages and disadvantages sections.