MIDDLE EAST TECHNICAL UNIVERSITY

ELECTRICAL & ELECTRONICS ENGINEERING

EE463 - STATIC POWER CONVERSION I

Hardware Project Simulation Report

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Introduction

The purpose of this project is to design a controlled rectifier which enables to drive a DC motor, by using one of three topologies which are 3-phase thyristor rectifier, 1-phase thyristor rectifier and diode rectifier plus buck converter. In this design process, our theoretical knowledge about power electronics area will meet experimental applications. In this report, these three different topologies, their advantages and disadvantages will be discussed. Moreover, we will get familiar with the common components and tools of rectifiers and the fundamentals of the motor driver design.

Comparison of Topologies

There are three given topologies for driver design:

- 3-phase Thyristor Rectifier
- 1-phase Thyristor Rectifier
- Diode Rectifier + Buck Converter

These three topologies are discussed with respect to four main parameters which are cost, simplicity, functionality and performance. All topologies will be investigated individually according to their trade-offs.

1. 3-phase Thyristor Rectifier

Three phase topology offers a wide-range power applications with properly synchronized firing angles. This topology used in power system and high power application. Three-phase thyristor rectifier can convert the ac voltage to controlled dc voltage. With the firing angle we can control the voltage and power flow. Nowadays, it is used in power system applications on the high voltage dc transmission. Because they can control power flow direction AC to DC or DC to AC with changing firing angle.Thyristor begins to conduct when voltage is positive and firing signal came from control circuit. It seems very simple but control(driver) circuit is very complex because firing angle must be synchronized with grid voltages.There is some component like TCA 785 which produces voltage pulse and pulse signal must be isolated with some devices which is optocoupler or pulse transformer. It needs more time than other topologies, however, when you calculate and isolate the firing signal you can control easily and it can transfer huge amount of power. Four quadrant operation is also available with this topology. It’s cost is high compared with one-phase thyristor controller.

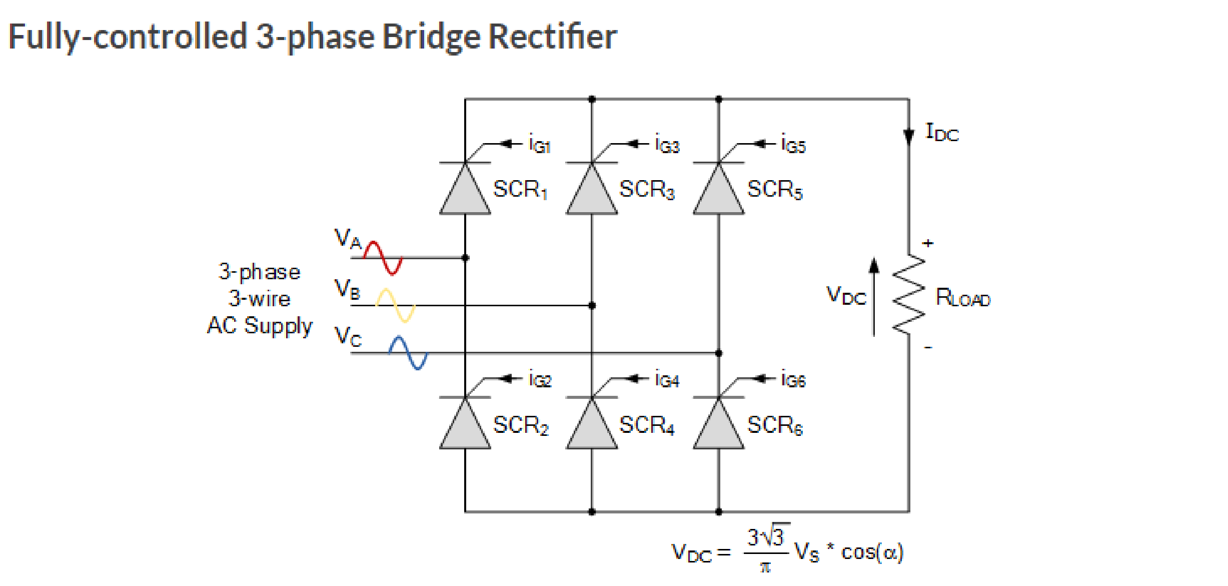

Figure 1: Three-phase Thyristor Rectifier

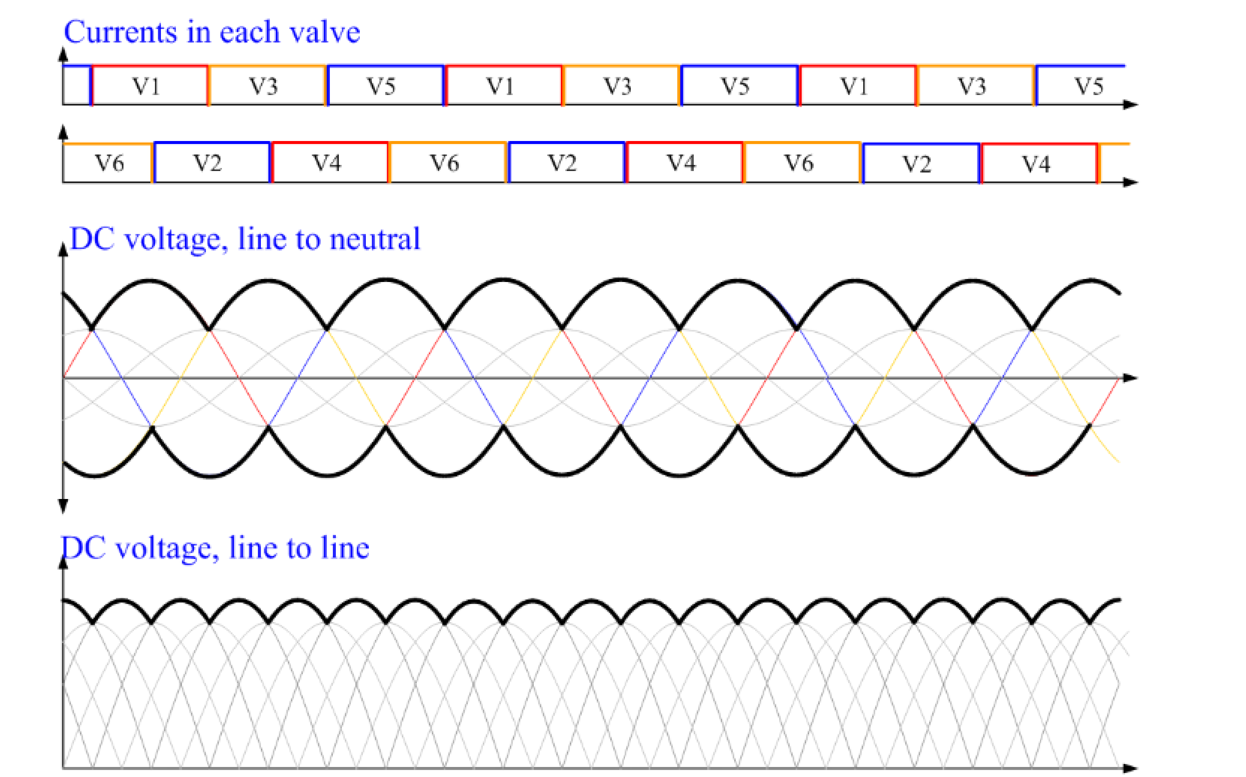

Figure 2: Three-phase Thyristor Rectifier Outputs

2. 1-phase Thyristor Rectifier

The topology of 1 phase controlled rectifier is shown in Figure 3 which provides to use less components while comparing it with the other topologies. In this application, the power flow can be provided from AC voltage waveform to DC voltage and current waveform. Also this topology will provide to control output power by changing the firing angle. When considering the 1 phase controlled rectifier, we will face to use different devices such as optocoupler, transformer in order to isolate firing angle from the circuit that involves thyristors and other circuit components. Moreover, in order to adjust the output power, we have to use a synchronization device for all thyristor. While making a brainstorming with team members, we thought that we could use Siemens TCA785 device to signal gates of thyristors if we decide to use 1 phase controlled rectifier. There are the same concerns with 3-phase thyristor rectifier which are mentioned above.

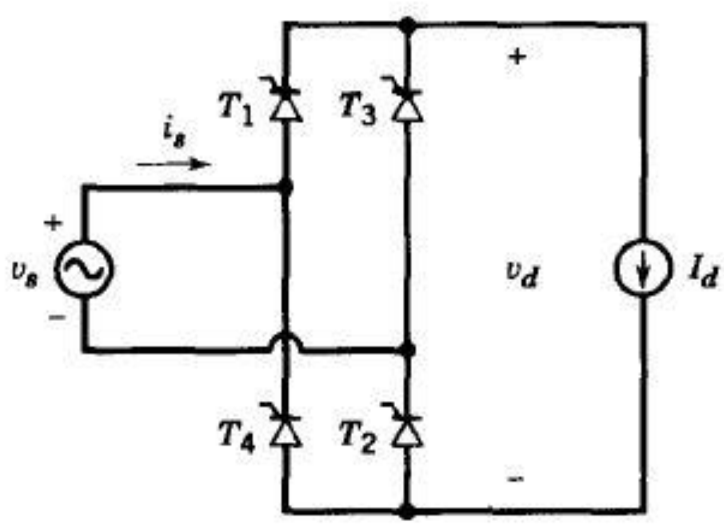

Figure 3: 1-phase Thyristor Rectifier

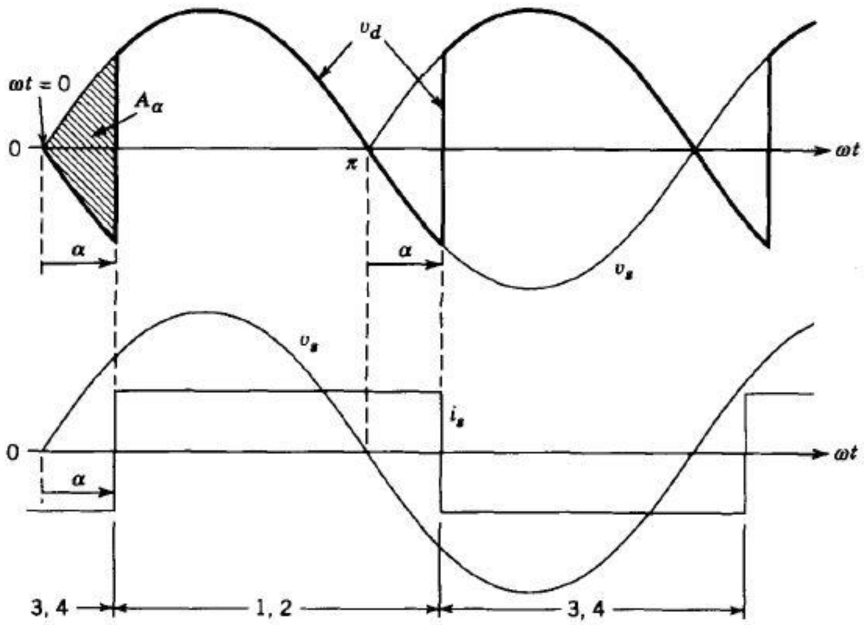

Figure 4: 1-phase Thyristor Rectifier Outputs

3. Diode Rectifier + Buck Converter

We have decided to choose three phase diode rectifier with buck converter because ıt ıs very easy to control when we compare the other thyristor applications. In this topology, we can control the voltage not current. Installatıon of this circuit is easier than thyristor circuits. We should apply soft starter for DC motor in order not to damage our design components.

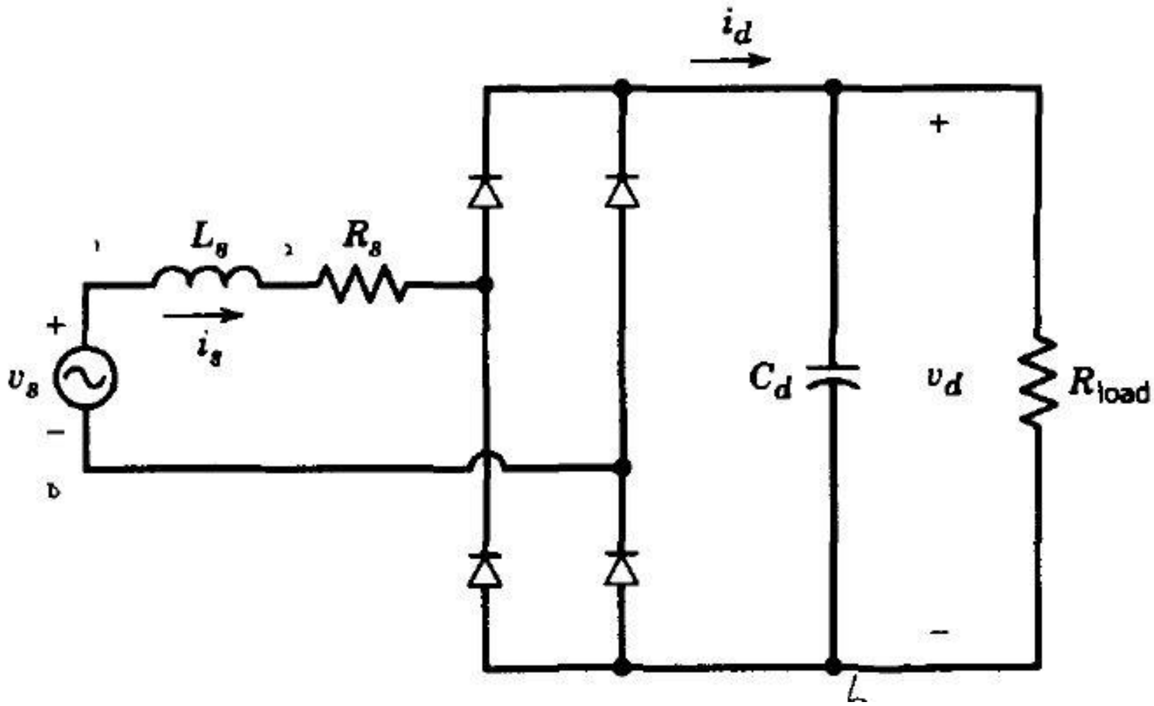

Figure 5: Three-phase Diode Rectifiers

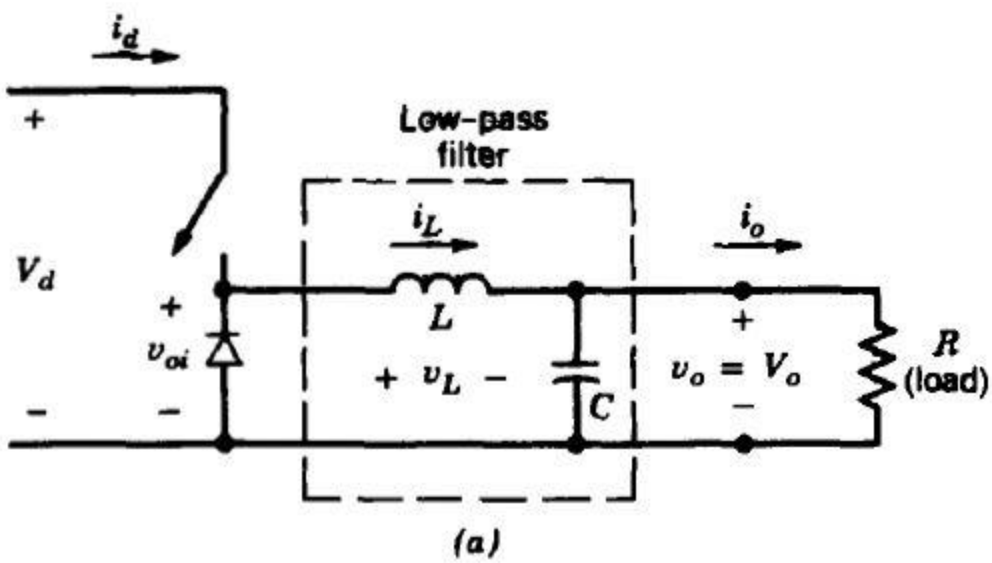

Figure 6: Buck Converter

Selected Components

Three-phase diode rectifier and buck converter topology was selected according to our criticizes. As three phase diode rectifier we choose 1600V 90A full bridge diode rectifier [1]. Part number is VUO86-16N07. It can stand up to 1600V and max forward surge current is 550A. It’s nominal current is 90A which is enough for our design. Forward voltage drop is 1.48V. Tolat power dissipation under full load is 135.

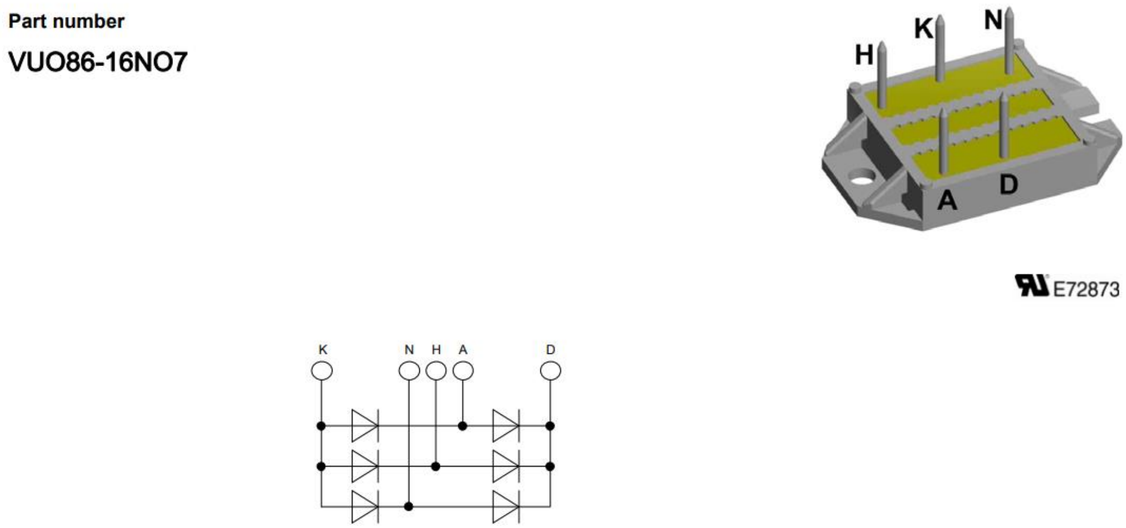

Figure 7:Selected Three-phase Rectifier

For controlling switch, we choose the IGBT DIS.SINGLE 60A 650V XPT TO247-3 [2] that has reverse voltage rating of 650 V and also ıts forward current ratings are 60 A and 116 A for 110 centigrade degrees and 25 centigrade degrees.

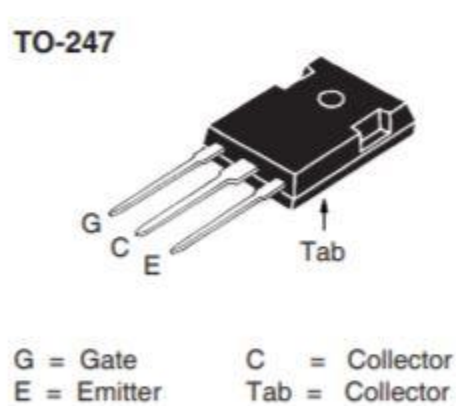

Figure 8:Selected IGBT

For our topology, we are planning to use Diode Hiperfred Single 60A 1200V THT TO247AD-2 at output of buck converter. Its forward current rating is 60 A that corresponds to our design. Also it is designed to stand 1200 V reverse breakdown voltage that is proper for our design.

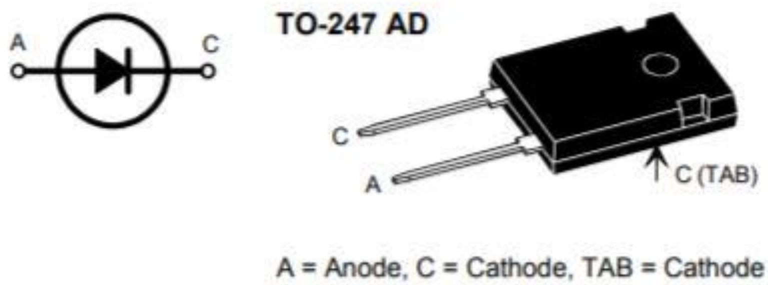

Figure 9:Selected Diode

Simulation Results

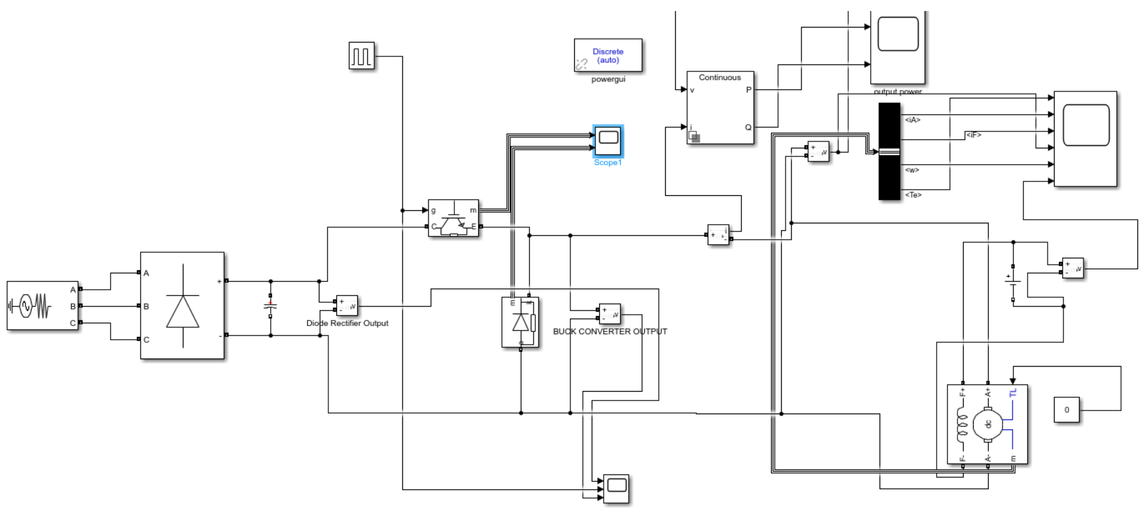

Figure 10: Simulation Schematic

In Figure 10, the simulation schema is constructed in Simulink MATLAB.The DC shunt motor models and rectifier parameters has been specified in order to find starting current, average current, voltage and power. All these measurements are very important for component decision process. The parasitic effects of components and possible safe margins are also considered to avoid common failures.

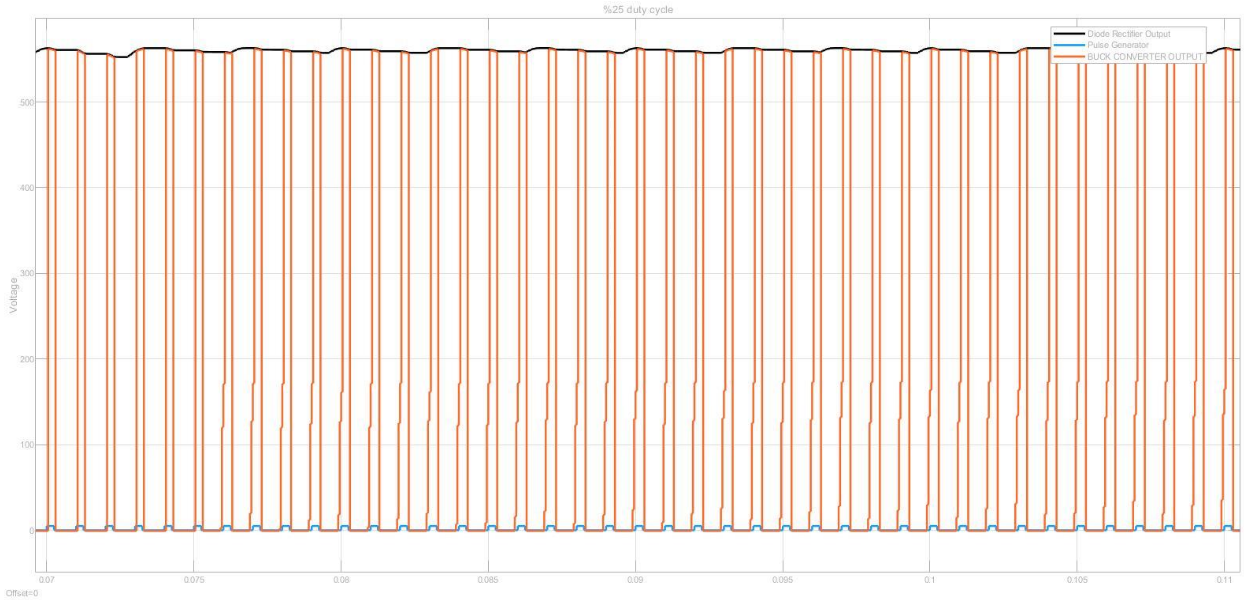

Figure 11: %25 Duty Cycle Buck Converter Input Output Waveform

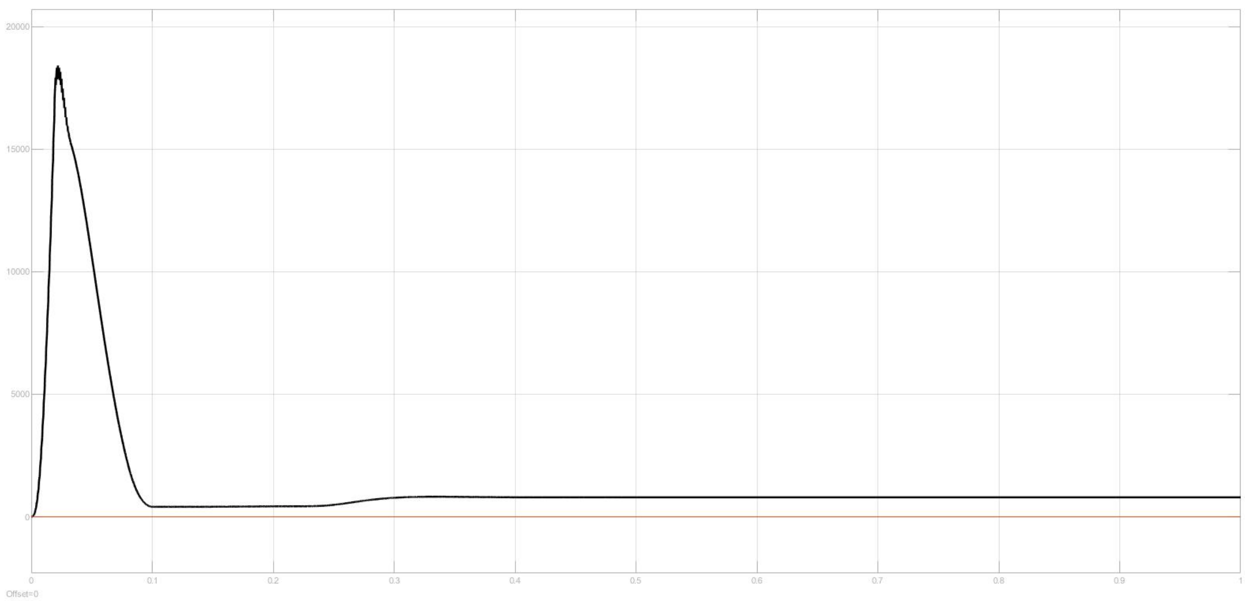

Figure 12: %25 Duty Cycle Buck Converter Output Power

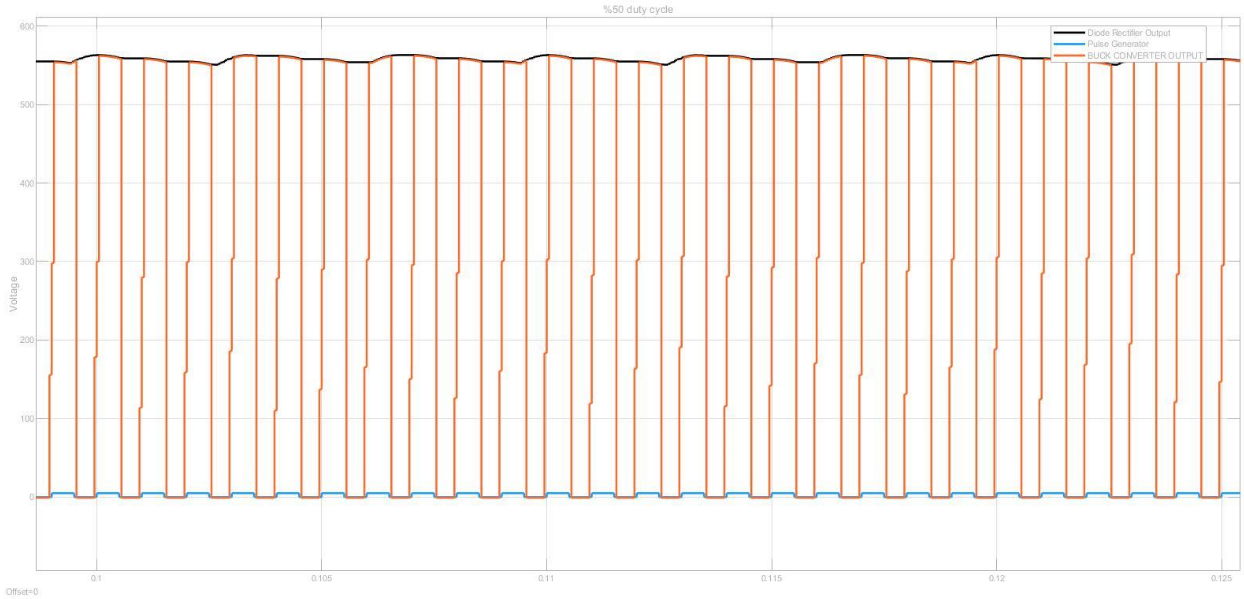

Figure 13: %50 Duty Cycle Buck Converter Input Output Waveform

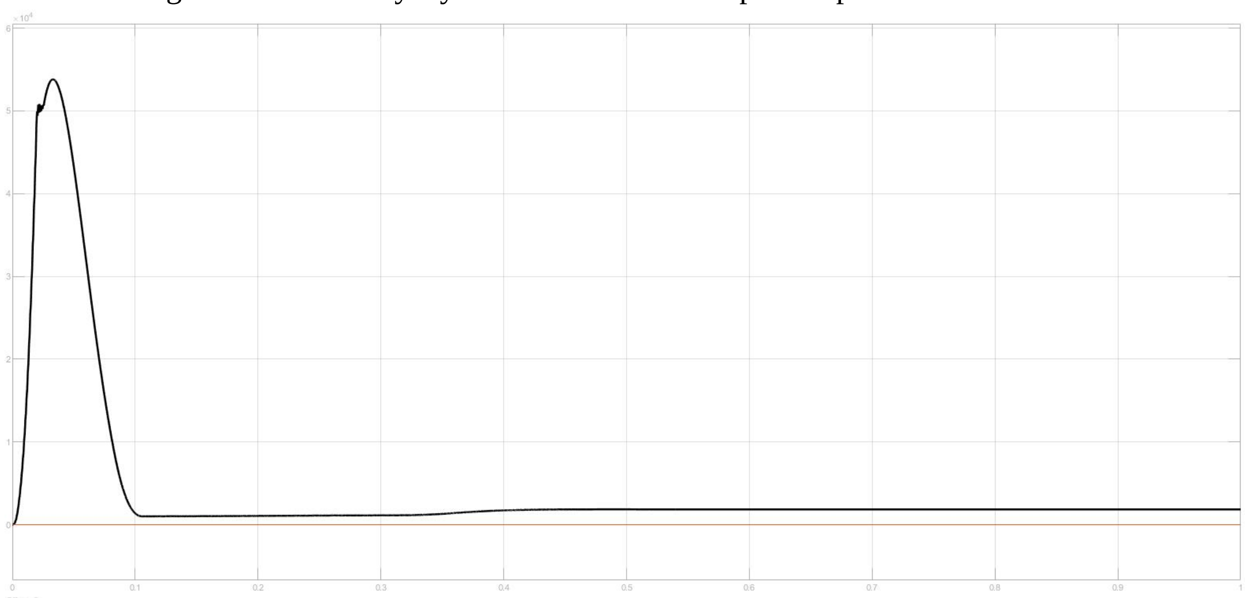

Figure 14: %50 Duty Cycle Buck Converter Output Power

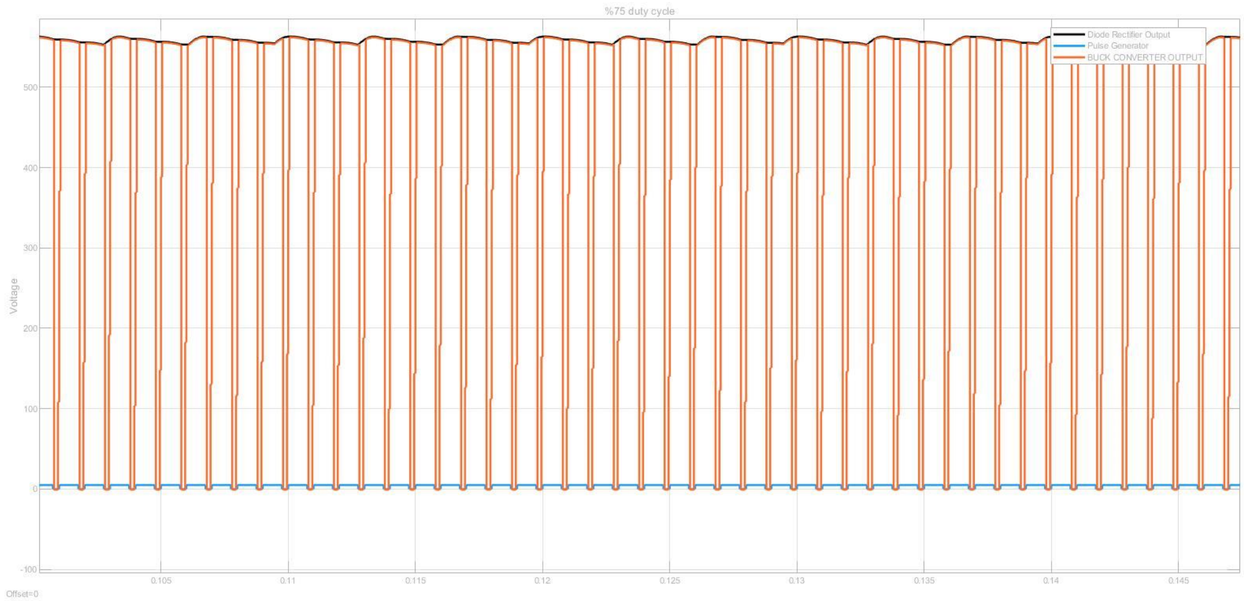

Figure 15: %75 Duty Cycle Buck Converter Input Output Waveform

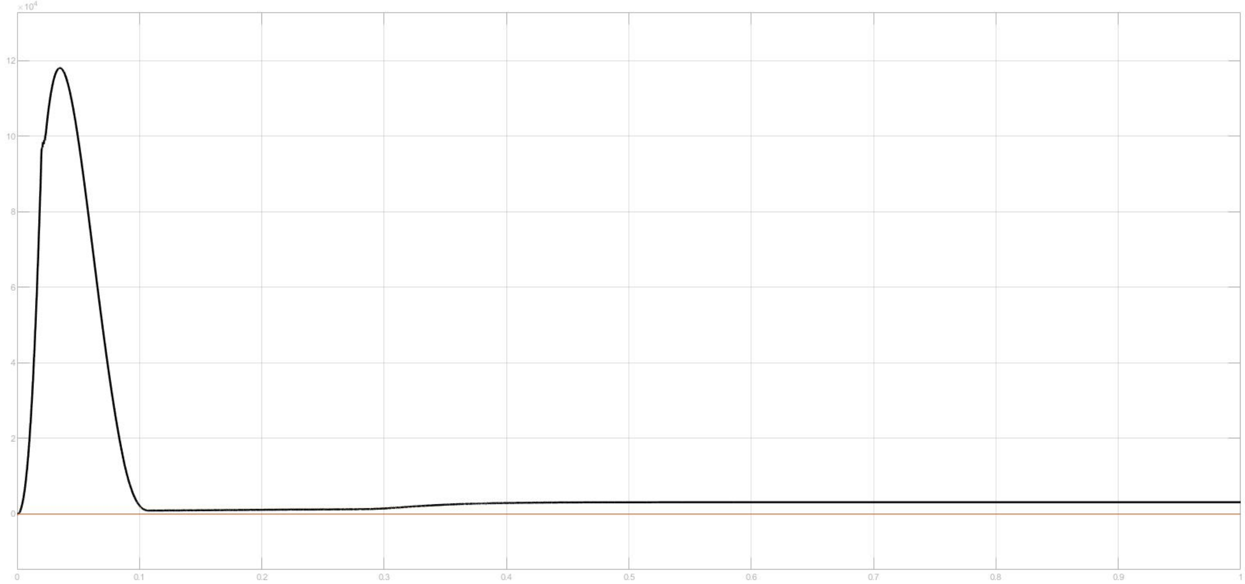

Figure 16: %75 Duty Cycle Buck Converter Output Power

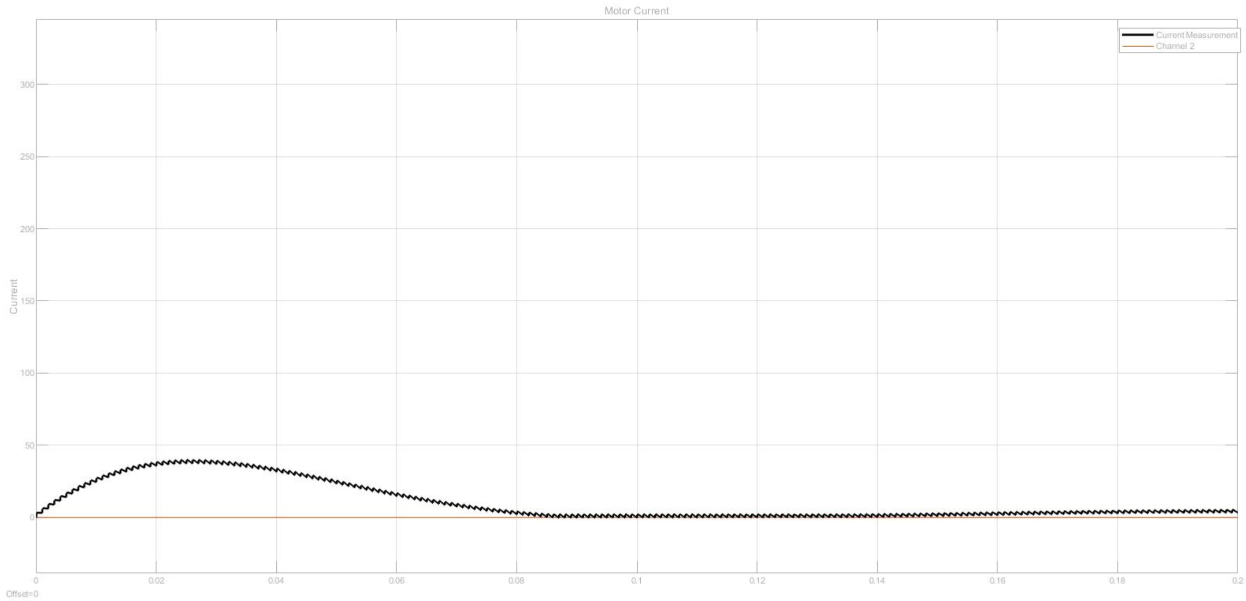

Figure 17: Motor Current When Duty Cycle is %5

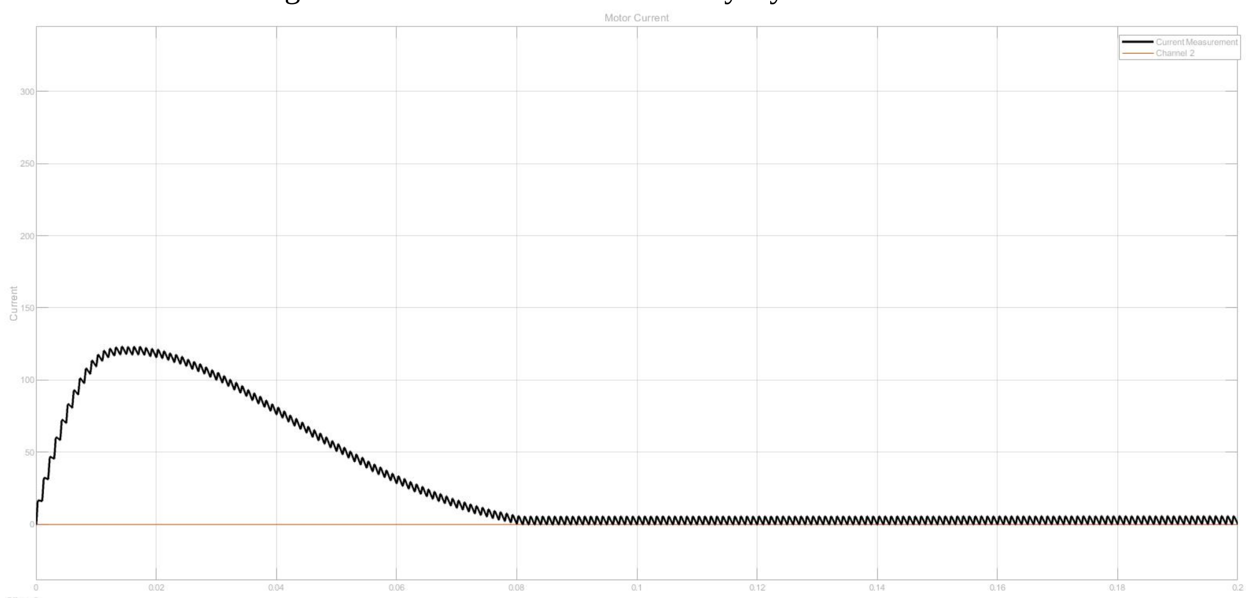

Figure 18: Motor Current When Duty Cycle is %25

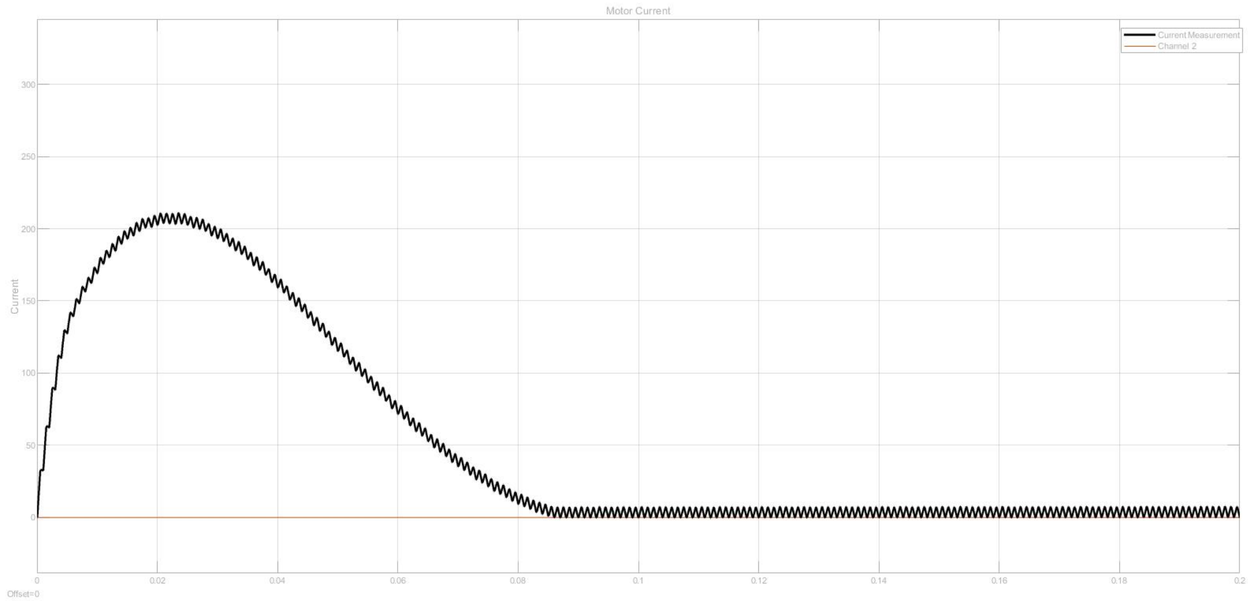

Figure 19: Motor Current When Duty Cycle is %50

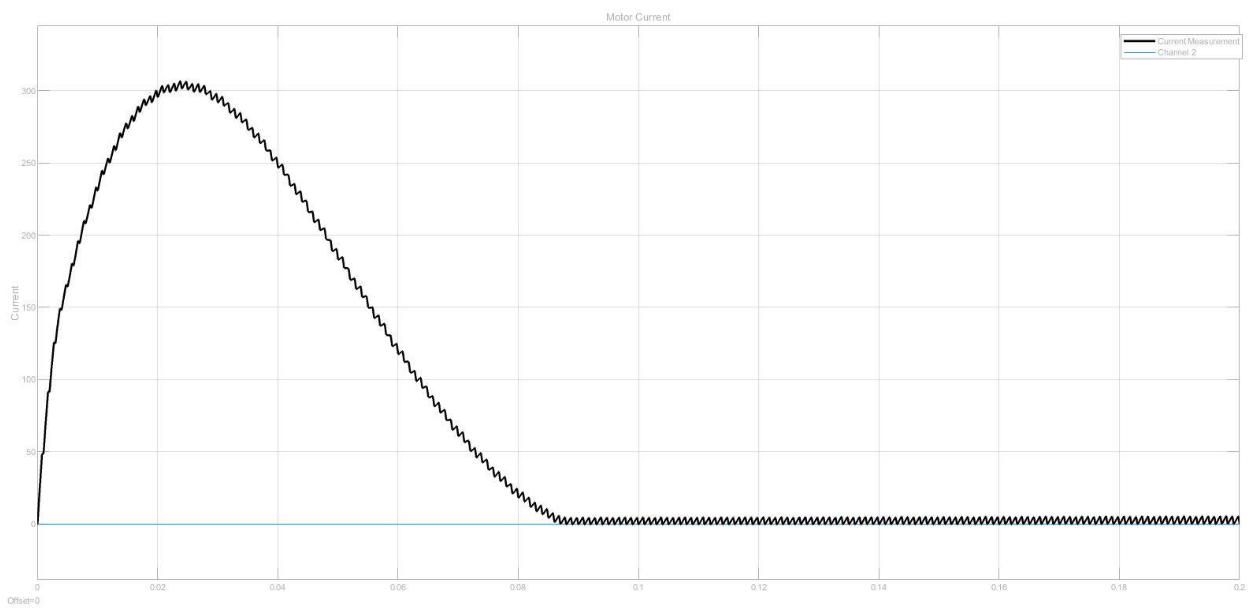

Figure 20: Motor Current When Duty Cycle is %75

As we see in figures we can change the input power of motor and control the power with duty cycle. When we increase the duty cycle buck converter average output starts to increase as theoretically expected. As seen in motor current graphs, there is a very huge current without soft-start because back emf of the motor is initially zero so it like a short circuit.So we must increase the duty cycle slowly. We are planning to use arduino for feedback and soft starting circuit.

Conclusion

As Dynamıc Power Team, we have determined our design topology, which is Three-Phase Diode Rectifier with Buck Converter, for hardware project and simulate it in Simulink-MATLAB. While choosing the topology, we consider installation and controlling parameters into account. For results of simulation, we have figured out that we will damage our circuit unless we apply a soft-starter to our motor. Because without soft-starter, the motor will absorb 300 A rating current which is hazardous to all components of our circuit.

Appendix

[1] https://cdn.ozdisan.com/ETicaret_Dosya/8856_6449478.pdf
[2]https://cdn.ozdisan.com/ETicaret_Dosya/483186_5503090.pdf