EE463 2022 Fall

Dolu Kapasitörü Ters Tut

Term Project Simulation Report

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1 Introduction

In this project, we are making a rectifier that drives the DC motor in the power laboratory. The DC motor specs are given in the project GitHub repository.

So far, diode rectifier and synchronous buck converter topologies are chosen. Basic components have been researched and some candidate power semiconductors are determined. Moreover, control methodologies have been studied so that at least closed-loop speed control is implemented. Ways of closing the loop have been discussed. Furthermore, the H-bridge circuit is selected to implement four quadrant operation. Again, some candidate MOSFETs and diodes are chosen.

The project is still ongoing and evolving.

1.1 Aimed Bonuses

We will go for the topology, current and speed control, and four-quadrant bonuses. Depending on our progress, we will try to achieve other bonuses such as tea, PCB, utilization, efficiency, industrial design, analog controller, compactness, and single supply bonuses. The bonuses mentioned later have little or no impact on the design of our circuit. Therefore, they will be considered after the main circuit design is completed. Eagle software will be used to design the PCB and the circuit will be realized with iron pressing and chemicals.

2 Converter Topology

Synchronous buck converter together with uncontrolled three-phase diode rectifier is selected as the DC/DC and AC/DC converters, respectively. Such a combination is simpler than a thyristor rectifier due to the less number of switches required. Besides, this suggests a lower cost for gate drivers. Further, a three-phase diode rectifier is more advantageous than a single-phase one since the output ripple is significantly lower.
The synchronous buck converter is chosen instead of an ordinary one. This topology is a variant of a regular buck converter where the diode is also replaced by a power MOSFET as in Figure 1. The two

transistors are controlled with a synchronized controller to prevent turning on at the same time. The new buck converter can have fewer losses provided that suitable components for the application are chosen [1].

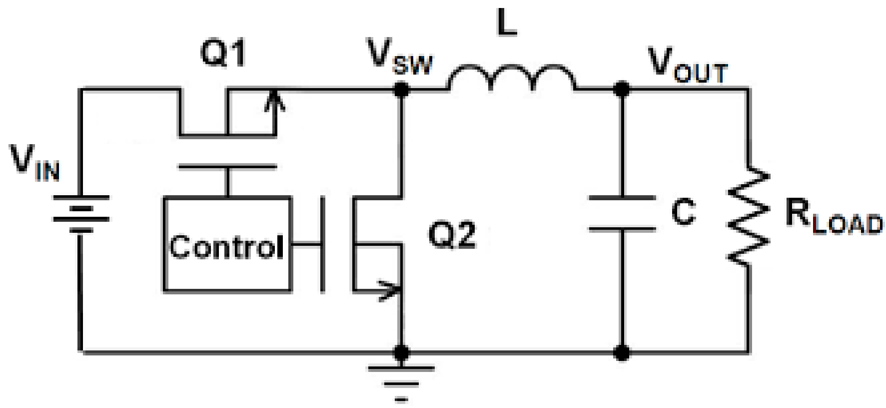

Figure 1: Synchronous buck converter

The simulations are done in LTspice as well as in Simulink. The simulations are done with a maximum input voltage amplitude of 120V. The obtained results are provided below in figures 2, 3.

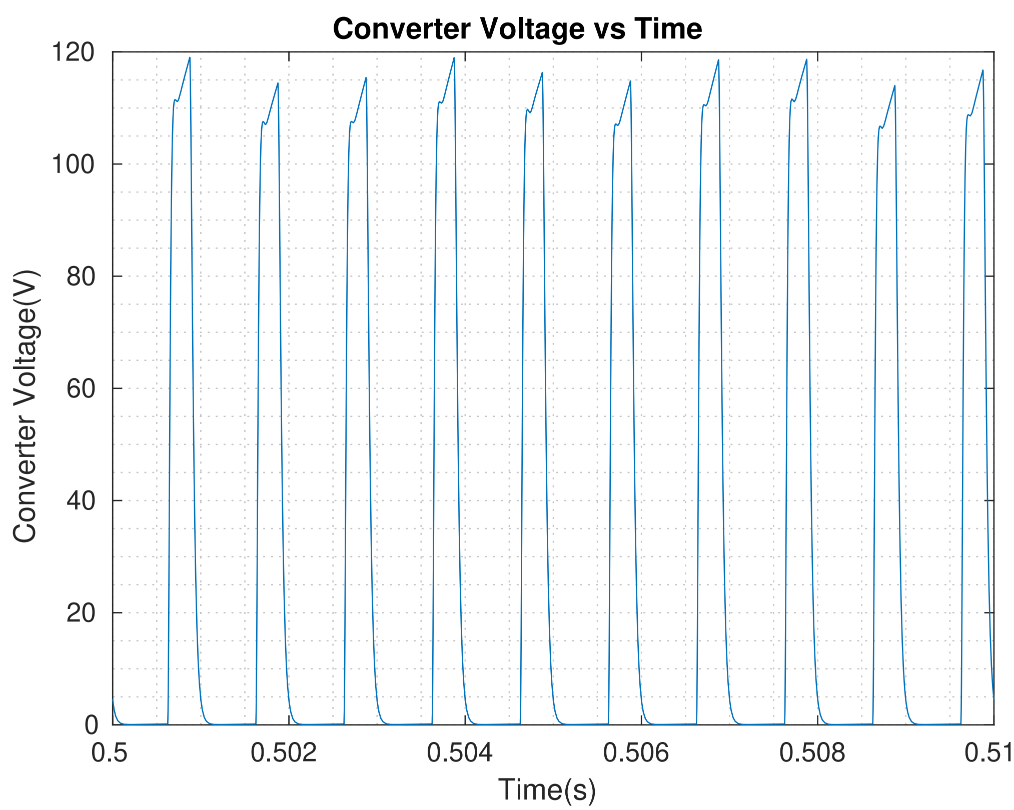

Figure 2: Armature voltage

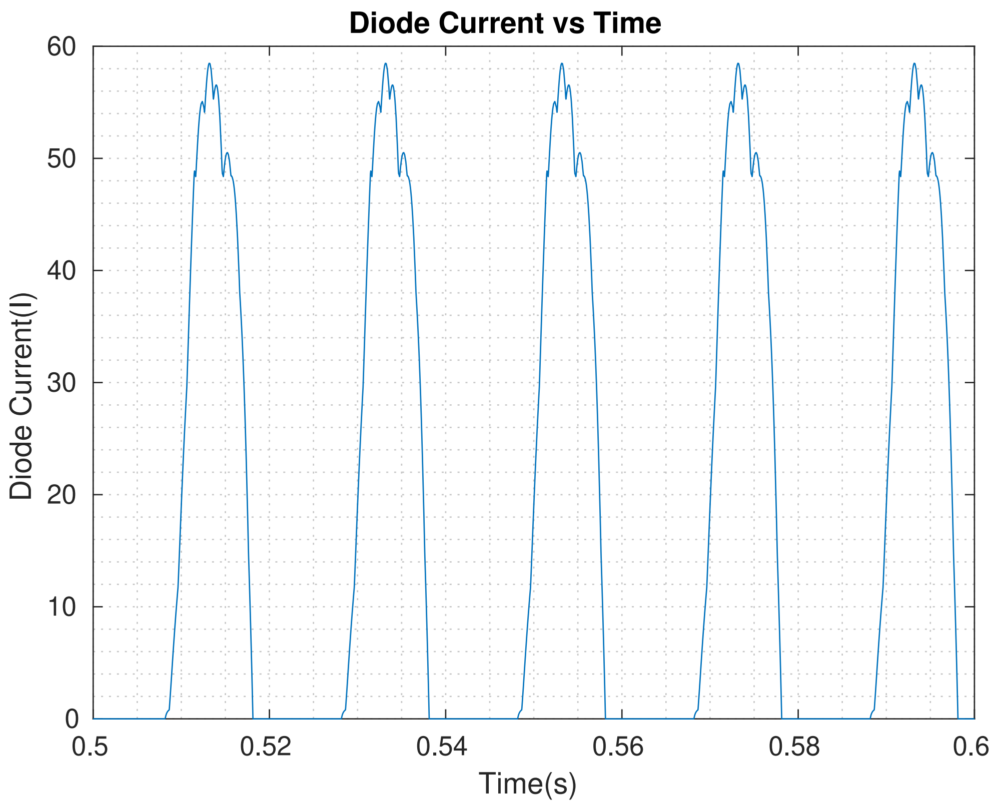

Figure 3: Input current of the rectifier

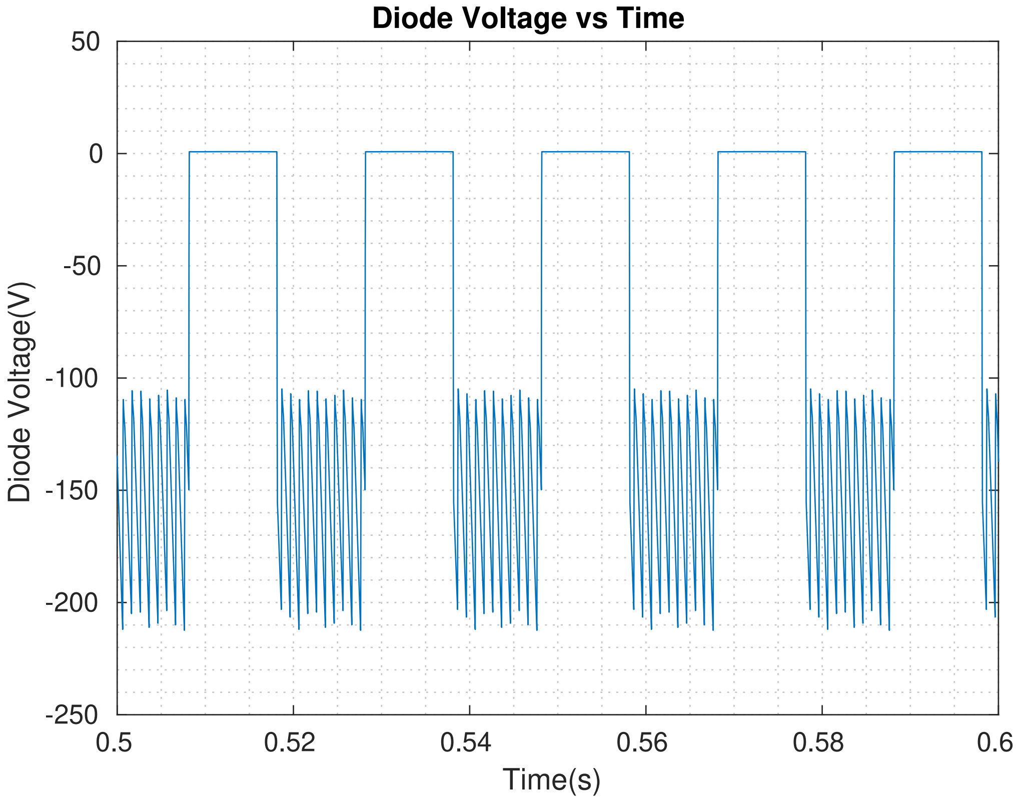

Figure 4: Diode voltage of the rectifier

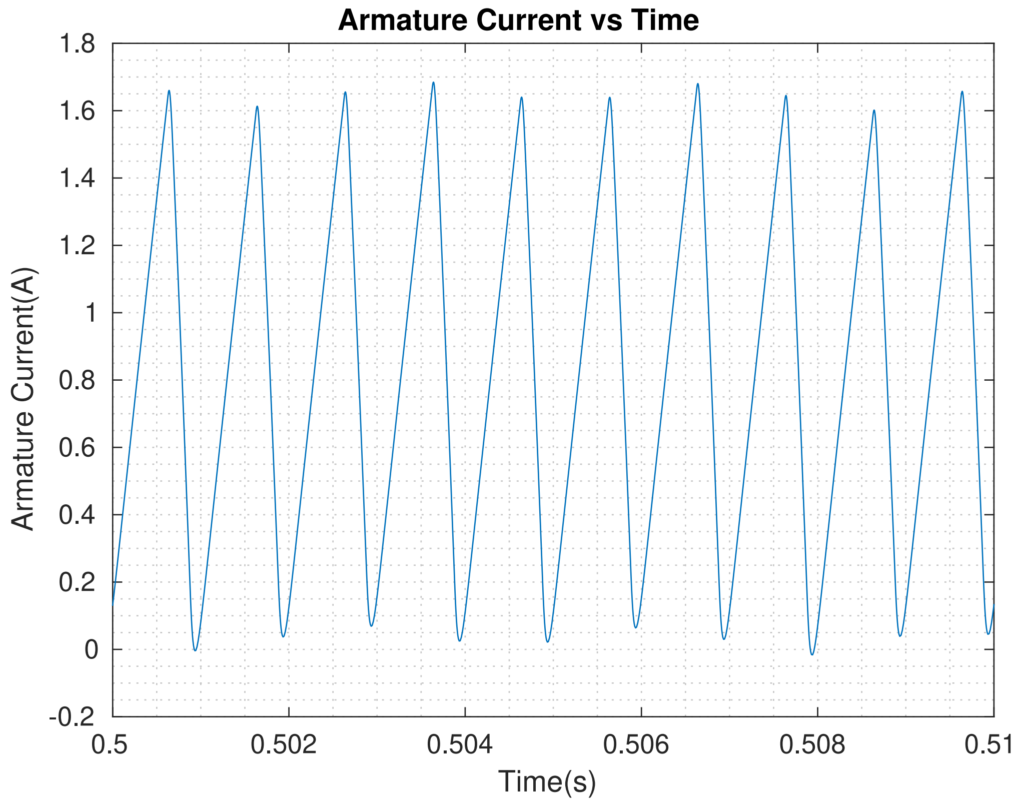

Figure 5: Armature current

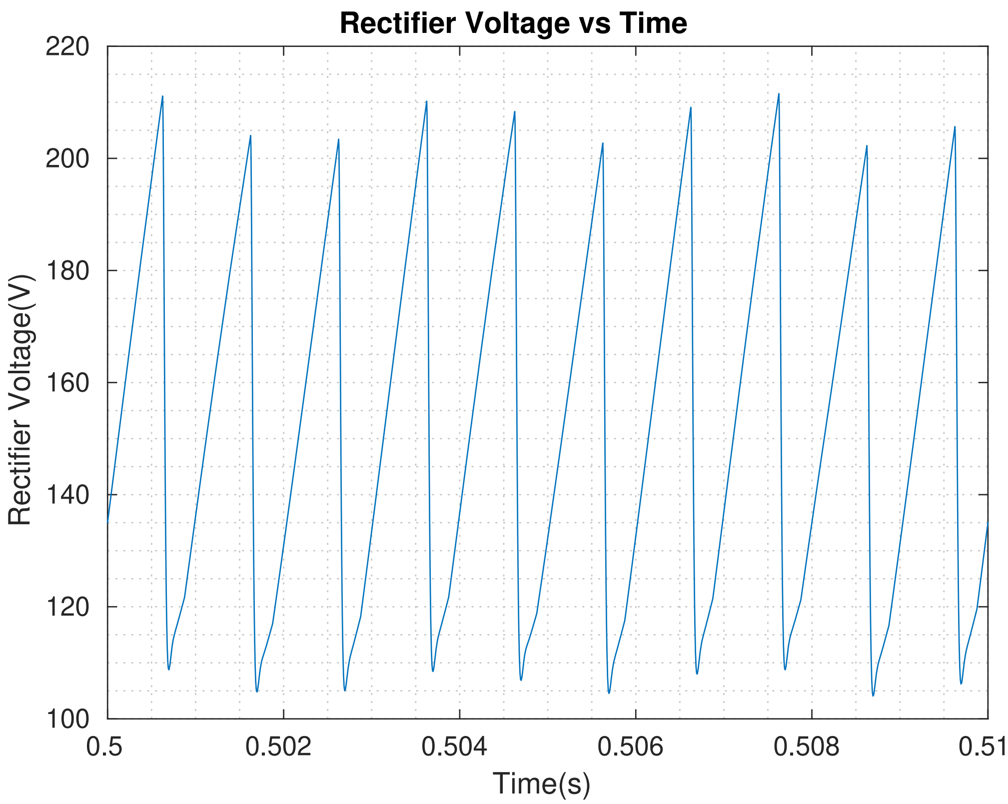

Figure 6: Rectifier output voltage

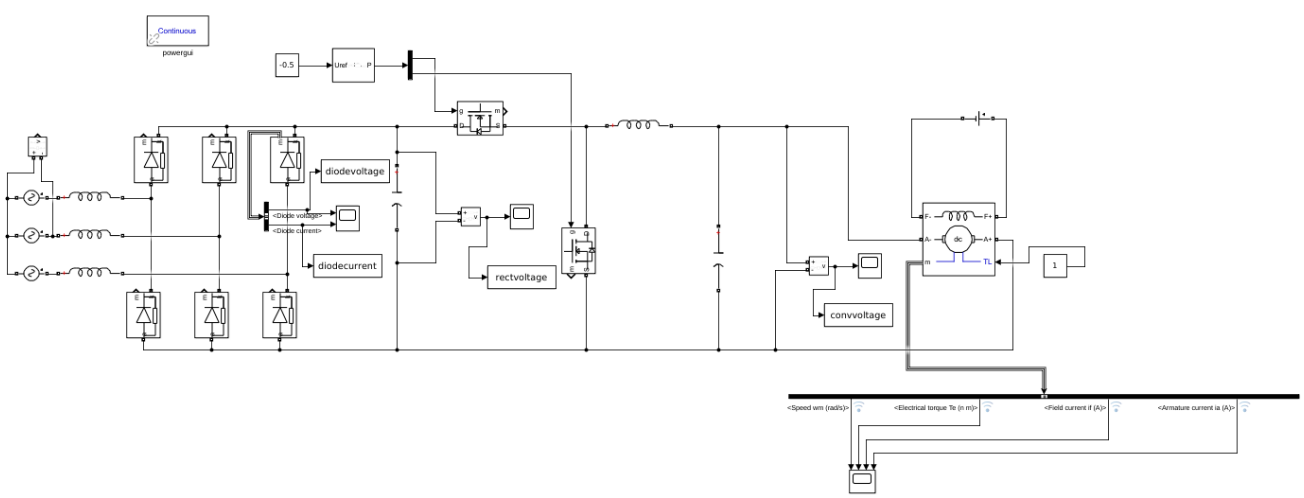

Figure 7: Simulink block

As can be seen in Figure 1, one of the MOSFETs is high side MOSFETs. In order to drive these switches IR2101 gate driver is going to be used [3]. The gate driver has an offset voltage of up to 600V, which exceeds our rectifier output voltage. IR2101 has logic high and low inputs. Such inputs will be generated by comparing a reference voltage with the desired voltage with a 555 timer. Hence, a PWM will be generated.

The rectifier diodes can be DHG 30I600 PA [5]. The MOSFETS in the buck converter can be IXFM35N30 [4].

3 Closed Loop Control

In the control subsystem, the rotor speed and the output current will be controlled in a closed loop. The block diagram is shown in Figure 8.

The rotor speed has to be measured for closing the control loop. It can be measured by using a Hall Effect Sensor. There are cheap sensors like A3144 which gives "LOW" as an output when it detects a magnet and vice versa. When it is put close to a magnet that is fixed on a rotating object, the sensor output could be used to interpret the rotor speed. The speed sensed as the output of the system is fed back to the system to close the feedback loop. A reference speed will be given to the control loop.

The block diagram consists of several blocks which are to be filled. There are several controller options to be chosen (PI, PID...) as the speed and current controller in the diagram.

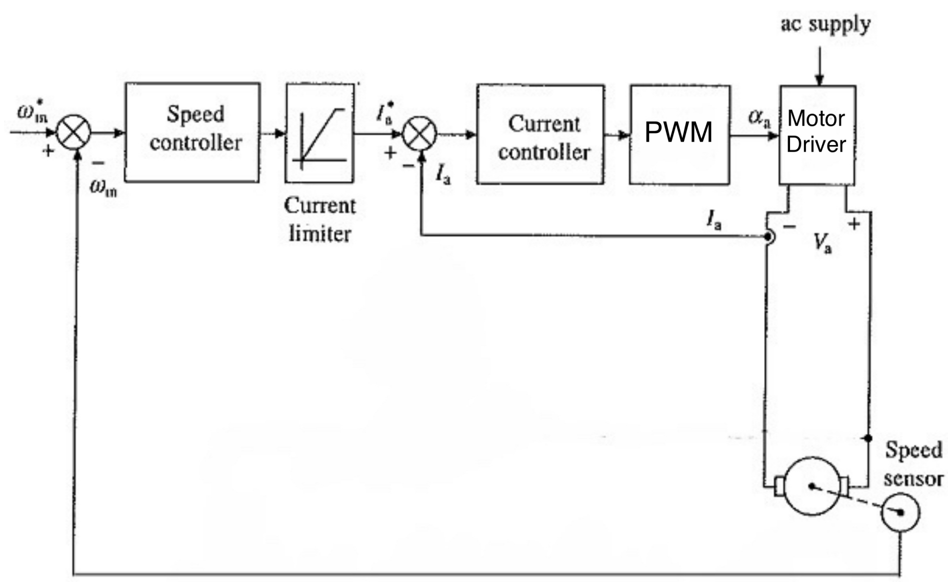

Figure 8: Caption

In the transient period, the motor will draw large currents. These large currents can go to higher values than the selected components' current ratings can compensate even with the safety margin. Therefore, a current limiting mechanism is needed to protect the component that is used.

A shunt resistor can be connected in series with the DC motor to sense the current for the current controller. When current passes through a shunt resistor, a small voltage is measured between its terminals. This voltage value can be used to interpret the output current. In the typical circuits of shunt resistors, this small voltage is usually used with an op-amp amplifier. This current signal is subtracted from the current limiter

The output of the current controller then adjusts the PWM waveform of the motor driver. By adjusting the PWM, large currents are avoided at the beginning. This method was used in the last lab of EE361, and we plan to do so in order to soft start the motor. EE361 lab blocks are shown in Figure 9.

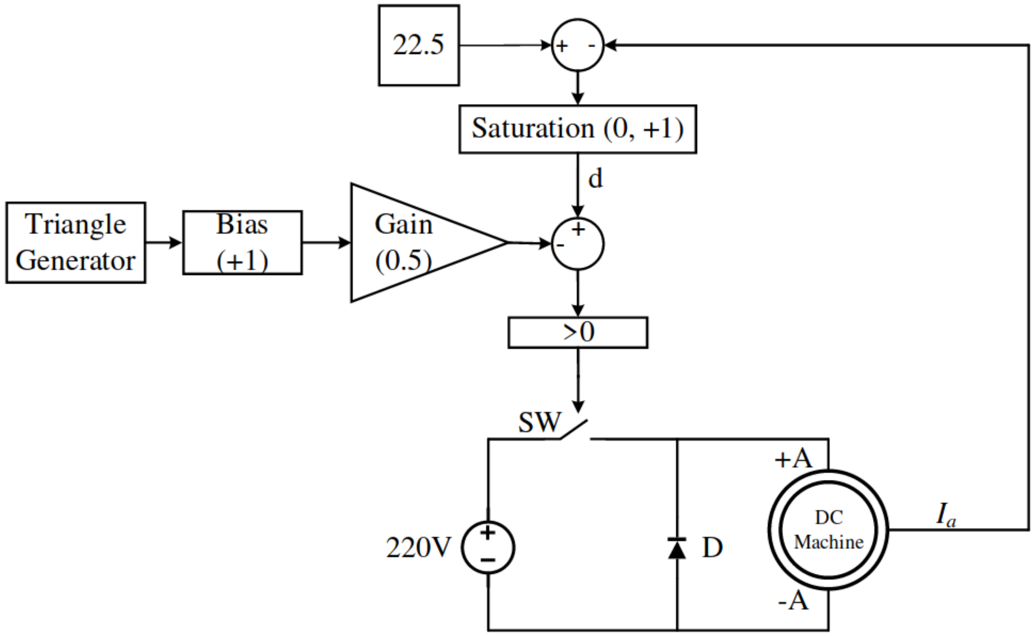

Figure 9: Starter circuit prototype

4 Four-Quadrant

The four-quadrant operation of the DC machine can be done by two methods. Either two antiparallel thyristor rectifiers are used or H-bridge is used. Since the thyristor rectifier is not chosen as the topology, H-bridge will be used. It is either that the H bridge will be after the buck converter or on its own as a voltage regulating module. In Figure 10, H-bridge is demonstrated.

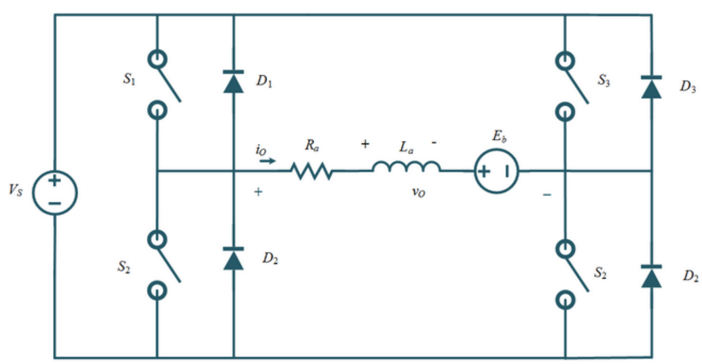

Figure 10: H bridge circuit with the motor model

Here, the switches are MOSFETs. It is obvious that each of these MOSFETs will have to stand the current passing through the motor. Therefore, it is a good idea to choose the MOSFETs according to the current rating of the motor, which is about 23A. Hence, IXFM35N30 [4] seems to be an appropriate choice, although a MOSFET with a less current rating may later be chosen so that the tightest rating bonus can be achieved.

The switches will once again be driven by IR2101 gate drivers.

5 Future Work

The project is currently under construction. We will finalize our components and circuitry. Then, we will redirect our focus to control methods. If possible, an analog controller will be implemented. Otherwise, the driver will be controlled by software. Moreover, PCB layouts and design will be done and PCB will be made using old IEEE-RAS techniques. Finally, single-supply bonus requirements will be analyzed and methods will be studied in detail.

6 References

[1] "On semiconductor is now." [Online]. Available: https://www.onsemi.com/pub/Collateral/AND9135-D.PDF. [Accessed: 10-Dec-2022].

[2] Alldatasheet.com, "A3144," ALLDATASHEET. [Online]. Available: https://pdf1.alldatasheet.com/datasheet-pdf/view/55092/ALLEGRO/A3144.html. [Accessed: 10-Dec-2022].

[3] "Data sheet no. PD60043 Rev - Infineon." [Online]. Available: https://www.infineon.com/dgdl/Infineon-ir2101-DS-v01_00-EN.pdf?fileId=5546d462533600a4015355c7a755166c. [Accessed: 10-Dec-2022].

[4] "IXFH40N30" [Online]. Available: https://cdn.ozdisan.com/ETicaret_Dosya/3561_3792109.pdf . [Accessed: 9-Dec-2022].

[5] "DHG 30". [Online]. Available: https://cdn.ozdisan.com/ETicaret_Dosya/352402_7529976.pdf . [Accessed: 10-Dec-2022]