

**MIDDLE EAST TECHNICAL UNIVERSITY**

ELECTRICAL AND ELECTRONICS ENGINEERING DEPARTMENT

EE 462-EE 464 COMMON PROJECT

Design of a SM-PMSM Variable Frequency Drive with MATLAB/Simulink

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Table of Contents

[1.Introduction 3](#_Toc77163377)

[2. Part A: Pre-design Stage 3](#_Toc77163378)

[1. 3](#_Toc77163379)

[2. 4](#_Toc77163380)

[3. Part B: Sinusoidal PWM 5](#_Toc77163381)

[1. 5](#_Toc77163382)

[2. 7](#_Toc77163383)

[3. 7](#_Toc77163384)

[4. Part C: Component Selection 8](#_Toc77163385)

[5. Part D: About the Project 8](#_Toc77163386)

# 1.Introduction

# 2. Part A: Pre-design Stage

## 1.

We can calculate the base speed of the PMSM from the calculation of voltage on MTPA. The base speed equation in d-q coordinates is written as follows:

In addition, Sinusoidal-PWM modulation is applied to the system. This means that the output voltage is half of the DC voltage.

Also, inductances in the d and q axes are equal to each other in SM-PMSM.

Another situation is that in case of MTPA there is only current on the q axis. The current value on the d axis is zero.

Moreover, flux linkage is given as shown below:

So:

The base speed we found above is electrical. A pole pair is required to find the mechanical base speed. The pole pair is found as follows:

The mechanical base speed is found by the equation given below:

There is a gearbox in the system, with a ratio of 8.5. With the help of the following formula, the mechanical shaft speed which is referred to as the vehicle speed is found.

In the project definition, vehicle speed is expected in km/h. Therefore, we must first multiply the velocity we found in rad/s by the radius. Then we have to multiply by 3600/1000.

## 2.

The maximum speed of the motor is given in the project description.

In order to find the maximum electrical frequency applied, we first need to find the mechanical frequency. So we need to find the maximum speed in rad/s.

Now that we have found the maximum speed in rad/s, we can calculate its frequency as shown below:

As is known, the electrical frequency is greater than the mechanical frequency. The ratio between them depends on the pole pair. The electrical frequency is found as shown below:

The frequency modulation ratio should be chosen as an odd value that is not too high to reduce harmonic effects. In electric vehicles, this ratio is usually chosen between 8 and 12.

As a result, choosing this ratio as 11 would be a good choice.

# 3. Part B: Sinusoidal PWM

In this part, we are expected to implement a motor drive using sinusoidal PWM (Sine-PWM), and implement a cascaded speed and current controller using parameters

## 1.

In this section , firstly , we need to calculate the equivalent inertia and the load seen at the electric machine shaft. Also, there is a single speed gear box connected between electric motor and wheels with 8.5 gear ratio.

The equivalent inertia is found as follows :

We know the inertia on the wheel. But this inertia is on the load side. Therefore, we need to transfer this to the electric machine side with the gear ratio. We can do this as follows:

Now we need to calculate the inertia of the vehicle. Since the result we found will be on the load side, we need to transfer it to the electric machine side with the gear ratio.

Since all inertia values are found and transferred to the electric machine side, the equivalent inertia is as follows:

The load characteristics of the vehicle are given in the project description. Here is given as shown below.

However, we need to calculate the load torque seen at the electric machine shaft. So, to obtain load torque expression, we should multiply the expression of the load force by radius.

## 2.

## 3.

In this part, first of all, we need to find out in which region our electric motor operates. First of all, we need to find the speed of the vehicle in rad/s and compare it with the base speed. In this way, we can determine in which region it works. If the speed of the vehicle is higher than the base speed, it means that it is operating in the field weakening region. If it is lower than the base speed, it means that it is working in the base speed region. Firstly, we need to convert the speed given in km/h to rad/s.

Now we need to transfer the speed we found to the motor side with the gear ratio.

We previously calculated the base speed. The base speed we found is 342.857 rad/s. We found the speed of the motor as 472.26 rad/s. As it can be understood from here, the speed of the motor is higher than the base speed. Obviously motor is operating in a field weakening region.

Also, we can find by multiplying by the pole pair:

In other words, considering the given conditions, the engine must operate in the field weakening region in order for the vehicle to drive at 60 km/h. It will not be enough to apply only current for the vehicle to drive at this speed. That's why we need to apply current to the system. Since the current is 0 in the base speed region, the vehicle will not be able to reach this speed. As a result, the motor operates in the field weakening region and by applying current along with the current in this region, we ensure that the vehicle drives at the given speed. As a result of this analysis we have done, we need to find and currents. As it is known, the vehicle here is driving at half of the rated torque. So the current will also be halved. current is as shown below.

We can also find the current with the formula given below:

Considering the above analysis results and conditions, we apply 265 A as current and current in the opposite direction to the motor operating in the field weakening region, so that the vehicle can drive at the desired speed.

# 4. Part C: Component Selection

# 5. Part D: About the Project