Final Project Report:

# Introduction:

## MTPA Control:

Maximum Torque Per Ampere (MTPA) control, is a method of motor control in which the maximum torque possible is achieved based on the provided current input. This is achieved by selecting “MTPA points”, in order to achieve maximum efficiency. These points are selected by optimizing the current flow and magnetic flux produced through the motor, choosing the point with the highest efficiency. By choosing the point with the highest efficiency, you are able to produce the highest torque available for the given reference current. The primary goal of MTPA is to achieve maximum efficiency, therefore performance in terms of overall torque output will be reduced compared to other methods that prioritize this.

This type of motor control is an excellent choice for automotive applications. Range, battery longevity, and price are common issues seen with electric vehicles. Improving the efficiency of your motor is one method of resolving these. The higher the efficiency, the less power draw is required from the EV’s battery, therefore increasing the range achievable from a single charge. MTPA also reduces overall peak currents seen by the motor by nature of minimizing the current needed to achieve the desired torque. This in turn can lead to smaller gauge wires needed throughout the vehicle reducing weight, in turn with being able to reduce battery pack size to achieve the same range, vehicle efficiency improves even more due to less torque being needed to accelerate.

## Problems With MTPA Control:

The largest problem with MTPA is the reliance on accurate motor parameters and motor feedback. MTPA points are typically calculated using motor speed, and while in theory this works without problem, in application there are many issues that come as a result. When calculating points, any offset between the reported motor state and the actual will cause significant problems in the optimization strategy as the resultant currant command may not be minimized properly. These offsets can happen for many reasons including temperature, manufacturing inconsistencies, noise from measurement devices, and normal wear over the lifespan of the motor. Other problems include operating in non-linear conditions, such as extreme speed ranges (both low and high).

## Solution Proposed:

To counter these problems, the following paper [] proposes a solution to account for these errors. Their solution is to apply a sinusoidal signal injected directly into the reference currents. This signal is meant to account for any errors in the calculated reference current and more accurately represent your specific motor’s parameters. This method is done with the following equations:

A diagram of a circuit

Description automatically generated

The injected signal (sinwht) is applied separately to each of the dq axis currents, acting as an offset. It then goes through a series of filters, ensuring no noise or other offset is applied in the process, creating more error. It is important to note that the signal applied is calculated using the Idc currents rather than motor speed (seen in ). This calculation avoids losses associated with transformations to polar coordinates, as well as the reliance on high resolution voltage or speed sensors. The paper proposes an injection frequency (wh) of 160Hz, and an injection gain (A) somewhere between 0 and 0.008.



There are however some concerns with this method. Due to the signal injection being sinusoidal, if the injected signal is not tuned properly, the system can undergo heavy oscillations and reduce the efficiency rather than improve it due to the lack of stability. As for tuning, the system as many parameters to be tuned, including the multiple PI controllers, 2 filters, the injection frequency, and the injection gain. Due to the purpose of this method, each of these parameters must be tuned to your exact machine, even if they are the same make and model, due to noise or error in the system varying between them. This can be a time-consuming process and if not done properly, the performance will be worse than without the injection. Another concern is the injection frequency recommended. Due to the model running in the order of KHz, the recommended 160Hz may be too slow to consistently improve the MTPA points.

# Methodology:

## Implementation:

This strategy was implemented in MATLAB/Simulink branching off of the lab 3 model provided.

A graph with a line

Description automatically generated with medium confidence

A red line in a white grid

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A computer diagram of a computer

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## Results:

### Baseline: PI, GVSI = 1

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A graph with a red line

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A diagram of a graph

Description automatically generated with medium confidence

### Baseline: PI, with inverter

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A graph with red and blue lines

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A diagram of a machine

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### Baseline: MPC, GVSI = 1

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Description automatically generated with medium confidence

A graph with a red line

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A diagram of a machine

Description automatically generated

### Baseline: MPC, With inverter

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A graph with red and blue lines

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A diagram of a graph

Description automatically generated with medium confidence

### Baseline: MPC, with injection

A = 0.03, wh = 160

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A diagram of a machine

Description automatically generated with medium confidence

### Baseline: MPC, with injection

A = 0.03, wh = 1000

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A red and blue line

Description automatically generated

A diagram of a machine

Description automatically generated with medium confidence

### Baseline: MPC, with injection

A = 0.08, wh = 1000

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A screenshot of a computer program

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### Baseline: MPC, with injection

A = 0.08, wh = 10000

A graph with a line

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A screenshot of a computer program

Description automatically generated

### Baseline: MPC, with injection

A = 0.08, wh = 10000, tp = 200e-6

A graph with a line

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### Baseline: MPC, with injection

A = 0.1, wh = 10000, tp = 200e-6

A graph with a line

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A screenshot of a computer program

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# Discussion and Conclusion: