Introduction

Passenger and commercial vehicles play a large part in environmental degradation. The transportation sector accounts for the largest portion (29%) of total U.S. GHG emissions. The majority (82%) of these emissions come from passenger cars and commercial trucks. While the contribution to environmental damage is undeniable, cars are so deeply rooted in American culture and identity that we will not soon see a shift away from passenger automobiles. Globally, the number of passenger cars is expected to increase from approximately 1 billion in 2015 to around 1.7 billion in 2030 and 2.4 billion in 2050. By 2050 it is expected that developing countries will own over three-quarters of the world’s vehicles, compared with slightly less than half in 2015. We need to meet the demand to move people and goods without exacerbating environmental damage. One part of the solution to this is transitioning away from gasoline and diesel-powered cars and trucks to electric power. There are several parameters that are affecting the performance of electric vehicles including powertrain and battery management strategy.

This project focuses on development of firmware to control MMCS as an ac power supply for a three-phase motor. The program uses MPC to generate required outputs to be used by an existing code. The controller accounts for non-linearities and has a fast dynamic response for required speed changes.

Methodology

Modular Multilevel Converters

Modular Multilevel Converters (MMCs) act as an ac power supply for the 3-phase induction motor. In this project, an MMC scheme with single phase full bridges has been used for each phase. The MMC generates a desired voltage \( V_{0 \rightarrow n} \) from separate dc sources. Each dc source is connected to a full bridge converter. By changing the state of switching devices, each converter can output \( V_u \), \( 0 \) and \( -V_u \). The output of the modules are connected in series to generate a near sinusoidal voltage with \( 2n+1 \) voltage levels, where \( n \) is the number of modules.

Model Predictive Control

In order to predict the required current, the measured motor velocity is compared to the reference velocity and the error is the input to the Proportional Integral Derivative (PID) controller. The output of this controller is the torque that is required by the MTPA block to find reference currents in d-q axis. An explicit model of the IPM motor can be used to predict future responses of the motor. The MPC scheme uses reference currents to predict future currents and minimize the cost function. The output of this stage is the PWM signals to drive the MMC.

Analysis and Results

In the flowchart below, \( m \) is an intermediate variable that changes from 0 to 2n where \( n \) is the total number of cells. In every cycle, currents for all three phases are being measured and converted to d and q axis currents. In the next step, future values of d and q currents are predicted for all possible values of voltage levels \( V(m) \).

\[
V(m) = V_{0 \rightarrow n}[-2n, 0, 2n]
\]

\( f(m) \) represents the cost function matrix for every voltage level. The m for minimum cost function is the total required number of levels (1) and \( V(f) \) is the required MMC voltage output.

To test the controller independently, data from a previously developed Simulink simulation were used as the input to the system. The input values for the MPC are reference current, measured current, back emf and rotational position. The input data from the simulation was saved as a .csv file and imported as the input of the system. The controller were imported from a previously developed Simulink Model. Results from Simulink and test data agree.

Acknowledgements

I would like to thank Dr. Mohamed Badawy for his guidance and support throughout this project.

I would also like to thank my teammates, Zack Smith and Xavier Ascate, for helping me with code development and testing.