Jackson Daniel, Graduate Intern
Mechanical Engineering
University of Missouri – Kansas City
Mentor: Peter Suh
Code: 530 Dynamics and Controls

Permanent Magnetic Synchronous Motor (PMSM) Model Development

Overview

The Advanced Air Transport Technology (AATT) Project seeks to enhance the capabilities of fixed-wing subsonic transport through improved energy efficiency and environmental compatibility. One element of this effort is the use of high efficiency PMSM systems. Understanding the behavior and limitations of these motors allows the National Aeronautics and Space Administration (NASA) to collaborate with and inform its partners worldwide. PMSM modeling is achieved using MATLAB® - Simulink® (The MathWorks, Inc., Natick, Massachusetts). Through the analysis of an existing high-fidelity NASA Electrical Aircraft Testbed (NEAT) model, simplified models of varying fidelity can be developed with the goal of building a PMSM model capable of running in real-time for use in a piloted simulation environment. By utilizing system identification methods, it has been demonstrated that internal electrical components like the inverter can be represented by a simple variable gain thus greatly reducing the required simulation step size and subsequently decreasing model run-time by multiple orders of magnitude.

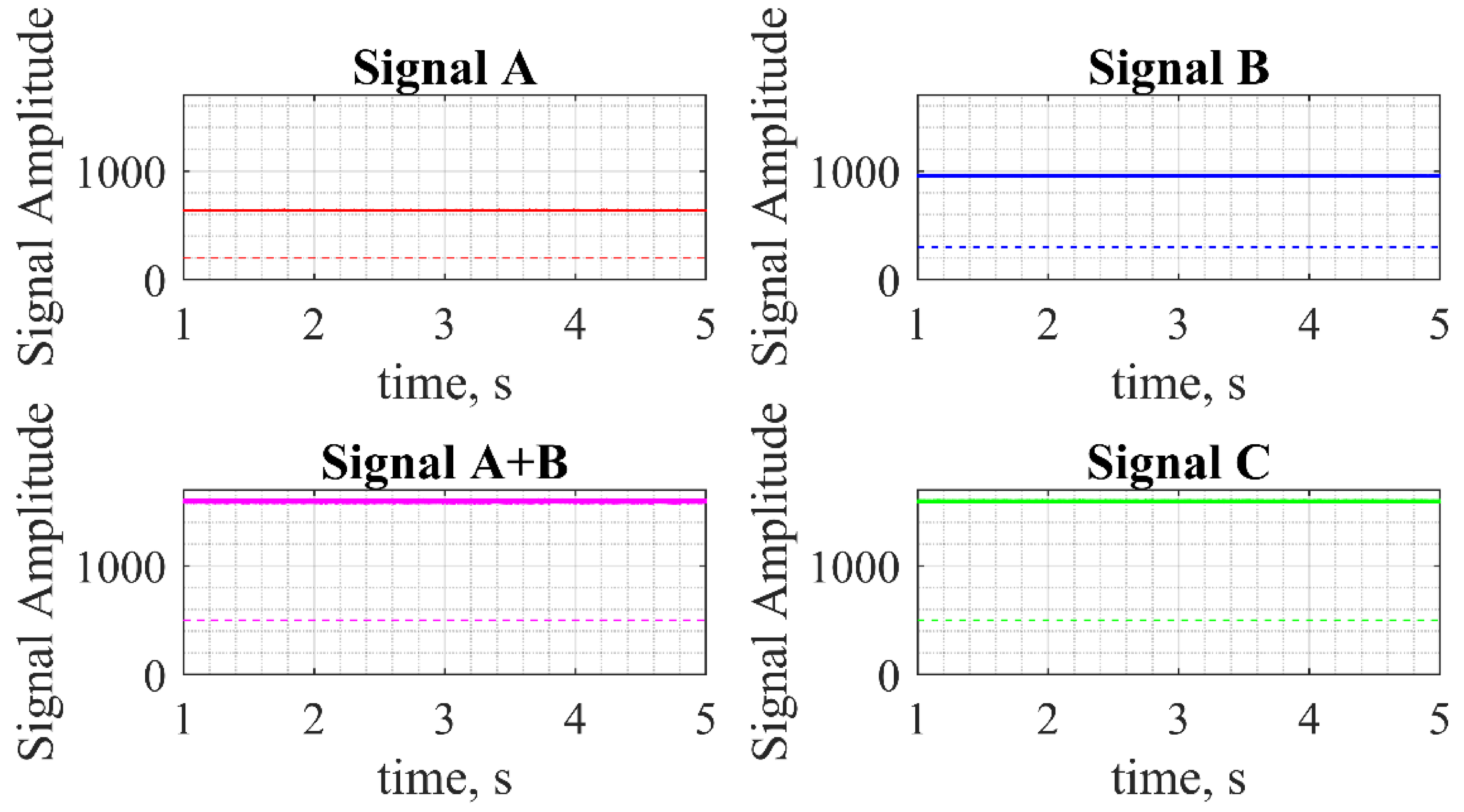

Figure 1. Superposition principle applied to inverter input (dashed) and output (solid)

Component Analysis

Through the investigation of the input parameters of the supplied (NEAT) model, it was determined that the chief contributor to excessive run-time was the three-phase inverter component. By nature of its operation, a step-size of 0.5 microseconds was required. Literature review suggested that the inverter could be represented by a simple first order filter with a gain dependent upon maximum control voltage and supplied battery voltage.

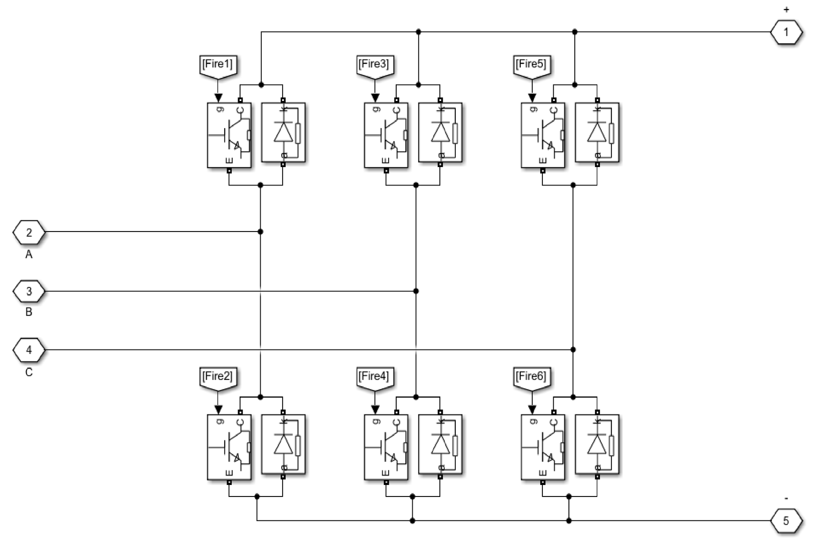

Figure 2. NEAT three-phase inverter

Initial analysis of the inverter based upon an approximation as a first order filter required a demonstration that the inverter behaves in a linear manner. Prior work indicated that the inverter's frequency response appeared to be linear. By testing a variety of input signals, it was shown that the inverter adhered to the principles of scaling and superposition thus indicating linearity. An example of the applied approach is shown in figure 1.

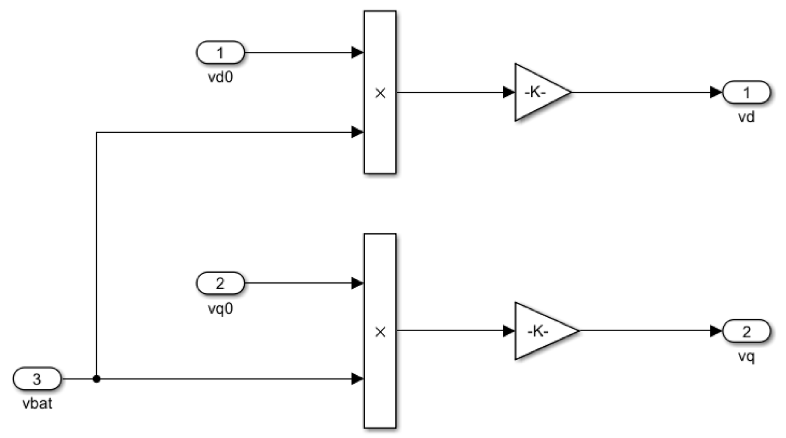

Figure 3. Simplified inverter

Using a variety of system identification methods including multisine and frequency sweep excitation, inverter gain variation could be demonstrated as a proportion of the battery voltage. However, attempts to excite the system above the suggested cutoff frequency in order to visualize the anticipated first-order roll-off behavior failed because the inverter ceased to function above the suggested frequency. Because of this, it was determined that the inverter could be represented not as a first-order filter, but as a variable gain dependent upon supplied battery voltage. Thus the NEAT electrical subsystem shown in figure 2 could be modeled by the simple variable gain structure shown in figure 3.

Ongoing and Future Work

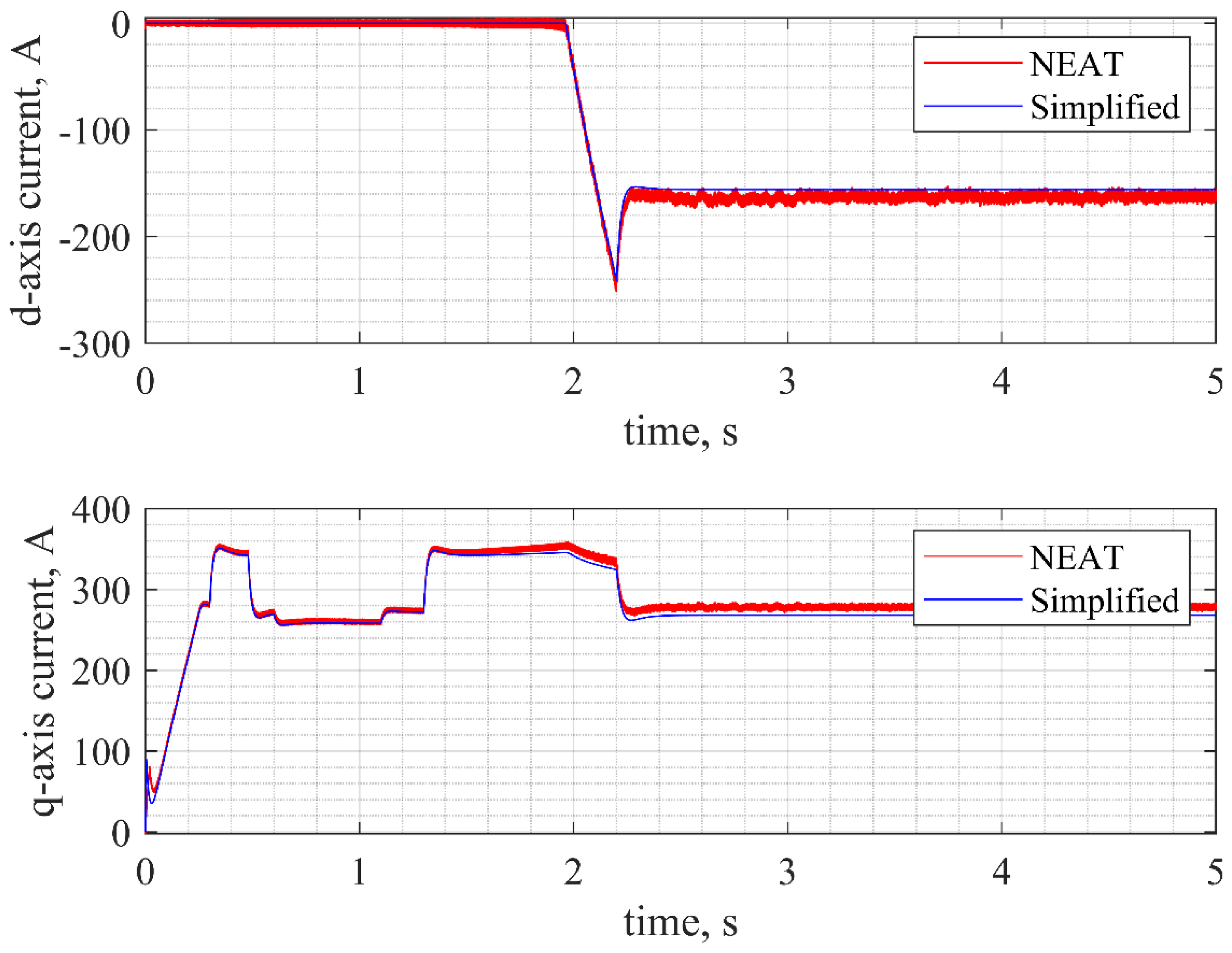

Figure 4. NEAT vs. simplified model current along principal axes

A key element of PMSM operation is system behavior within the flux-weakening region, an area wherein there is constant power but torque decreases as motor speed increases. Due to the non-linear nature of flux-weakening, investigation needed to be made as to whether the simplified inverter is valid within that region. As shown in figure 4, the stator current along the d-axis and q-axis in flux-weakening operation matches closely between the NEAT model and the simplified model. This suggests that the simplified non-linear model including the simplified inverter is suitable for implementation in a simulation environment. Investigation into the viability of a fully linearized model in order to perform control design and stability analysis is ongoing.