A Fuzzy Logic-Based Gain tuner for Energy-Efficient Control of Brushless DC Motors

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Abstract

Brushless DC Motors (BLDCM) are fast outstripping their commutator-driven predecessors as the future of electric motors. Their implementation in electric vehicles and unmanned aircraft has shown such promise that BLDCM are even working their way into industrial settings. To this end, the goal is always to find more cost/energy-effective strategies to drive and control these motors. Improving BLDCM's response characteristics such as speed and torque control also has its place in academic pursuit and has been traditionally undertaken using PID controllers. By following the process outlined in the other papers, this paper provides an insightful approach to acquire a Fuzzy Logic Tuner (FLT) to make the PID controller more robust using a feedback loop to adjust the gain constants K_p , K_i, and K_D thereby lessening the torque stress and current draw under varying conditions of load application. By modeling in Simulink, we will show that the FLT applied PID controller will reduce M_p (percent overshoot) and t_s (settling time), which has direct effect in its energy usage. As this system is a modification of a stable system, we will be less concerned with system stability and more focused with using dynamic modeling to improve response characteristics.

Background

- While ubiquitous, PID controllers do not provide maximum efficiency under dynamic load conditions.
    - Fuzzy Logic Tuners offer non-linear weight flexibility, therefore rigid instruction sets are not required
    - This benefit can be easily placed into the system without disrupting the control loop

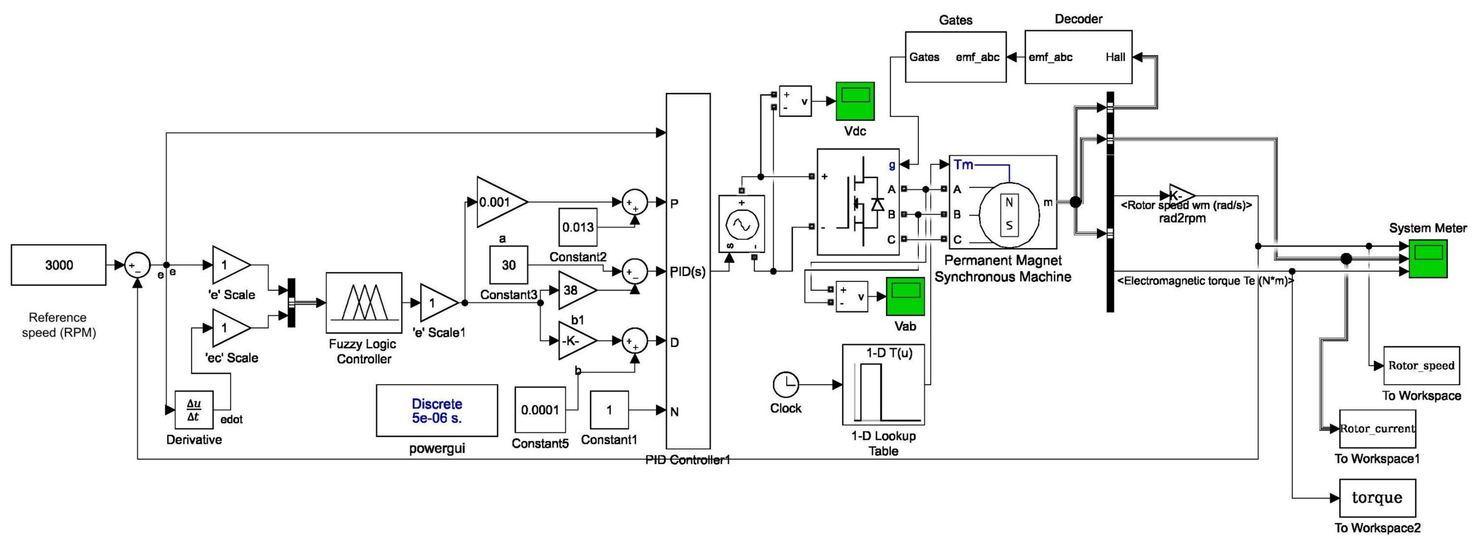
Objectives

- Implement Fuzzy Logic – Gain Tuned PID for BLDCM
- Show that characteristics such as M_P (Percent Overshoot), Peak Current Draw, t_s (Settling Time), and t_r (Rise Time) can be manipulated by FLC-PID
- Determine tuning parameters and Fuzzy Logic membership functions which will maximize energy-efficiency

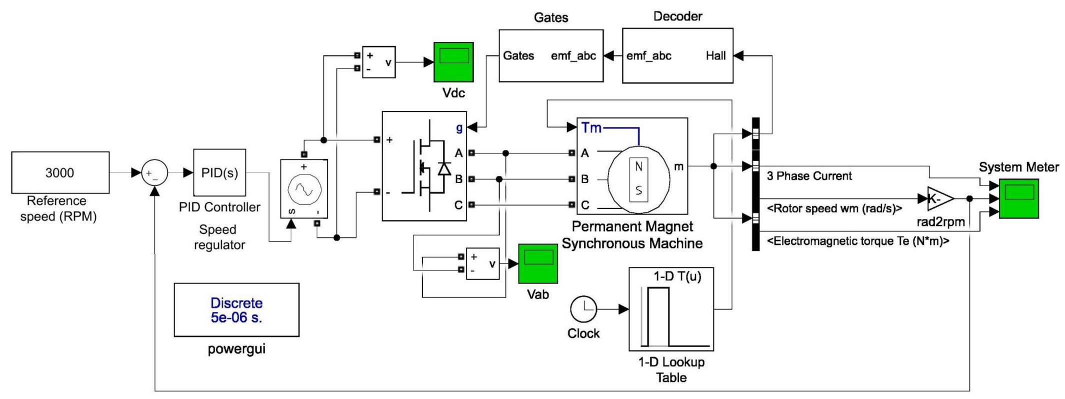
Fuzzy Tuned PID Model

- A Base model with standard PID tuning was created for a control
- An architecture for the Fuzzy Logic Controller was designed and implemented
- FLC membership functions and signal gains were tuned for optimal performance

Fuzzy Tuned PID Model



Standard PID Model

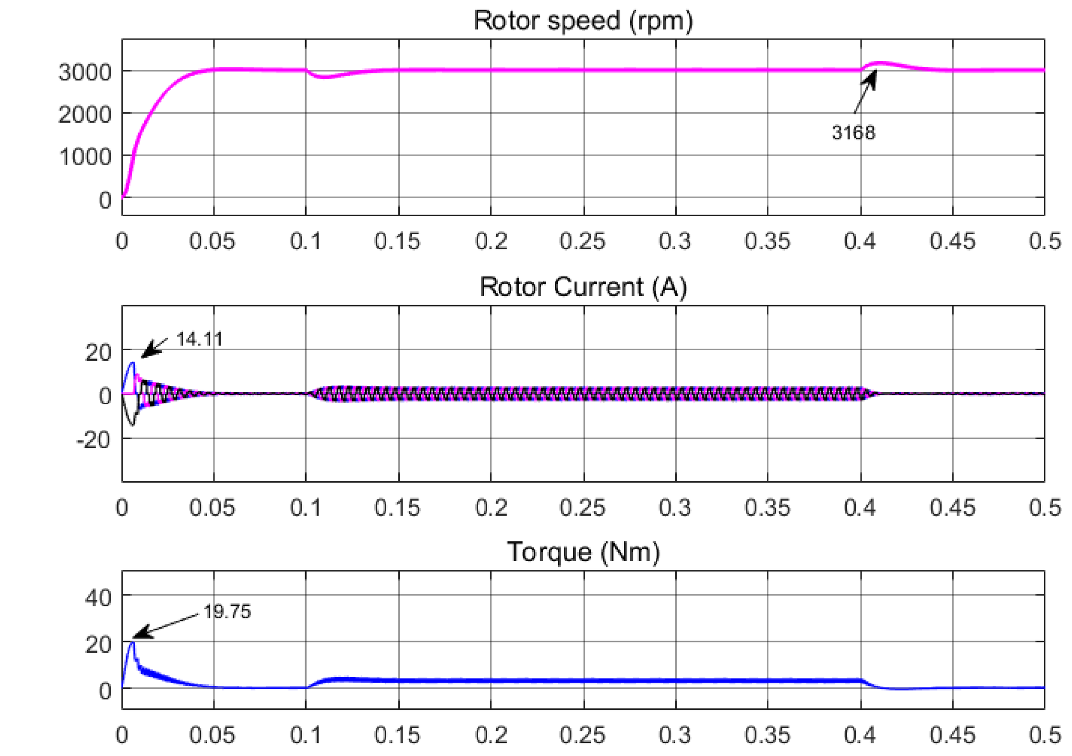


Results

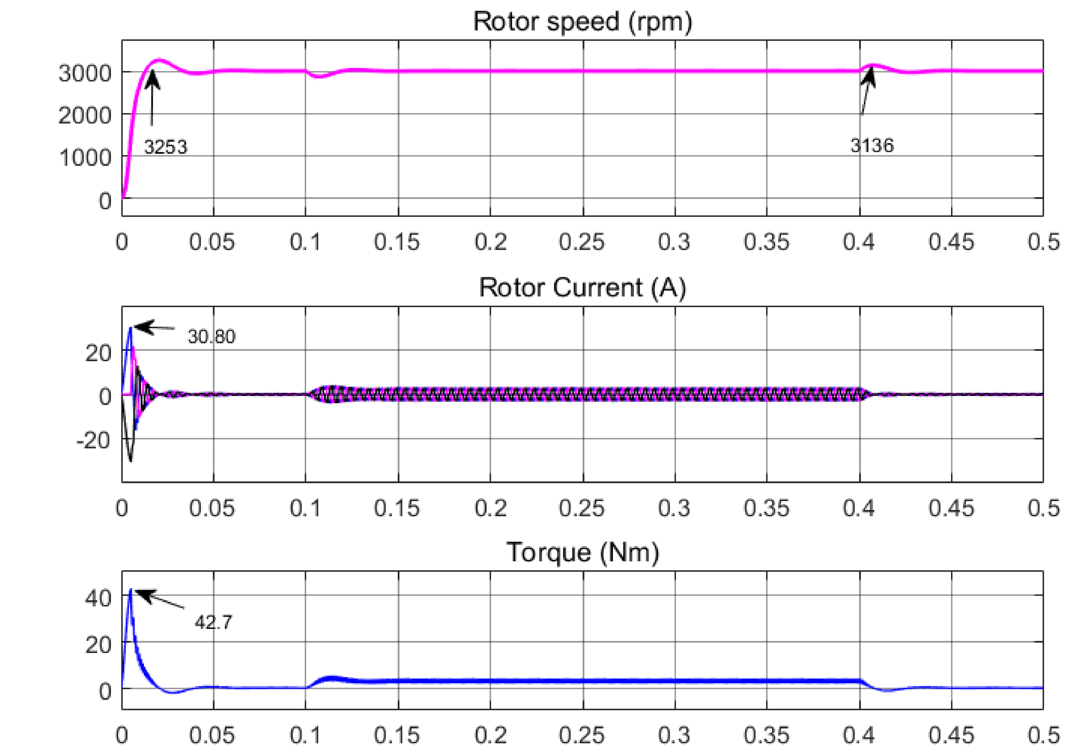
- 7.9% Reduction of M_P
- Peak current down from 30.8A to 14.1A
- Under step load conditions T_s is lowered by 0.005s
- Increase of t_r by 0.018s

Results

Implementing Fuzzy Controller



Without Fuzzy Controller



Conclusions

- Significant Reduction in Power Usage
- Mechanical Strain on Motor more than ½ as measured by Torque
- More Robust under Dynamic Conditions