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Redesign and Control of a Trolley Propulsion System with a PMSM using FOC

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1. Introduction

The popularity of hoverboards (or segboards) has driven down the price of their driving PMSM units. This is a comparably efficient, high torque, low speed unit, which makes it interesting to investigate whether it could be used to improve the propulsion system of the battery powered MixFeeder by GEA Mullerup, illustrated below:

With point of departure in the propulsion system of the automated cow feeding system (MixFeeder) by GEA Mullerup, the feasibility of implementing a PMSM solution is investigated in terms of efficiency, the number of PMSMs and the amount of maintenance requiring components.

2. Mechanical & Electrical Design

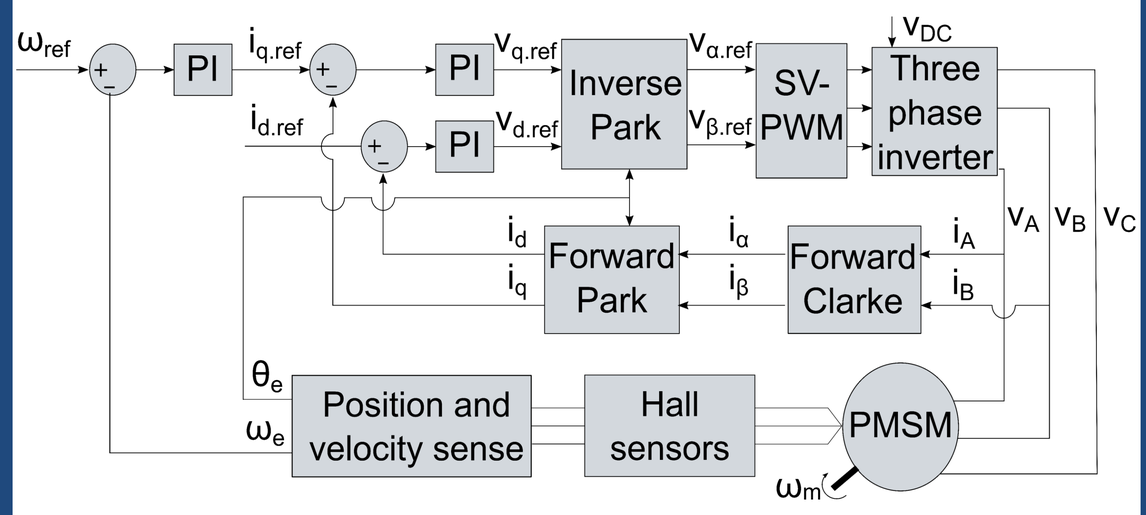
Three power transmission methods are considered, and a direct drive is chosen for its possibility of low power losses and few components. The prototype is seen below. A flexible coupling is designed in order to allow a slight misalignment of the driving wheel and the PMSM.

An inverter is designed according to the chosen Three-Phase Gate Driver (DRV8353RH) datasheet design guide by TI. Unfortunately, the produced inverter is faulty, and the trouble-shooting has been unsuccessful.

3. Control of the PMSM

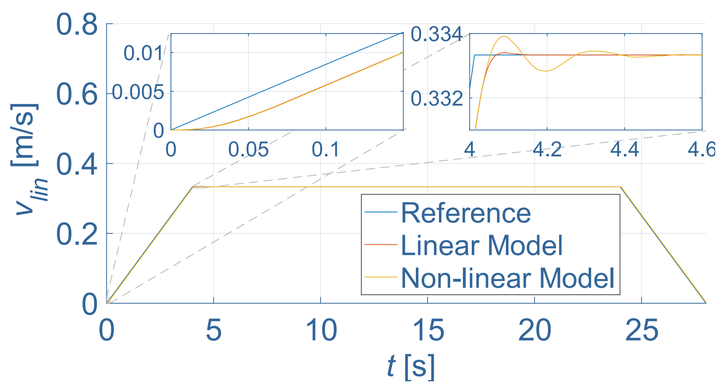
Field Oriented Control (FOC) is the control method used in this project, which has the capability of a smooth and precise control of the machine. Its principle is based on manipulating the measured currents in a rotating reference frame in order to generate reference voltages, which will be applied to the machine terminals. These voltages will generate a net magnetic field vector in the stator that will be orthogonal to the one from the rotor, providing maximum torque. The transformations used for going from the stationary (ABC axes) to the rotating (dq axes) reference frame are called Clarke and Park transformations.

The control structure is based on a cascade scheme, with an inner current and an outer velocity loop. In order to satisfy the control requirements, PI controllers are designed for the linear model of the system. Afterwards, these are validated on the non-linear system. The FOC structure is depicted in the following figure.



4. Results

Based on the developed control structure, the amount of PMSMs are swept from one to eight while updating the controllers, yielding different efficiencies for the defined velocity reference curve. Based on this, four PMSMs are chosen for driving the MixFeeder, yielding an efficiency of approximately 60 % for the linearized model as opposed to the assumed 38 % of the MixFeeder propulsion system. The dynamic response of the linear and non-linear systems is depicted to the right, without implementation of the hall sensor feedback. As seen, the reference tracking is highly satisfactory, though it is deemed that especially the hall sensors will introduce a large phase lag upon implementation.



5. Conclusions

In conclusion, it is feasible to replace the original propulsion system of the MixFeeder with the designed direct drive, if four PMSMs are used. This will presumably yield an increased efficiency and a reduction of the amount of wearing parts. This conclusion is drawn without practical implementation as the produced inverter did not function.

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