Accepted Manuscript

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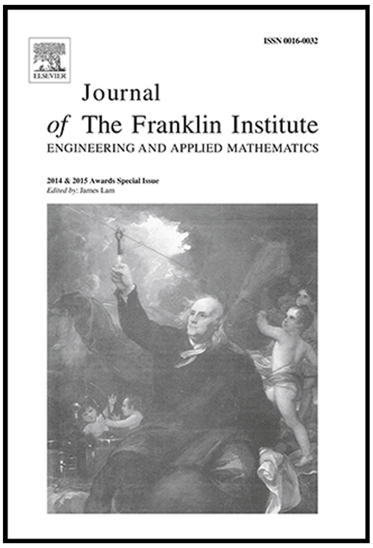

PII: S0016-0032(17)30344-7
DOI: 10.1016/j.jfranklin.2017.07.030
Reference: FI 3069

To appear in: *Journal of the Franklin Institute*

Received date: 6 May 2016
Revised date: 9 April 2017
Accepted date: 5 July 2017

Please cite this article as: Sabin-Constantin Carpiuc, Corneliu Lazar, Modeling of synchronous electric machines for real–time simulation and automotive applications, *Journal of the Franklin Institute* (2017), doi: 10.1016/j.jfranklin.2017.07.030

Modeling of synchronous electric machines for real–time simulation and automotive applications

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Abstract

Recent research in the field of vehicle electrification has indicated that synchronous machines, which include the permanent magnet synchronous machine (PMSM) and the externally excited synchronous machine (EESM), represent a viable solution for electric propulsion. A challenging problem for synchronous machines drives employed in automotive applications is to obtain accurate mathematical models which can deal with parametric variation and which are suitable for real–time simulations and synthesis of control laws. The goal of this paper is to provide a mathematical modeling framework for synchronous machines that can answer to this challenging problem. To this end, using the rotor reference frame, the mathematical models of PMSMs and EESMs are constructed taking into account also the parametric variation due to magnetic saturation and temperature variation. Then, a complex state–space bilinear model for both EESM and PMSM with parametric variation due to magnetic saturation and temperature are developed. Considering the parametric variation as a polytopic bounded disturbance, it is then shown how to split the bilinear complex model in two PWA variable parameter state-space models suitable for a cascade control structure. Based on the developed models, a dynamic unified simulator was constructed in Matlab®/Simulink®. Measurement data obtained in a real test–bench system were used to verify the accuracy of the simulator. The discrete–time simulator was then integrated in an industrial hardware–in–the–loop test bench for real–time evaluation of a current control scheme in EESM drives.

Keywords: synchronous machine, rotor reference frame, state–space model, nonlinear model,