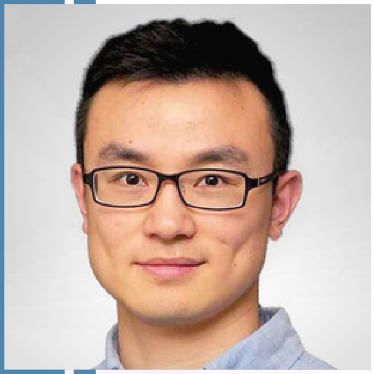

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ITEC2021

BIO

Dakai Hu is an application engineer at MathWorks supporting customers adopting Model-Based Design for motor and power controls. Prior to joining MathWorks, Dakai worked for Emerson Network Power on the controller design of 400 kVA to 1600 kVA uninterruptible power supplies. Dakai received his Ph.D. in electrical engineering from Ohio State University. While studying at OSU, he published five first-author conference and journal papers, with topics related to motor control and hardware-in-the-loop simulation designs.

ABSTRACT:

Calibrating Optimal IPMSM Torque Control with Flux-Weakening Using Model-Based Calibration

Calibrating the control of an e-motors is a required step in the design of a high-performance electric traction drive. Traditionally, the calibration process involves extensive hardware dynamometer (dyno) testing and data processing, and its accuracy depends largely on the expertise of the calibration engineer. Model-based calibration is an industry-proven workflow designed to optimally calibrate complex nonlinear systems using statistical modeling and numeric optimization. Compared to traditional calibration procedures, which usually involve heavy scripting and an unnecessary amount of testing, the model-based calibration workflow is an automated and robust approach that can deliver consistent results within minutes.

PMSM Calibration: Challenges and Requirements

Among all types of e-motors, IPMSM stands out with high efficiency and torque density. This is because the permanent magnets inside the machine can generate substantial air gap magnetic flux without external excitation. This special trait makes IPMSM an excellent candidate for both non-traction and traction motor drive applications.

Most non-traction PMSM applications only require the machine to operate in the constant torque region, where its control scheme is relatively straightforward. Traction IPMSM control, in addition to fast dynamic response, also requires accurate torque output and wide constant power-speed range operation. To achieve these control goals, particularly in an electric or hybrid electric vehicle, the traction IPMSM must operate in the flux-weakening region, where trade-offs need to be made between torque, speed, and efficiency.

To design high performance IPMSM drive controls, IPMSM characterization tests often need to be performed on actual hardware using a dyno setup or through an FEA tool like ANSYS Maxwell or JSOL JMAG. Then, based on the characterization data, optimal flux-weakening control lookup tables can be calculated to achieve specific control goals.

Here we need to distinguish IPMSM characterization from calibration. IPMSM characterization refers to performing a series of tests either on a dyno or using an FEA tool, with the goal to extract important machine information such as flux linkage and torque. IPMSM control calibration means calculating controller lookup tables that will generate maximum torque or optimal efficiency at different operating points. The control calibration process usually happens after IPMSM characterization, and both processes are required for high performance IPMSM control design.

Applied to PMSM control calibration, model-based calibration involves four steps:

1. Design the experiment for characterization.
2. Preprocess the PMSM characterization dataset.
3. Fit PMSM characterization models.
4. Optimize PMSM controller lookup table data.