Dynamic Modeling, Simulation, and Control of Electric Motor Drives for Automotive Motion Control Applications

SPEAKERS

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SUMMARY

Safety critical, high performance motion control systems, particularly those employed in automotive applications such as electric power steering, employ electric motor drive systems that are expected to meet stringent dynamic performance requirements in terms of torque tracking performance, disturbance rejection, robustness and noise, vibration, and harshness (NVH).

ABSTRACT

Safety critical, high performance motion control systems, particularly those employed in automotive applications such as electric power steering, employ electric motor drive systems that are expected to meet stringent dynamic performance requirements in terms of torque tracking performance, disturbance rejection, robustness and noise, vibration, and harshness (NVH). Due to the cost sensitivity of such applications, the sizing of both the power converter and the electric motor is typically marginal, thus requiring dynamic controllers that can ensure optimal performance throughout the expected operating range of the vehicle. Torque control of electric motor drives is typically achieved via dynamic current control that involves either feedback regulators or feedforward controllers.

This tutorial covers the design variants, embedded software implementation and tuning methodologies utilized for the development of control architectures for the dynamic current control of permanent magnet synchronous motor drives, under both linear and voltage saturated (non-linear) operation. Precise mathematical models describing different machine design and power converter topologies and are presented first, followed by a detailed description of strategies for the design of current controllers as well as anti-windup schemes that dominate performance under saturated operation, to achieve desired electric drive system control performance characteristics. Estimation of four quadrant dynamic torque-speed characteristics is discussed considering system level constraints including supply voltage and supply current limits.

The effects of non-idealities in system due to manufacturing issues along with effect of errors in current and rotor position sensing on current regulation and torque control is presented. The embedded software implementation of the controllers is covered next, and this section explores digital loop rate selection in a multi-loop rate system, effects of PWM and sensor delays, and controller architectures and the tutorial is concluded with deriving performance metrics such as torque ripple, average torque, software throughput etc. that are used to assess drive performance.