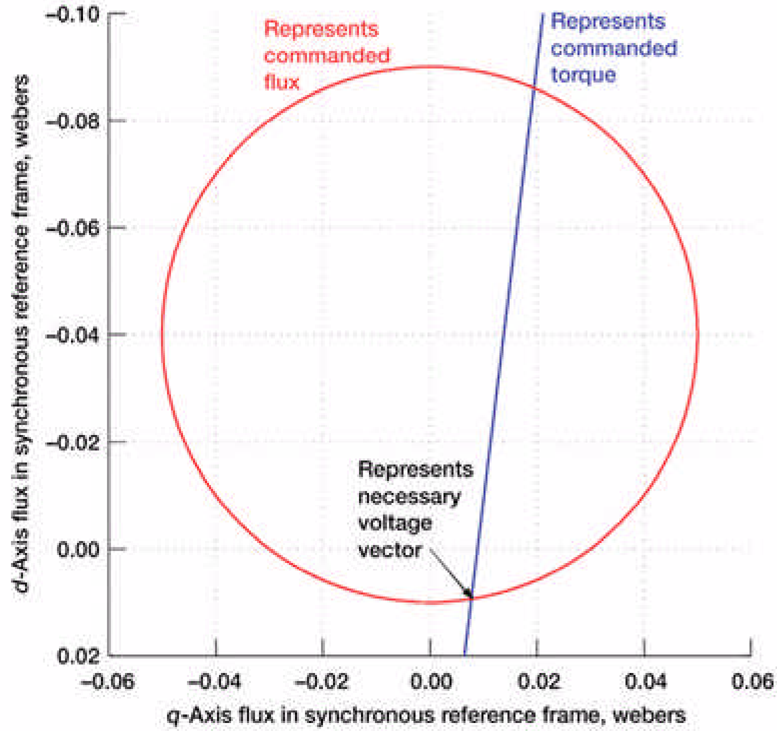
New Technique of High-Performance Torque Control Developed for Induction Machines

Two forms of high-performance torque control for motor drives have been described in the literature: field orientation control and direct torque control. Field orientation control has been the method of choice for previous NASA electromechanical actuator research efforts with induction motors. Direct torque control has the potential to offer some advantages over field orientation, including ease of implementation and faster response. However, the most common form of direct torque control is not suitable for the high-speed, low-stator-flux linkage induction machines designed for electromechanical actuators with the presently available sample rates of digital control systems (higher sample rates are required). In addition, this form of direct torque control is not suitable for the addition of a high-frequency carrier signal necessary for the "self-sensing" (sensorless) position estimation technique. This technique enables low- and zero-speed position sensorless operation of the machine. Sensorless operation is desirable to reduce the number of necessary feedback signals and transducers, thus improving the reliability and reducing the mass and volume of the system.

This research was directed at developing an alternative form of direct torque control known as a "deadbeat," or inverse model, solution. This form uses pulse-width modulation of the voltage applied to the machine, thus reducing the necessary sample and switching frequency for the high-speed NASA motor. In addition, the structure of the deadbeat form allows the addition of the high-frequency carrier signal so that low- and zero-speed sensorless operation is possible.

The new deadbeat solution is based on using the stator and rotor flux as state variables. This choice of state variables leads to a simple graphical representation of the solution as the intersection of a constant torque line with a constant stator flux circle. Previous solutions have been expressed only in complex mathematical terms without a method to clearly visualize the solution. The graphical technique allows a more insightful understanding of the operation of the machine under various conditions.



Voltage vector solution to a commanded torque and stator flux.

The figure shows the graphical solution for a given operating condition and commanded torque and flux. The vector drawn from the origin to the intersection of the line and the circle represents the voltage vector to apply to the machine to achieve the commanded torque and flux. In the control algorithm, the required voltage vector is summed with the high-frequency carrier signal voltage and the total is synthesized by pulse-width modulation of a constant direct-current voltage. The result is a high-performance sensorless torque control suitable for a high-speed induction machine.

Bibliography

1. Kenny, Barbara H.; and Lorenz, Robert D.: Stator and Rotor Flux Based Deadbeat Direct Torque Control of Induction Machines. NASA/TM-2001-211100/REV1, 2002.

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Glenn contact: Dr. Barbara H. Kenny, 216-433-6289, Barbara.H.Kenny@nasa.gov
Author: Dr. Barbara H. Kenny
Headquarters program office: OAT
Programs/Projects: Energetics, RLV