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Torque-speed formulation for torsional vibration analysis of electrical powertrains

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ABSTRACT

Torsional vibrations must be considered in design of all high-power drive-train systems including an electric motor. Magnetic field in the air gap of electric motor generates additional stiffness and damping between the rotor and stator. The inclusion of these magnetic effects is limited by the availability of portable motor models. Recently, it was proposed to apply traditional equivalent circuit models with parameters identified by the finite element method. Further, a linearized system model can be derived to evaluate the vibrations in operating conditions. This approach seems to yield an accurate electromechanical motor model with a small number of variables.

An electro-mechanical powertrain consists of separate components as shown in Fig. 1. The power flow is represented by the familiar voltage-current and torque-speed pairs between the components. Usually, the electromagnetic part of the motor models is described by the system of first order differential equations with currents and speed as free variables, and voltage and torque as input variables. In the contrary, the mechanical drive train is usually described by the system of second order differential equations with angular positions as free variables and torque as input variables. There are many alternatives to couple these different systems together and carry out the combined analyses.

The aim of this paper is to introduce a torque-speed formulation for the mechanical drive train. This formulation describes the drive train by a system of first-order differential equations. The free and input variables are the torque and speed. Thus, the electromagnetic and mechanical first-order systems can be straightforwardly coupled by fixing the equal interface variables together.

As a calculation example, a motor-driven variable-speed reciprocating-compressor is used. The calculation results demonstrate the accuracy and advantages of the developed approach.

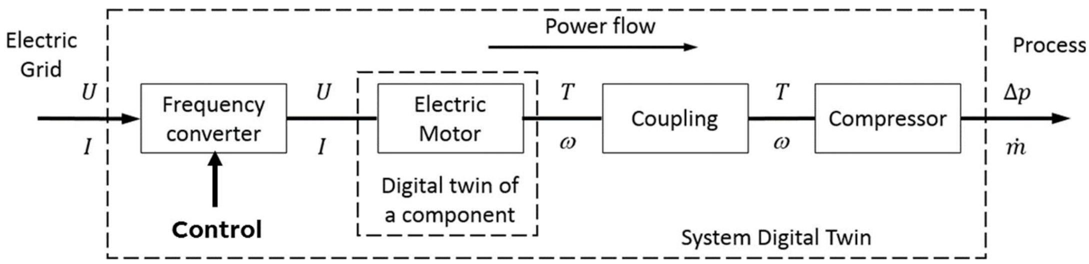

Fig. 1. Digital twin of a motor-driven variable-speed reciprocating-compressor system.

Keywords: torsional vibrations, digital twins, electromechanical interaction, finite element formulation.