DESIGN AND EXPERIMENTAL CHARACTERIZATION OF A THREE-PHASE, 1KN REGENERATIVE ACTUATOR

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Abstract

This paper reports on experimental research being conducted at Duke, regarding the characterization of a transducer capable of vibratory power conversion at the 10W-100W scale, for force levels ranging from 100N-1kN. The transducer consists of a precision ballscrew, coupled to a three-phase permanent-magnet synchronous machine, and interfaced with an electrical power bus via an active three-phase power-electronic drive. Design procedures are discussed, which illustrate the tradeoffs which must be balanced, such that the conversion efficiency of the transducer is acceptable. This involves characterization of the various losses and dynamics in the system, including friction losses in the screw conversion system, force harmonics due to bearing circulation, viscous damping on the generator shaft, generator shaft inertia, and conduction losses in the drive circuitry. Experimental data is presented in which the electronics are adjusted to present an opposing force which resembles a controllable viscous damper.

Introduction

Large-scale electromechanical transduction in vibrating civil structures has a number of useful applications. Perhaps the most immediate among these is their use in large scale energy harvesting applications, in which the vibratory energy in a structure, when excited by its surrounding environment, is converted and stored for use by electronic subsystems. Such environmental disturbances may include, for example, wind excitations on buildings, wave excitations on offshore structures, and traffic-induced vibrations in bridges (Priya & Inman, 2009). Such systems also have application in vehicles, including automotive suspensions (Zuo *et al.*, 2010) as well as railway systems (Nagode *et al.*, 2010). The energy harvested from these vibrations can be used to power wireless sensing networks and other intelligent systems for structural health monitoring (Roundy *et al.*, 2003; Glynne-Jones *et al.*, 2004; Ward & Behrens, 2008). It can also be used to provide parasitic power for semiactive structural control devices, such as magnetorheological dampers (Choi & Wereley, 2009; Jung *et al.*, 2009).

More directly, electromechanical transduction itself has the potential to be used as a semiactive energy absorber, for the purpose of structural control (Jolly & Margolis, 1997; Scruggs & Iwan, 2003, 2005; Palomera-Arias *et al.*, 2008). When operated in this mode, these devices are sometimes called "regenerative actuators," as they involve the same hardware used for active actuation, but operate in regenerative (i.e., dynamic braking) mode. By controlling the electrical impedance at the terminals of the transducer, such devices are analogous to various mechanically-adaptive semiactive devices, such as variable-orifice and controllable-fluid dampers. Such electromechanical semiactive devices have some interesting features which are more difficult to achieve via mechanical means, because it is straight-forward to transfer energy from one device to another, which gives multi-device semiactive systems built from this technology a greater degree of versatility.