CHALLENGES in REAL-TIME HYBRID SIMULATION

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Numerous devices have been recently developed which can reduce the seismic hazard of new and existing civil engineering structures. These devices include passive and semiactive dampers. A majority of these devices are load-rate dependent. Real-time hybrid simulation offers a viable method to evaluate the performance of these devices and the structural system which contains them. The devices alone, or the devices combined with part of the structure (e.g., dampers and the adjacent braces) can be physically modeled, and the remaining part of the structural system analytically modeled. As a result, the use of hybrid simulation avoids the creation of a test structure of the complete structure, yet captures the interaction effects between the devices and the complete structure, and thereby results in realistic demand on the devices. The need for real-time testing to evaluate the above devices was part of the vision that resulted in the development of the Lehigh NEES Equipment Sites, whose focus includes real-time hybrid simulation.

Real-time testing has several challenges. These include: the need for continuous actuator motion to capture the proper velocity and acceleration effects; minimizing latency (which can otherwise lead to phase and amplitude error) between the command and feedback displacement of actuators imposing motion to the test structure; and, minimizing phase and amplitude error in the restoring forces fed back to the integration algorithm.

An inadequate integration algorithm can result in inaccurate results, where the effects of real-time are consequently not properly captured during the simulation. In addition, latency results in phase and amplitude error in the restoring forces, which can cause the test to be inaccurate and the algorithm to become unstable. These aspects are presented and their effects on the accuracy of real-time hybrid simulation are discussed. Using control theory to improve the servo-hydraulic control laws, solutions to reduce latency and errors due to phase and amplitude in the actuator displacements and restoring forces associated with the experimental test structure have been developed and implemented at the Lehigh NEES Equipment Site. These solutions are illustrated using numerical simulations in Simulink and through real-time experiments of a steel frame with elastomeric dampers using the real-time hybrid simulation capabilities at the Lehigh NEES Equipment Site.

Keywords: dynamics, Hybrid Tests