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# Real-Time Hybrid Testing

Servotest Testing Systems Ltd

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Real-time hybrid testing involves the combination of physical testing and numerical modeling of 'hybrid' test structure. This'hybrid' structure consists partly of physical components and partly of components which only exist in the form of a numerical model.

In this context the physical components are tested using one set of 'test' actuators or a 'test' motion platform, while additional 'simulation' actuation components provide the forces to represent those reaction forces that would have been seen at the actuator connection points if the part of the structure that in being modelled were physically present.

This technology enables the motion of large civil structures to be modeled when only a part of the physical structure is available. At the same time the dynamic properties of physical components (the physical substructure) that are otherwise difficult to model can be incorporated in the overall 'hybrid' model via the application of physical test loads and associated measurements.

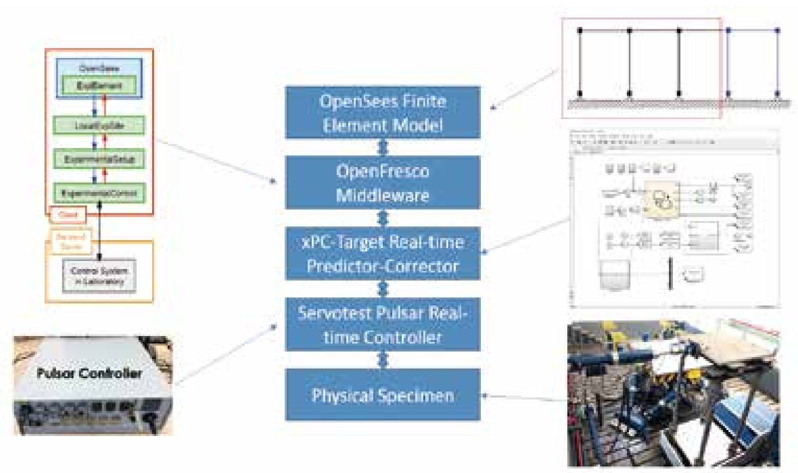
During hybrid testing the Pulsar digital servo-control system provides direct commands to control the motion of the 'test' actuation components. In addition data related to set-point commands for the 'simulation' actuators are sent to Pulsar from the numerical substructure model to provide the simulated 'reaction forces'. These are applied by the digital servo-control system in real-time in parallel with the 'test' actuation commands. At the same time feed-back signals from the 'simulation' actuator transducers and other measured signals are fed back to the numerical simulation substructure, also in real-time, for inclusion in the next model & control loop iteration.

A typical Servotest real-time hybrid testing system consists of the following components:

- A test bed-plate and/or reaction fixturing for actuator mounting
- One or more high-performance linear hydrostatic bearing actuators and/or motion platform for application of the 'test' input signals
- One or more high-performance linear hydrostatic bearing actuators for application of the 'simulation' loads
- A hydraulic power supply, solenoid control manifold and distribution system to energize the test system
- A Pulsar digital servo-control system with operator PC workstation
- A high-speed data communication interface
- A numerical substructure model, typically running on a separate simulation PC workstation

Advanced Pulsar digital control system capabilities, including time-delay compensation algorithms and high-performance low-friction hydrostatic bearing linear actuators delivering high-fidelity motion responses, in combination with SCRAMNet® reflected memory communication modules, makes the above a viable solution for real-time hybrid simulation work.

Pulsar also offers extensive expansion capabilities, including support for single- & multi-table 6 degree-of-freedom seismic motion platforms, ensuring confidence that both current and future test and simulation laboratory requirements can be satisfied.




The key Servotest control system components required for hybrid testing include:

- A Pulsar digital servo-controller capable of real-time control loop update rate (including processing & transfer) between 1 kHz & 10 kHz
  - ◎Note that when using finite element software to perform the iterative computation within the numerical substructure, the numerical model convergence rate can be relatively slow and the step length is variable. In this case, a Predictor-Corrector model can be embedded in xPC-Target to bridge the two time scales Servotest adopts following model and the prediction that in-built the xPC-Target to mediate the time-scale.
- A SCRAMNet® reflected memory communications module connected to the Pulsar real-time front-end Digital Signal Processor
- A simulation PC workstation, referred to as an 'xPC-Target' also incorporating a SCRAMNet® reflected memory communications module
- A dedicated high-speed fiber-optic communications interface running between the SCRAMNet® communications modules, enabling both devices to 'share memory'
  - ◎The SCRAMNet® data transmission rate can exceed 210 Mb/s
  - ◎The delay is at sub-microsecond level
  - ◎SCRAMNet® can be used to connect multiple controllers and simulation workstations for multi-platform testing offering exciting expansion possibilities moving forward

Within the Pulsar context three approaches are available for development of numerical substructure simulation models

- Using OpenSees (Open System for Earthquake Engineering Simulation) & OpenFresco (Open-source framework for Experimental Setup & Control)
  - ◎In this case, numerical model is simulated using OpenSees and communicates with xPC-Target through Open Fresco which acts as a middle tier server. Then the xPC-Target communicates with Pulsar controller via Servotest uses OpenSees as a numerical driving module. Based on the connection between OpenFresco and xPC-Target platform, the numerical driving module can communicate with the controllers through SCRAMNet® shared memory.
- Using a Pulsar 'sockets' capability
  Note that this approach does not require SCRAMNet®
  - ◎Pulsar provides a unique capability referred to as 'sockets' which allows a Simulink model to be run within the real-time front-end
  - ◎In this case the Pulsar digital servo-controller compiles the dynamic model and uses it to calculate the dynamic characteristics of the numerical sub-structure inside the control loop at the control system iteration rate
  - ◎This provides a powerful self-contained capability for substructure models of a reasonable size. Since it is built-in to the Pulsar front-end the numerical model can receive, process and output data without the time-delay associated with external modelling approaches
- A Simulink, or other, real-time model running on xPC-Target PC
  - ◎The model represents the dynamic characteristics of the numerical substructure, i.e. the missing physical components
  - ◎One example approach would be to use a model developed using the MATLAB® real-time toolbox which is then downloaded to run within the xPC-Target PC
  - ◎The data calculation rate is determined by the complexity of the model and the capability of the xPC-Target workstations
  - ◎Data communication takes place within the bandwidth offered by the SCRAMNet® system components