Instrumentation of a WEC device for controls testing

METS – April 28 2015
Resilient NonLinear Control (RNLC) program

- US DOE Sponsored Controls Program
  - Multi-year Program with four major phases
  - Theoretical Development: performance model and controls
  - Experimental Validation:
    - Multiple phases
    - Each major phase is tied to a validation program to be carried out at the Carderock MASK Basin

12.2-million-gallon tank in Carderock, West Bethesda, MD
Naval Surface Warfare Center
Resilient NonLinear Control (RNLC) program

- **Goal**
  - What is the potential of control systems in WECs?
  - Validate the extent to which control strategies, given real world limitations, can increase the energy production of resonant WEC devices.
Resilient NonLinear Control (RNLC) program

Methodology (Problem Inversion)

- Release limitations forced on implementing the control strategies by:
  1. Using the “controlled environment” of the wave tank
  2. Selectively activating configurations of the physical model

- Selectively probe the sensitivity of the control strategies by introducing the limitations in a structured manner.

- Outline the “minimum requirements” for each control strategy to be successful and determine the level of performance given the minimum requirements.

- Nonlinear control
Sensors selected for specific objectives of testing

- **MODELING**
  - System identification
    - Validate linear model
      - Small motion/wave amplitude
    - Models nonlinear effects
      - Hydrostatic
      - Drag
      - Submergence
      - Slamming
      - ...

- **CONTROL**
  - Real-time
    - Ideal conditions: all available measurements
    - Realistic conditions: reduced set of measurements available
Device overview

- 1/17th scale
- Motion: 5 DoF
  - heave, surge sway, roll pitch
- Absorption: 1 DoF
  - Heave
  - Linear generator
Translation measurements

- X, Y direction
  - String potentiometers
- Z direction
  - Encoder in linear generator
- Optical tracking
  - Natural point
Rotations: sensors layout

- Roll + Pitch
- String potentiometers
  - Linear measurements
Rotations: from lengths to angles

- Two reference frames
  1. Fixed to vertical tube
  2. Fixed to floating body

\[ \vec{PC} = \vec{OC} - R^3_b(\theta, \phi) \cdot \vec{P}^b \]
Force measurements

- Heave
  - Load cell between linear motor slider and vertical tube

- Surge + Sway
  - Restoring (spring) on PMT
Pressure measurements

- Two sets of pressure transducers
  - Low accuracy
    - (modeling)
  - High accuracy
    - (modeling + control)
    - Accuracy
      - Wave elevation ~5mm
Slamming

- Slam panels
  - Simulate/emulate compliance of structure (novel design)

- Pressure sensors
  - (validation)
Housing for pressure sensors and slam panels

- Modular design
  - “Tube” enclosure
  - Cheaper PT (sealed tube)
Wave probes: provided by the basin

- #2 arrays of wire probes (Real Time control)
  - Directional measurements
- #1 Acoustic system (Modeling)
  - Distributed around basin
Safety probes and switches

- End stops/switches
- Accelerometers
- Flooding
  - Humidity
  - Current-loop
- Temperature
Acquisition system: Overview

- **Requirements**
  - Simultaneous sampling
    - Reduce latency
  - High processing power
    - For real time control
  - Modularity
    - WEC sensors
    - Wave basin sensors

- **National Instrument Compact RIO 9082**
  - Simultaneous sampling
    - FPGA
  - Processing power
    - Intel Dual core 1.33Ghz
    - NI Real Time OS
  - Modularity
    - MXI
    - EtherCAT
    - Ethernet
    - compact RIO interface
Acquisition system: Physical Layout

- Cable length
  - Several meters between buoy and DAQ
- Signal transmission interfaces
  - Current loop
  - SSI
  - Voltage
Acquisition system: data transmission and sampling

- **Data transmission**
  - Current loop
    - Pressure
    - Forces
  - SSI
    - Horizontal translations
  - Wave probes
    - Ethernet

- **Sampling rate**
  - 100Hz
    - Pressure
    - Force
    - Position
  - 10kHz
    - Slam panels
    - Accelerometers
Thank you.

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