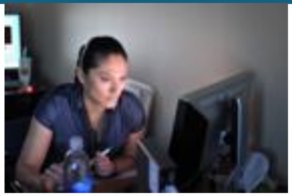
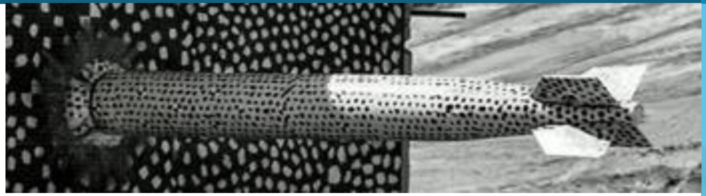
Microgrid applications for WECs





Giorgio Bacelli, David Wilson, Wayne Weaver

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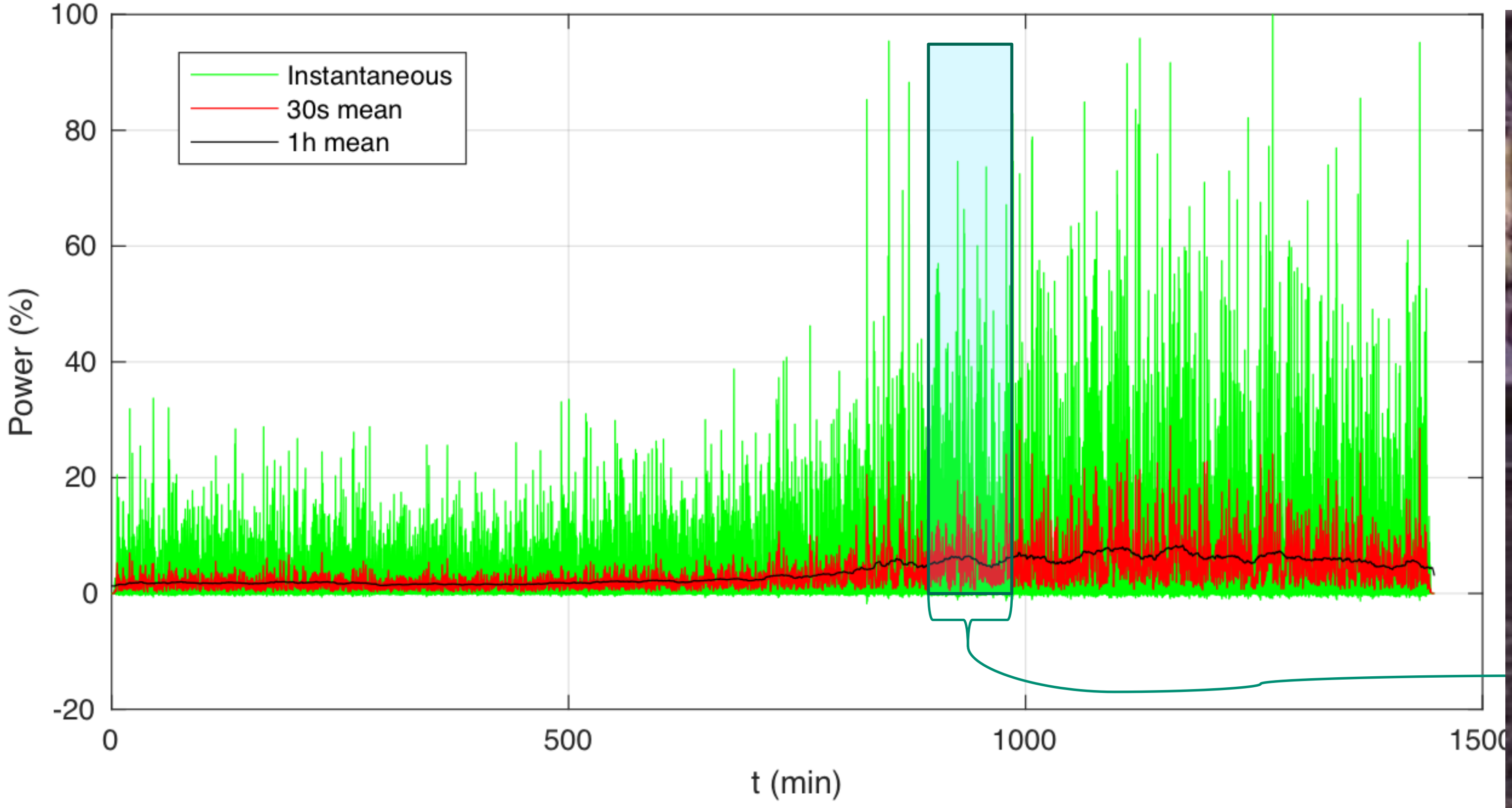
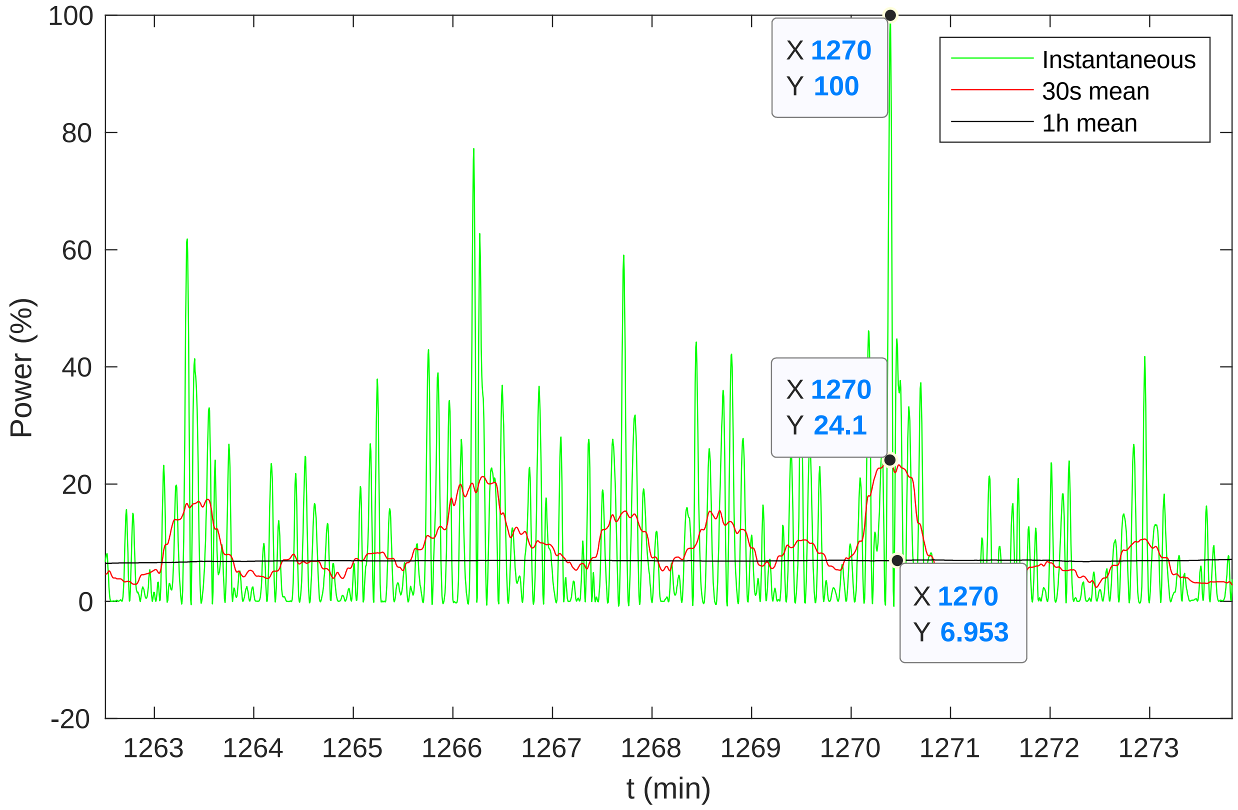
Power profiles from a WEC



Experimental data from CDIP225 buoy and MASK 3 testing at NSWCCD (May-June 2019)

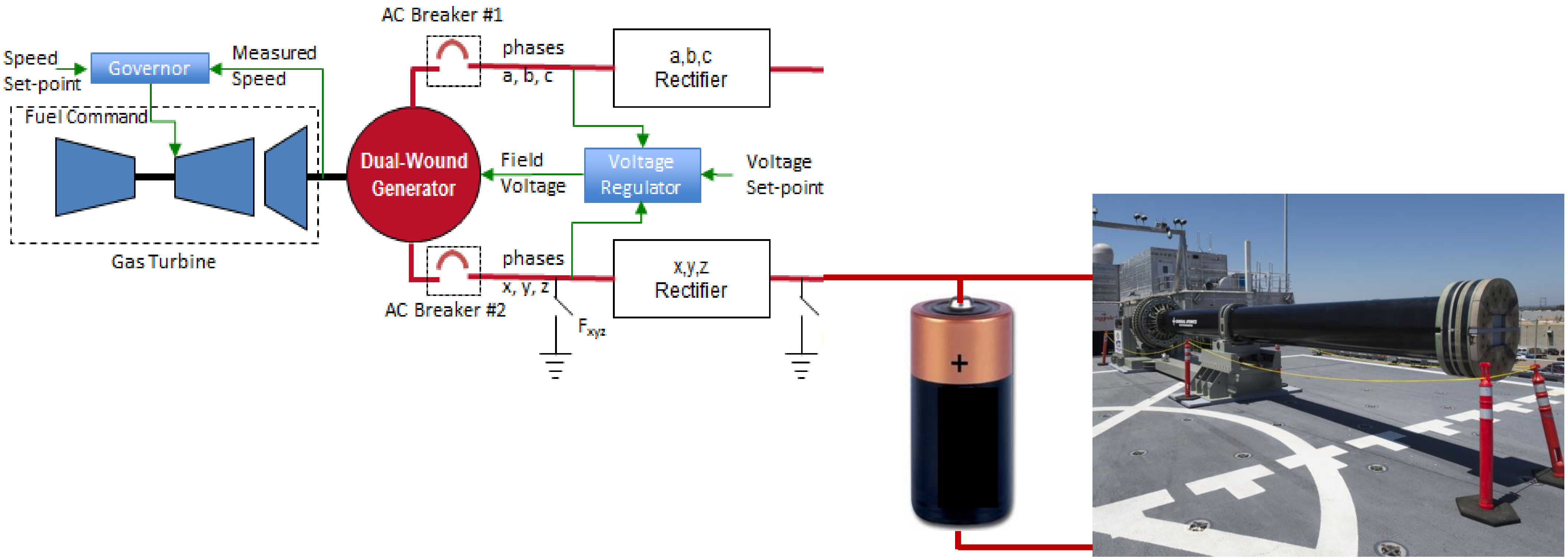
Peak-to-mean power and storage

1. Small amount storage
   - Peak-to mean power ~ 1:4
   - Allow large variation of bus voltage
2. Large amount of storage
   - Peak-to mean power ~ 1:14
   - Small variations of bus voltage



Energy Storage Helps Address Stochasticity

- It can increase stability.
- It can reduce the performance requirements of the distribution system.
- It can address impedance mismatch between the source and the load



Rashkin, L.J., Neely, J.C., Wilson, D.G., Glover, S.F., Doerry, N, Markle, S., and McCoy, T.J., Energy Storage Design Considerations for an MVDC Power System, INEC 2018, Oct 2-4, Glasgow, UK, 2018.

Enabling High Performance Requires Techniques for Addressing Energy Storage Requirements

To achieve lean and mean with no barge full of storage

New model and design tools advancements are needed

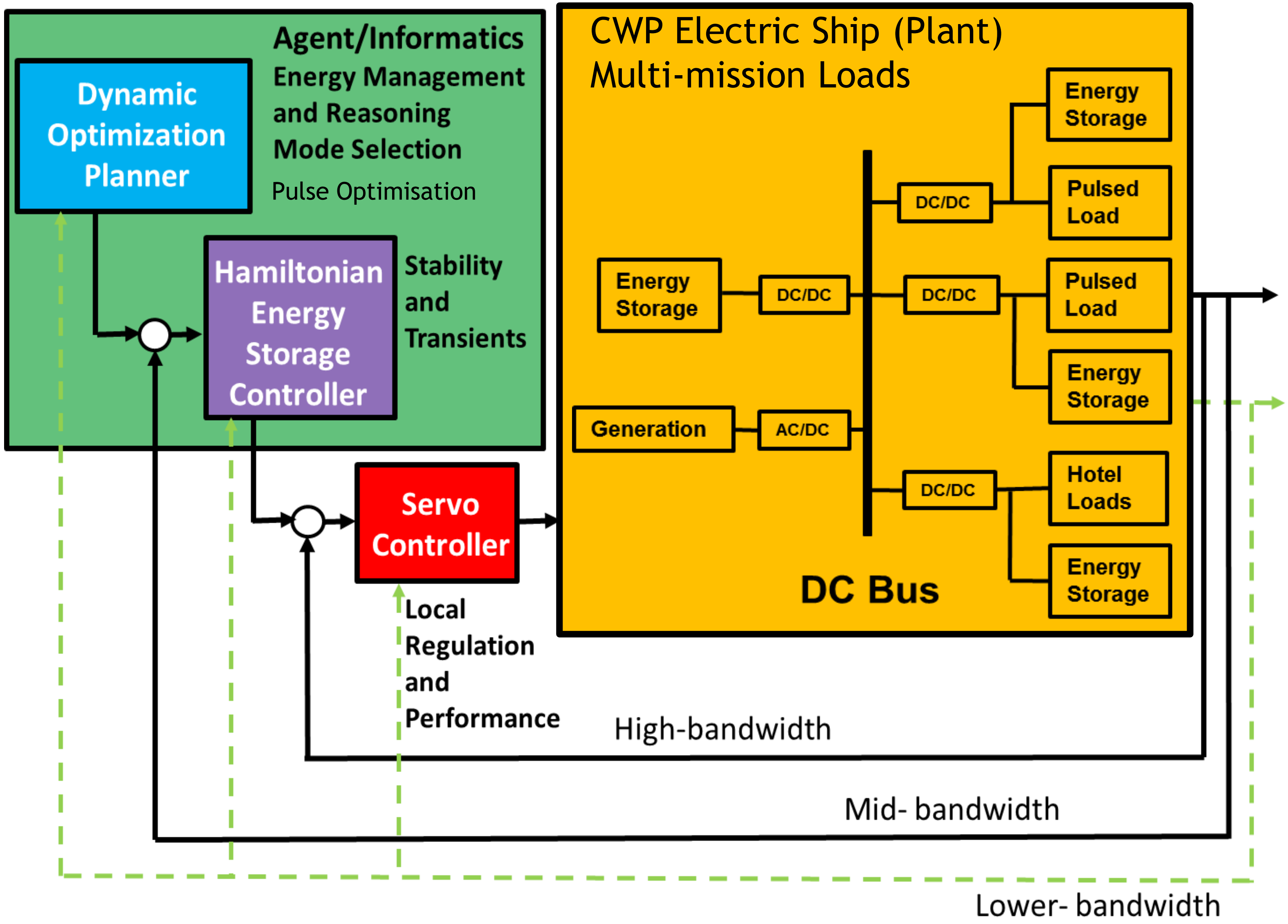
New architectures and controls are being created

Optimization computational efficiencies must be optimized

Rashkin, L.J., Neely, J.C., Wilson, D.G., Glover, S.F., Doerry, N, Markle, S., and McCoy, T.J., Energy Storage Design Considerations for an MVDC Power System, INEC 2018, Oct 2-4, Glasgow, UK, 2018.

Control Structures are Enabling New Insights and Performance

- **Agent based** implementation / Optizelle I/F through host computer (slowest update rate)
- **Hamiltonian Energy storage** control realized in the RT-control level
- **Servo** Controller realized in RT-controller level with faster computation capable at the FPGA level

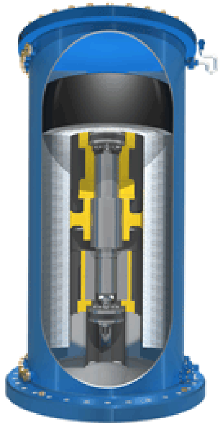


Rashkin, L.J., Neely, J.C., Wilson, D.G., Glover, S.F., Doerry, N, Markle, S., and McCoy, T.J., Energy Storage Design Considerations for an MVDC Power System, INEC 2018, Oct 2-4, Glasgow, UK, 2018.

Energy Storage Technologies Vary in Specific Power / Specific Energy and Frequency Response

Energy storage strategies vary in the technology used; each technology has different size/weight and performance capabilities, examples include:

- Flywheel energy storage
- Electrochemical Cells/Batteries (i.e. Lithium Ion)
- Super Capacitor



Capabilities are usually identified over a range of values based on demonstrated systems

Technology	Energy Density (Wh/L)	Power Density (W/L)	Specific Energy (Wh/kg)	Specific Power (W/kg)	Approx. Bandwidth (Hz)
Flywheel	20-90	1000-5000	5-100	400-1500	20
Lithium-Ion	150-500	1500-10000	75-200	150-2000	80
Super Cap	10-30	>100000	2.5-15	500-10000	80

Xing Luo, Jihong Wang, Mark Dooner, Jonathan Clarke, Overview of current development in electrical energy storage technologies and the application potential in power system operation, Applied Energy, Vol 137, 2015, pgs 511-536, Thank you