

USNA Power and Energy Lab Group

John Stevens
Associate Chair
ECE Dept
US Naval Academy
2 November 2018

John D. Stevens, CDR, USN

- Surface Warfare Officer (1993-2000)
 - **USS COWPENS (CG63)**
 - USS ELLIOT (DD967)
 - Naval Postgraduate School (MSEE 2000)
- Engineering Duty Officer (2000-2014)
 - **Ship Repair Facility, Yokosuka, Japan**
 - Military Instructor, USNA (Naval Architecture)
 - **Naval Postgraduate School (PhD 2010)**
 - **PMS 320, Washington Navy Yard (Tech Dir)**
 - Baghdad, Iraq (Systems Eng, Counter-IED)
 - **PMS 500, Washington Navy Yard (HM&E APM)**
- Permanent Military Professor (2014-2021)
 - **Assoc. Chair, ECE Dept, US Naval Academy**
 - **Power and Energy Systems**
 - **Capstone Coordinator**



Mission:

To serve the U.S. Navy's interest in advanced power and energy science, technology, research, and education by:

- **Equipping Midshipmen with education and leadership skills that keep pace with the technical demands of the Fleet**
- **Collaborating with other U.S. Navy Science and Technology/Research and Development organizations**
- **Contributing original research for the advancement of Naval Power Systems.**



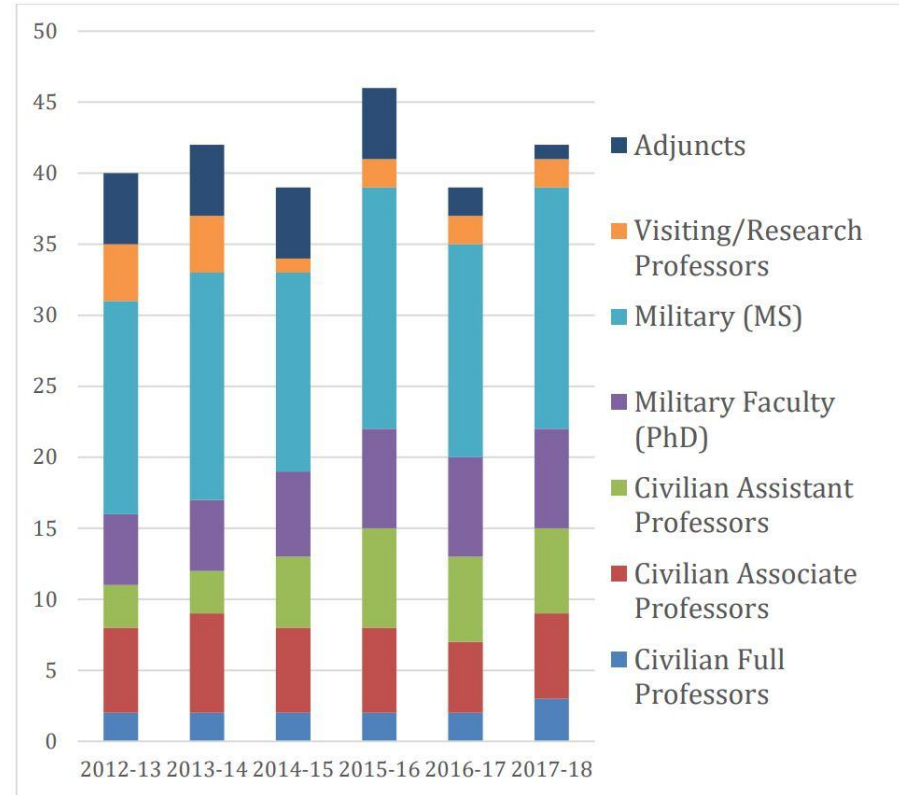
USNA ECE Dept Ties to NPS

USNA Military Faculty with degrees from NPS

- CDR John Stevens (PhD 2007)
- CAPT Owens Walker (PhD 2009)
- CDR Chas Hewgley (PhD 2014)
- CDR Chris Martino (PhD 2015)
- LtCol Joseph OConnor (PhD 2017)
- CDR Sean McConnon (MSEE 2010)
- Maj Mitch Rubenstein (MSEE 2016)
- Maj Michael Gardner (MSEE 2016)
- Capt Andrew Iobst (MSEE 2015)
- LCDR Brian Schaus (MSEE 2015)
- Maj Perez (MSEE 2018)

Note:

1. **About 50% of military faculty in the ECE Dept at USNA have an MSEE or PhD from NPS**
2. **All have taught (or are teaching) topics in power and energy systems**



Power and Energy Classes Taught at USNA

Current Courses:

- EE301: Electrical Fundamentals and Applications (3-2-4)
- EE331: Electrical Engineering I (3-2-4)
- EE320: Intro to Electrical Engineering II (2-2-3)
- EE488: Power Conversion (3-2-4)
- EE420: Electric Machines and Drives (3-2-4)
- EE411/EE414/EX485M: Design I/II Capstone Design Course (2-2-3)

Future Courses:

- Renewable energy and microgrid systems
- Power systems (protection, reliability, fault detection, and cyber-security)
- Applied magnetics and magnetic materials

USNA Power and Energy Lab Spaces

- Complete AY21
- Power and Energy Lab
 - 10 student workstations
 - Mobile power stations
 - Rapid prototyping
 - Faculty research space
 - High Voltage Capability
 - Hardware-in-the-loop
 - Renewable energy lab
 - Wind generators
 - Solar panels
 - Net-zero lab



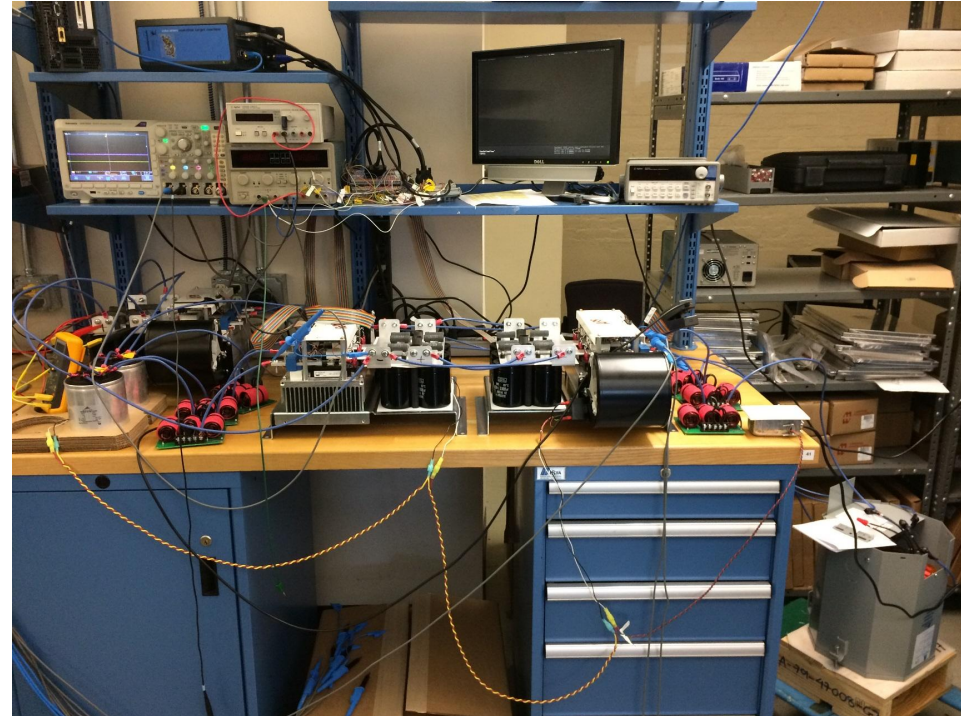
AY19			AY20			AY21			AY22			AY23		
Summer 2018	Fall 2018	Spring 2019	Summer 2019	Fall 2019	Spring 2020	Summer 2020	Fall 2020	Spring 2021	Summer 2021	Fall 2021	Spring 2022	Summer 2022	Fall 2022	Spring 2023
Hopper Hall Construction														
Rickover Tower Renovation		Under Terrace Work				Maury Hall Renovation (planned)						Nimitz Hall Renovation (planned)		
ECE loaning ~9K sq. ft. for swing (Figure 7-3)		ECE Labs Down	ECE returns to AY18 footprint (Figure 7-3)			ECE offices and most of labs move to Hopper. Some labs remain in Rickover (Figure 7-4)						ECE in Hopper & Nimitz (Figure 7-5)		

Figure 7-2. Schedule for Upcoming Facility Changes



Active USNA Power and Energy Projects

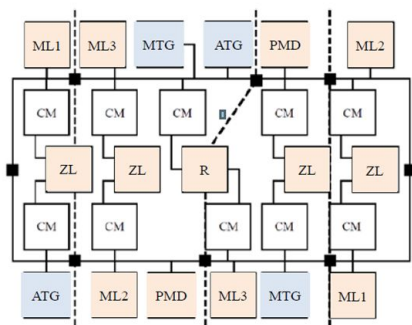
1. Shipboard power system optimization
2. Cyber physical anomaly detection in power systems
3. Oscillators etc.
4. Load profile generation
- 5 EV charger topology
6. DC-DC power supply
7. Multi-frequency power converter modeling
8. Diode Characterization



Operational Vignette-based Electric Ship Load Demand



Notional MVDC Power System



	Ship A (pu%)	Ship B (pu%)	
Gen.	Main (MTG)	43.9	43.9
	Aux. (ATG)	6.1	6.1
Loads	Propulsion (PMD)	73.7	73.7
	Radar (R)	3.5/4.6	8.9/11.7
	Service (ZL)	7.5/15.7	9.0/18.8
	Mission Load 1 (ML1)	24.4	41.7
	Mission Load 2 (ML2)	0.9	43.8
	Mission Load 3 (ML3)	0.6	4.2
	Converter Module (CM)		

Converter Module (CM)

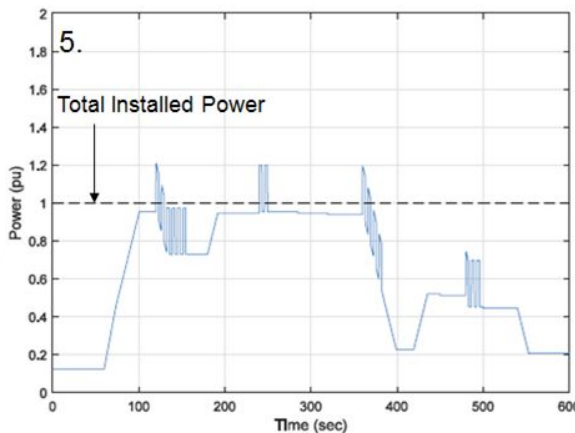
- Operational vignette-based load demand profile
 - Efficient and effective time domain trade space exploration
 - Basis of load generation models based on realistic worst case load demand
 - Stochastic load parameters allows for variations – suitable for exploring the trade space
 - Add state machine approach for modeling human-in-the-loop decisions under disruptive conditions
- Ready for transition to design tool builders and users
 - Energy storage
 - Control architectures
 - Resiliency performance



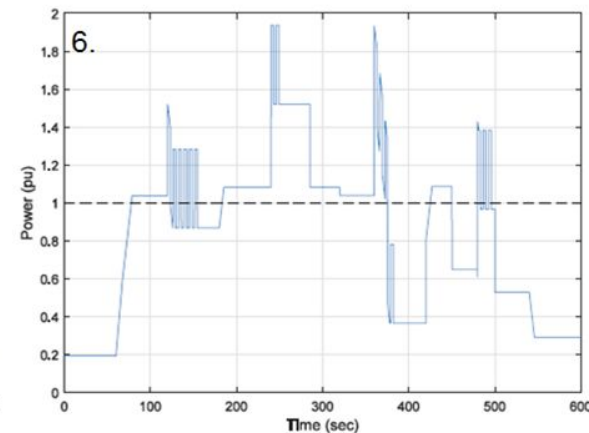
Total Ship Power Demand: Aggressive Ship Maneuver



Ship A



Ship B

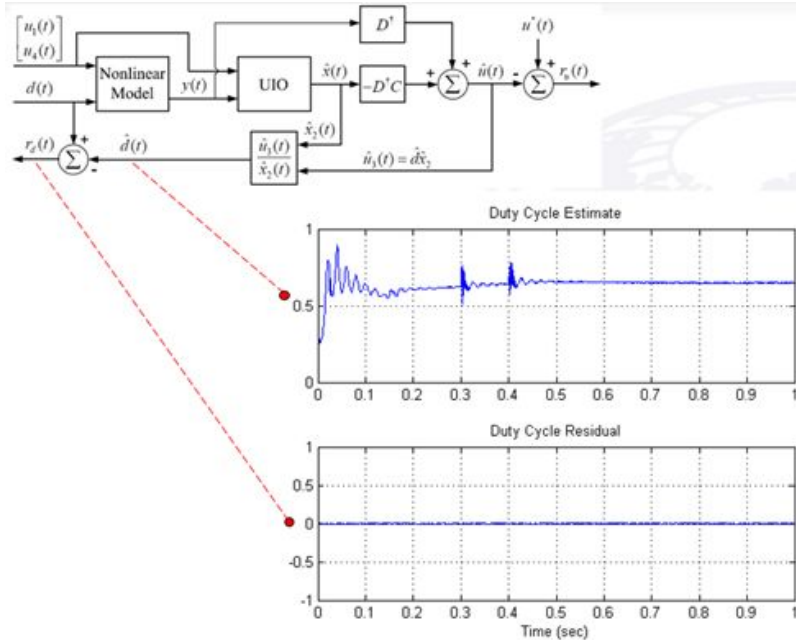


- Ship A begins to breach the total installed power line
- Large power demand variance – Ship A (~100% pu), Ship B (170% pu)
- Integrate the power profile for energy demand profile
 - Explore energy storage capacity, charge/discharge rates, location, etc.

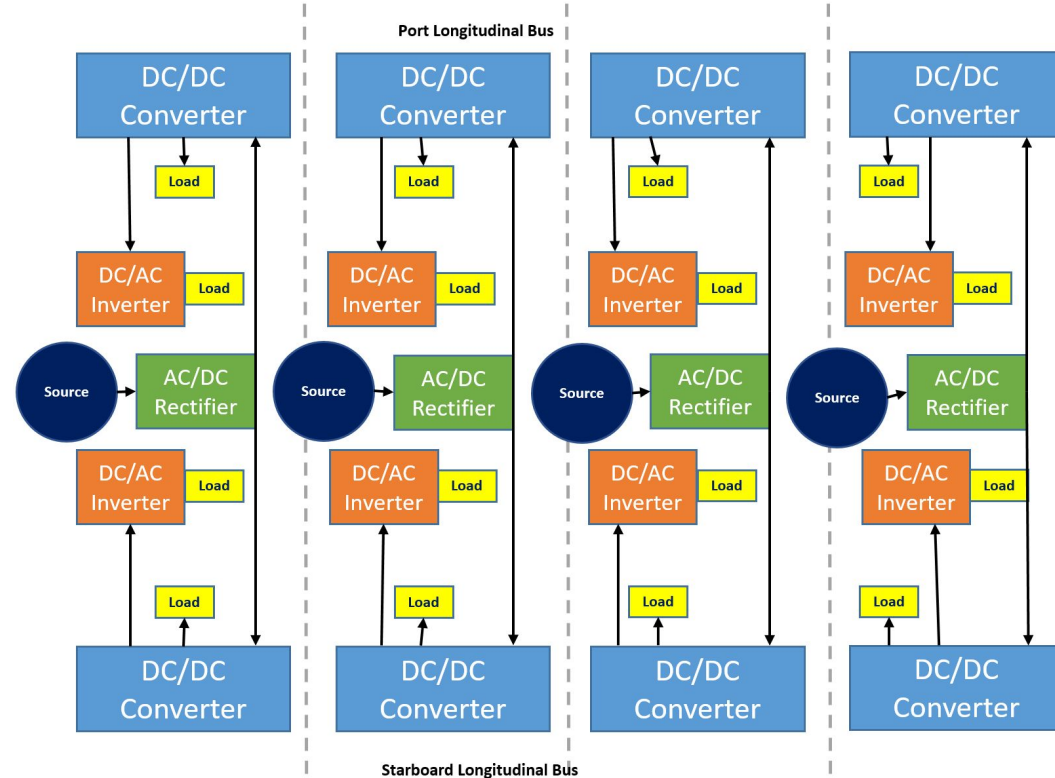
Model-based Power System Fault Diagnosis

Cyber-physical Systems:

Linearization techniques to detect anomalies in power systems



Notional MVDC Power Distribution System



Power Electronics

5-Level MV Drives
Luke Solomon (GE)
Chris Lee (GE)

**Stability of Phase Lock
Loops in Weak Grids**
Kathleen Lentijo (UEC Electronics)

**Network Power
Systems (DURIP)**
Stevens/Zivi

**Distributed
Control
Security**
Fairbanks

**Vehicle to Grid
Frequency Regulation**
Willett Kempton
(U. Delaware)

**Nonlinear Oscillators for
Converter Control**
Trident (Shabshab)
Stevens
S. Dhople (U. Minnesota)
B. Johnson (NREL)

**Ship Power Systems
and Dynamic Control**
Stevens
Zivi (WSE)
Cramer (U. Kentucky)
Post-Doc

**Energy Management
Route Identification**
Xiaoyong Wang (Ford)
Ajay Prasad (U. Delaware)

**Control Theoretic Tools for
Power System Topology**
Kiriakidis (WSE)
Rodriguez-Seda (WSE)
Connett (WSE)
Severson (WSE)

Vehicles

Power Systems

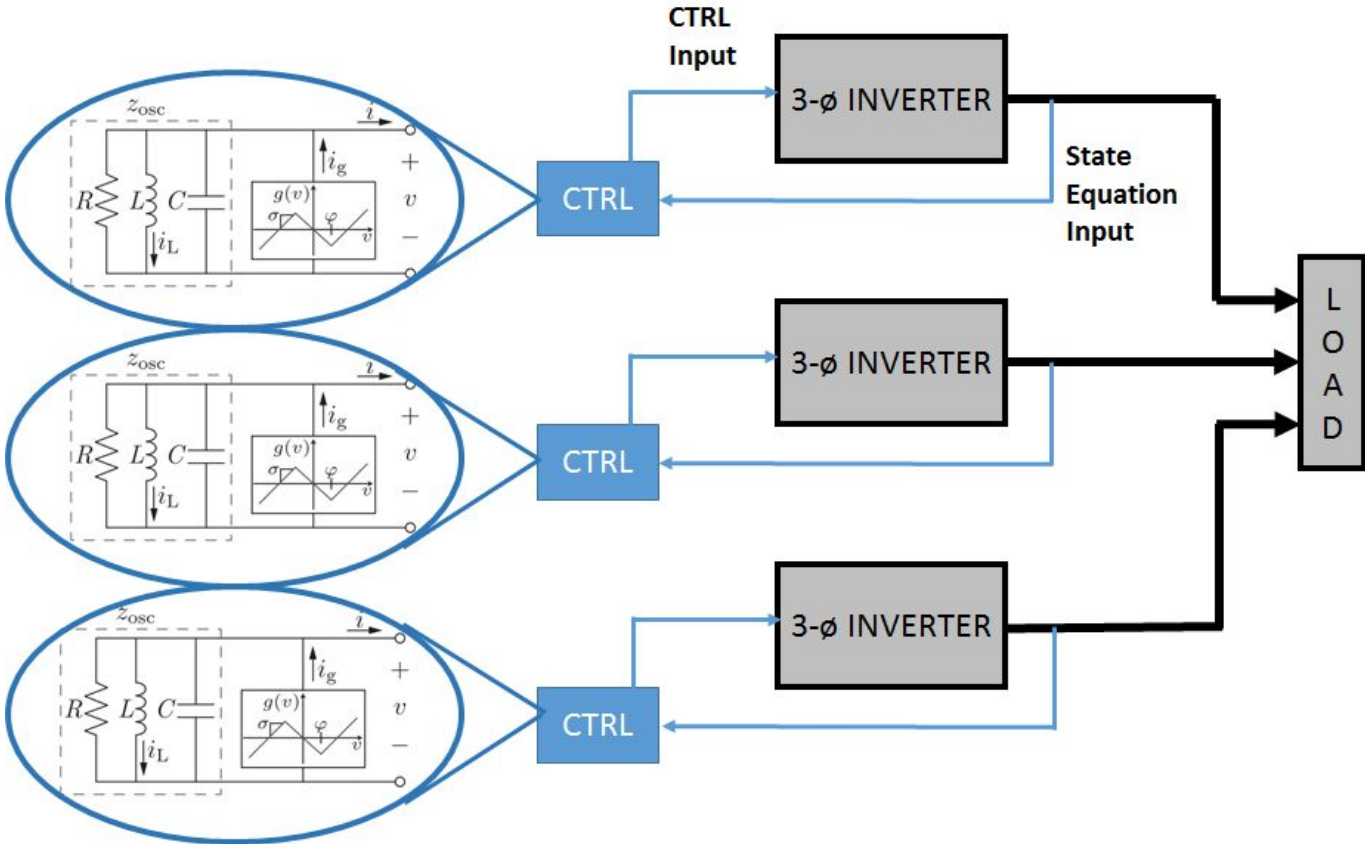
**Collaboration is
Key!**

Conclusion

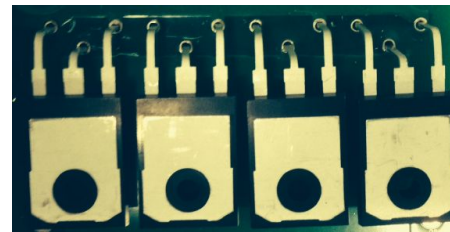
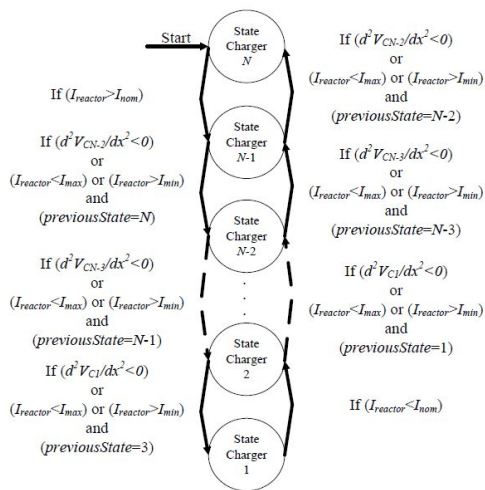
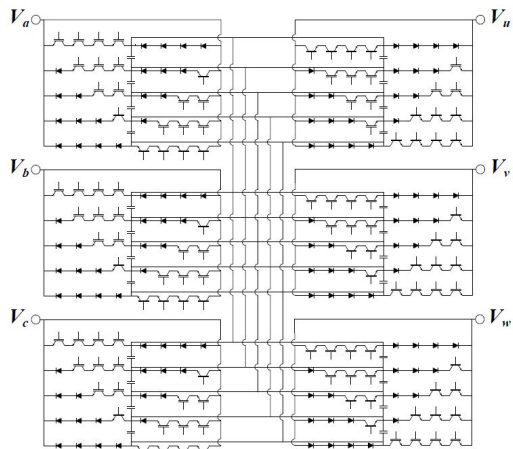
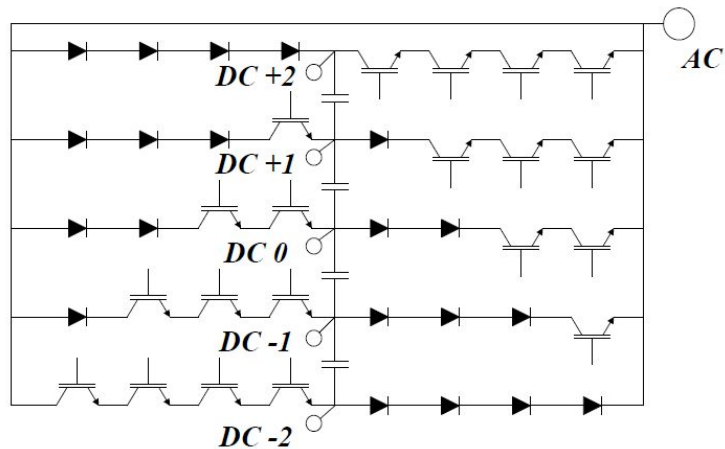
- Personal “Thank you” to the Naval Postgraduate School
- NPS is making a tremendous impact to the Power and Energy Program at the U.S. Naval Academy
 - Faculty: ~50% of all military faculty in ECE Dept are NPS-educated
 - All NPS graduates are teaching power and energy topics in their courses to
 - Advanced topics in power systems for EEE and ECE majors
 - ALL midshipmen from EVERY major (EE301 and EE331)
 - NPS power and energy program is vital to
 - Keeping the US Naval Academy’s power program well-equipped
 - Keeping pace with the technical demands of the Fleet.
- Collaboration is key
 - Students projects - Bowman scholars
 - Faculty research
 - Resource sponsors

backup

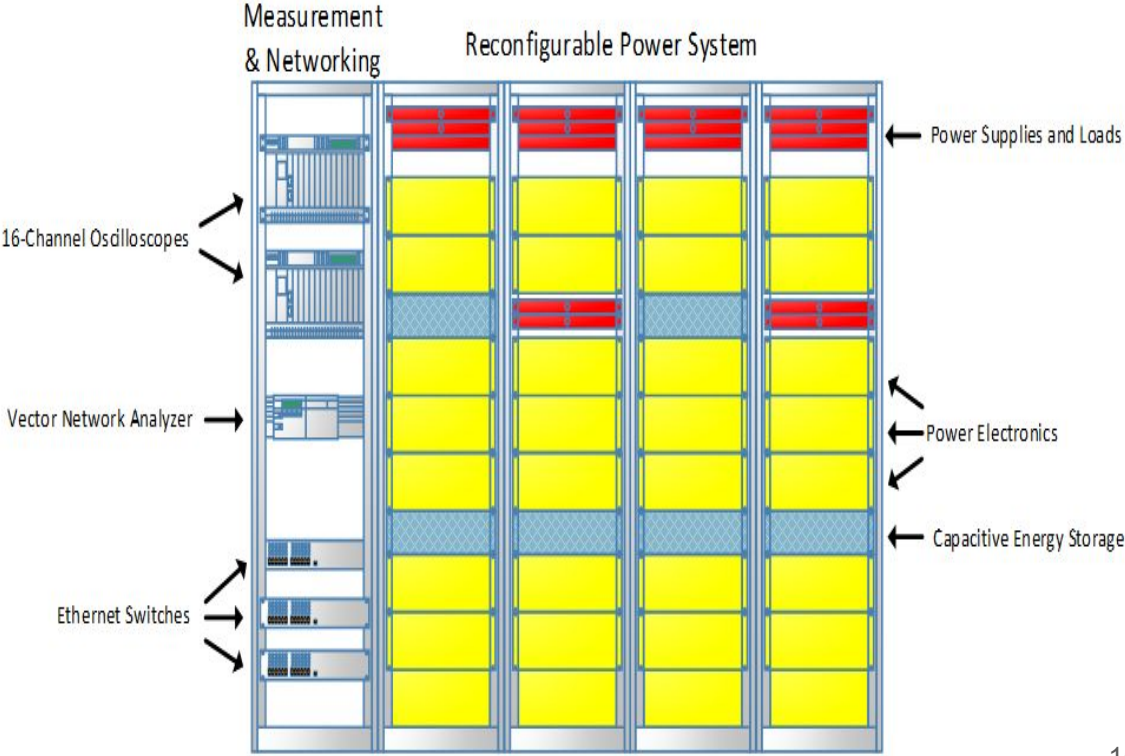
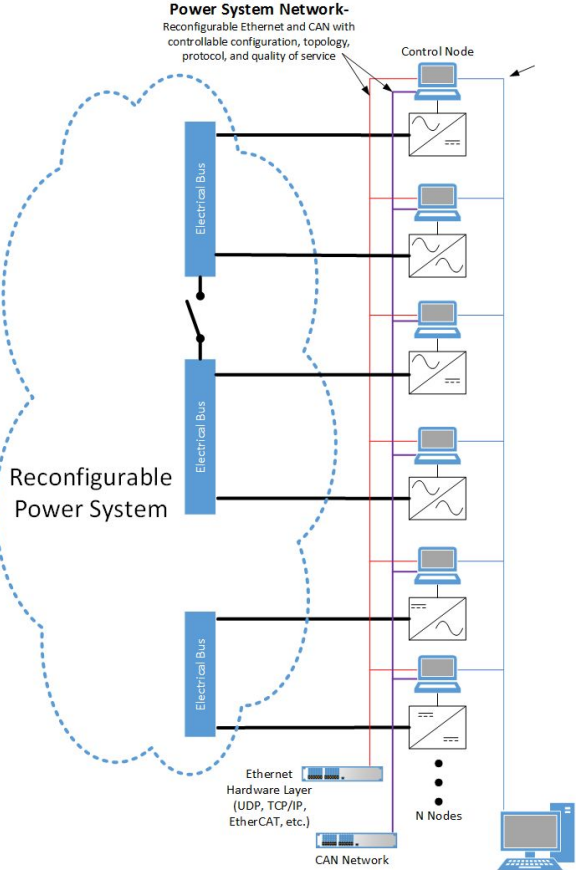
Coupled Nonlinear Oscillators for Converter Control



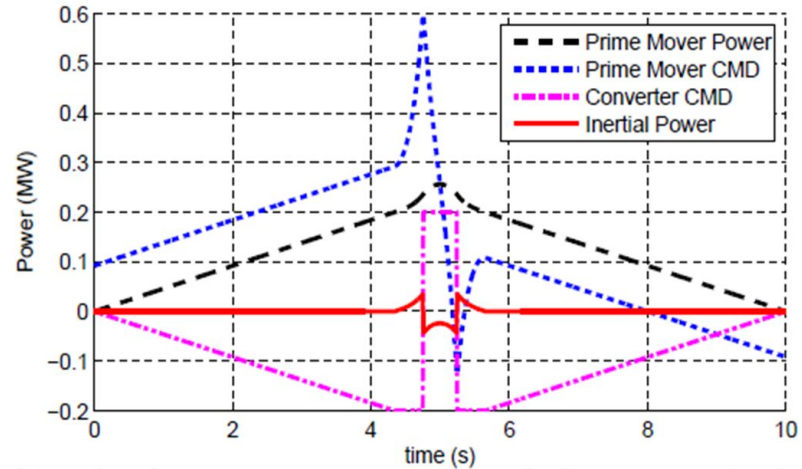
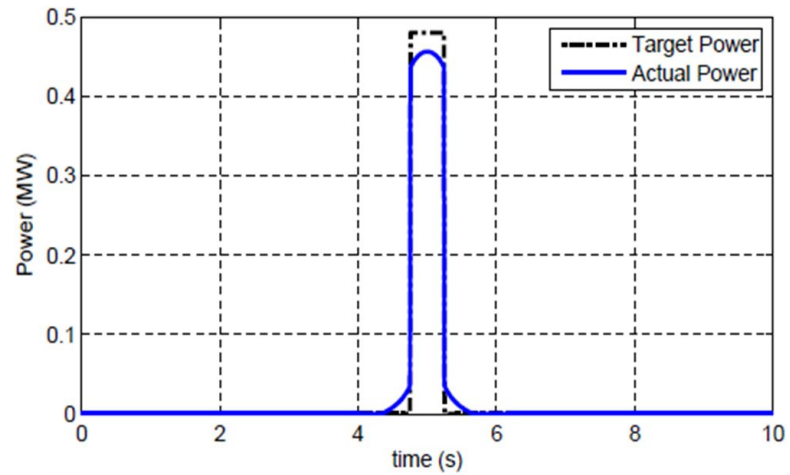
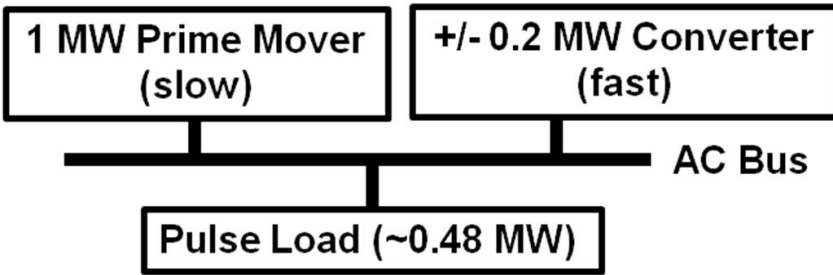
5-Level MV Drives



Reconfigurable Adaptive Network Power System Testbed (RANPS) - DURIP



Power System Dynamic Control



Algorithm tracks power commands and allows a controllable amount of power draw from system inertia (solid red), causing frequency deviation

Community Sponsors and Affiliations:

- Office of Naval Research (Code 331)
- Electric Research and Development Consortium ([ESRDC](#))
- Naval Sea Systems Command (SEA O5T)
- Naval Surface Warfare Center - Philadelphia
- Electric Ships Office (PMS 320)



Recent Funding (2015)

Investment 2015- \$315k Labvolt, scopes, AC/DC supplies and Loads, Controllers

Research Office - \$50k Electromagnet + Gaussmeter

ONR - \$250k Vibrating Sample Magnetometer + Hall Effect Measurement System

PEO/NAVSEA \$15k - Microgrid components, power amplifiers, relays etc.

Trident Funding- ~\$8k Nonlinear Oscillators

DURIP 2015 - \$293k Network Power Systems Testbed (RANPS)

Boeing - \$50k Capstone Sponsorship (ACES)

ONR - \$15k Nonlinear Oscillators (Trident Project)

ONR - \$125k Electric Ship Research (With Zivi)