The ERC Program and Wide Area Control for the Future Power Grid

NSF JST DFG RCN Workshop – Washington DC

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NSF Engineering Research Centers

• Created in 1984. Sought to bring industry and universities together to address US economic competitiveness.
• Funded to date: 61 with 20 still active.
• Broadly breakdown into:
  • Manufacturing
  • Biotechnology and healthcare
  • Energy, sustainability and infrastructure
  • Microelectronics, sensing and IT
• Estimated economic impact 10s of billions USD.
NSF Engineering Research Centers

- Program of focused research on an engineering problem. Among most significant investments NSF engineering makes in an area with support up to 10 years.

- Program elements include:
  - Outreach (K-12 education)
  - Research experience for undergraduates
  - Entrepreneurship training
  - Industry program
  - Systems engineering approach
  - International collaboration
CURENT – NSF/DOE ERC

• One of only two ERCs funded jointly by NSF and DOE. Core budget: ~$4M/year for 5-10 years but highly leveraged to be able to fully support programs.

• CURENT devoted to wide area controls and one of only two in power systems (FREEDM at NCSU).

• Partnership across four universities in the US and other international partner schools. Many opportunities for collaboration.

• Presently have 26 industry members.

• Center began Aug. 15th 2011.
US Wind and Solar Resources

Best wind and solar sources are far from load centers.

Transmission networks must play a central role in integration.

CURENT Vision

- A nation-wide transmission grid that is fully monitored and dynamically controlled for high efficiency, high reliability, low cost, better accommodation of renewable sources, full utilization of storage, and responsive load.

- A new generation of electric power and energy systems engineering leaders with a global perspective coming from diverse backgrounds.
What is CURENT?

Wide Area Control of Power Grid

Measurement & Monitoring

Communication

Actuation

HVDC

Storage

Solar Farm

Wind Farm

Generator

PSS

WAMS

FDR

PMU

Communication

HVDC

Solar Farm

Wind Farm

Generator

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PMU
Example Value of Improved Controls

Northwest Pacific Intertie

• Two 500kV AC lines and +/- 400kV DC line
  ▪ Designed for transfer of 2000 MW AC and 1440 MW DC
  ▪ Actual capacity was 1300 MW AC due to instability caused by AVRs
  ▪ Power system stabilizers allowed increase to 1800 MW AC
  ▪ Dynamic brake added at Chief Joe allowed up to 2500 MW AC

• Transmission upgrade – third AC line and DC upgrades
  ▪ AC capacity today about 4800 MW (primarily voltage)
  ▪ DC capacity today about 3000 MW

→ 1990s work by DOE and BPA on WAMS and WACS a direct result of this type of need for improved controls.
Today’s Controls
Some wide area and some fast but not both

- Ultra-wide Area
  - HVDC

- Wide Area
  - Unit Commitment

- Balancing Authority
  - Economic Dispatch

- Region
  - AGC
  - RAS Schemes

- Substation
  - SVC Fixed Comp.
  - LTC

- Device
  - PSS
  - AVRs
  - UFLS
  - Device Protection

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Major Research Questions

Future Control Architecture

• Information flow
  • What information is needed where?
  • How much latency can be tolerated?
  • Trade-off – more information leads to better decisions but slower response

• Control architecture
  ▪ Do all devices contribute to control?
  ▪ For which phenomena do devices contribute (some fast and some slow)?
  ▪ How much contribution is needed to ensure performance?
  ▪ Trade-off – more devices contributing properly expands viable operating region but requires greater sophistication

• Economics and optimization
  ▪ Contributions from certain devices are more cost effective
  ▪ Trade-off – greater optimization leads to lower cost but requires more voluntary sharing of information and more susceptible to market manipulation

→ Design needs to be a series of trade-offs between communication needs, device sophistication, resiliency, speed of response, economic performance and device reliability vs. system reliability.
Three-plane Diagram
<table>
<thead>
<tr>
<th>Year 1~3</th>
<th>Year 4~6</th>
<th>Year 7~10</th>
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</thead>
<tbody>
<tr>
<td><strong>Generation I</strong></td>
<td><strong>Generation II</strong></td>
<td><strong>Generation III</strong></td>
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<tr>
<td>Regional grid models with &gt; 20% penetration of renewables and HVDC connections.</td>
<td>Reduced North American system model with &gt; 50% penetration of renewables and HVDC connections.</td>
<td>Positive sequence model of North American system with &gt;50% renewables and HVDC connections.</td>
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<tr>
<td>Model development for primary and secondary frequency and voltage controls in regional grids.</td>
<td>Extension of frequency and voltage control models to North American grid for damping control and transient stability control.</td>
<td>Fully integrated system model of real time communication, coordinated control, actuators, monitoring and load response.</td>
</tr>
<tr>
<td>Scaled down system models suitable for testing in RTDS and HTB.</td>
<td>Communication system modeling including cyber attacks.</td>
<td>Scalability of cyber security approaches and resilience to coordinated attacks.</td>
</tr>
<tr>
<td>Scenario development to include diverse system operating conditions.</td>
<td>Scenario development for North American grid.</td>
<td>Detailed scenarios for contingencies.</td>
</tr>
</tbody>
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## Industry Collaboration and Innovation

| Industry Partnership Program | • Three tier membership structure  
| • Industry consortium  
| • Industry Advisory Board (IAB) |
| Research Collaboration | • Mentors and thrust partner  
| • Sponsored research |
| Industry Connectivity | • Industrial residence program  
| • Summer internships  
| • Short courses |
| IP & Technology Transfer | • Intellectual Property Protection Fund (IPPF)  
| • Build partnerships with local government  
| • Engage small businesses |
| Innovation Program | • Entrepreneurship and IP training  
| • Faculty award for winning SBIR/STTR  
| • Student award for patent |


**Education Program Pipeline**

**Diversity Efforts**

- Early intervention
- Operates at all levels (diversity)
- Tailored research opportunity
- Sustained involvement
- Model-based assessment & research

- RET
- Lab Tour; Science Fair; Parents' Night
- Young Scholar
- Summer Bridge
- Mentorship
- Freshmen
- Upper Classmen
- REU semester & summer; Senior Projects; Internship
- Research; Industry Connectivity
- Graduate Students
- Career
International Research Collaboration Opportunities

• Incorporate projects into strategic research plan
• Use of testbeds
• Education exchanges – students and researchers
• Unique aspects of different systems across countries can more fully test new control architectures, e.g.,
  • Japan
    • Multiple frequency system
    • Highly dense urban distribution systems
  • Germany
    • High levels of wind and solar
    • Tight integration with larger continental system
  • Norway
    • High levels of hydro
    • Longitudinal system