CURENT
CENTER FOR ULTRA-WIDE-AREA RESILIENT ELECTRIC ENERGY TRANSMISSION NETWORKS

Infrastructure, Assessment and Sustainability

Kevin Tomsovic

Center Director

NSF-DOE Site Visit
November 9, 2020
Virtual

THE UNIVERSITY OF TENNESSEE KNOXVILLE · Rensselaer · Northeastern · TUSKEGEE UNIVERSITY

People and Equipment

INFRASTRUCTURE

Leadership

Council of Deans

Industry Advisory Board

Scientific Advisory Board

Internal Academic Board

Director
K. Tomsovic, UTK
Deputy Director
Y. Liu, UTK

Administrative Director
J. Cooley, UTK

Technical Director
F. Wang, UTK
ERC Research Thrusts

Monitoring
Y. Liu, UTK

Modeling
A. Abur, NEU

Control
J. Chow, RPI

Actuation
F. Wang, UTK

Engineered Systems
L. Tolbert, UTK

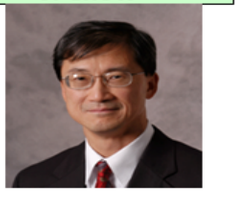
Education and Diversity Director
C. Chen, UTK

Education and Diversity Co-Director
D. Costinett, UTK

Innovation & Industrial Collaboration Program
L. Beard, UTK
T. Xia, Integrated Power Eng., Inc.
K. Jones, Grid Widget Lab. LLC

UTK Campus Director
F. Li

RPI Campus Director
J. Chow

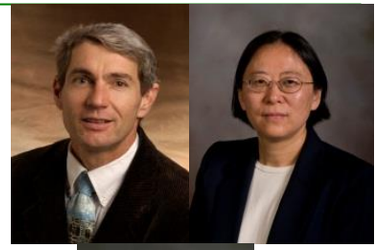


NEU Campus Director
A. Abur

TU Campus Director
G. Murphy

Leadership Roles

- **Director and deputy director**
  - Strategic planning
  - Policy and administrative oversight
- **Technical director**
  - Planning – milestones and long term goals
  - Operations – ensure thrusts are meeting objectives and working towards Center goals
- **Thrust leaders**
  - Planning – focused milestones and long term goals
  - Operations – ensure projects are meeting objectives
- **Campus directors**
  - Administrative oversight at each campus







Leadership Roles

- **Education and diversity – Director and co-Director**
  - Overall responsibility for education, diversity and outreach programs
- **Industry Liaison Officer**
  - Industry interactions
  - IAB meetings and communications
  - Technical support on reports
- **Administrative director**
  - Financial and administrative oversight

Support Staff

- **Education and outreach coordinator –** Claire Duggan, Jarron Decker, Anne Skutnik, Elizabeth Herkenham, Rachelle Reisberg and Richard Harris

- **Communications –** Wendy Smith
- **Infrastructure and labs–** Bob Martin, Joe Calloway

- **IT –** Ryan Smiley

- **Administrative assistants –**Janellen Greer, Laraine Michealides, Lisa McMullian, Samantha White, Missy Hodge

Council of Deans

- Governing board – Deans of Engineering from each partner institution
- Approval of Center research and education activities
- Review annual and external consultant reports
- Annual meeting

Dr. Janis Terpenny
Dean of the College of Engineering
University of Tennessee

Dr. Shekhar Garde
Professor and Dean of the College of Engineering
Rensselaer Polytechnic Institute

Dr. Heshmat Aglan
Professor and Dean of the College of Engineering
Tuskegee University

Dr. Jacqueline Isaacs
Interim Dean of the College of Engineering
Northeastern University

Scientific Advisory Board

These technical experts advise on ERC research program directions. We meet once annually and have at least one teleconference per year. The SAB participates in SWOT analysis.

T. Başar
University of Illinois

D. Bertagnolli
ISO New England (Retired)

T. Boston
PJM (Retired)

C. Clem
TVA

B. Cummings
NERC

J. Giri
GGM Consulting

N. Hingorani
EPRI (Retired)

J. Heydt
Arizona State University

J. Lyons
Novus Energy Partners

T. Overbye
Texas A&M University

W. Reder
Grid-X Partners

P. Sauer
University of Illinois

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Industry Advisory Board

Matthew Gardner
Dominion Energy
Chair

Xiaoming Feng
ABB
Vice Chair

Dominion Energy
TVA
Lawrence Livermore National Laboratory
GEIRINA GEIRI NORTH AMERICA
ABB
NREL NATIONAL RENEWABLE ENERGY LABORATORY
KUB
aps
ATC AMERICAN TRANSMISSION COMPANY
NRECA
LINEVISION
epb
Southern Company
ConEdison
BOEING
Sandia National Laboratories
New York Power Authority
KEYSIGHT TECHNOLOGIES
EPRI ELECTRIC POWER RESEARCH INSTITUTE
ISO new england
CURENT
OAK RIDGE National Laboratory
Pacific Northwest NATIONAL LABORATORY
PEAKRELIABILITY assuring the wide area view
pjm
UL

New Faculty Hires and Lab Investments

UTK – Helen Cui

Power electronics, magnetics

- Power electronics packaging lab (on-going).
- Expanding high voltage power electronics laboratory to 250 kVA load at voltages up to 25 kV. (on-going)

Extensive Shared Software Capabilities

- Power system simulation – positive sequence modeling
  - Andes (in house development)
  - Commercial – DigSilent, DSATools, GridDyn, PSS/E, PowerWorld, PSLF, TSAT
  - Other open-source – PSAT, MatPower
- Distribution systems
  - CYME
  - GridLab-D
  - OpenDSS
- Real-time digital simulators
  - ePhasorSim
  - OPAL-RT
  - RTDS

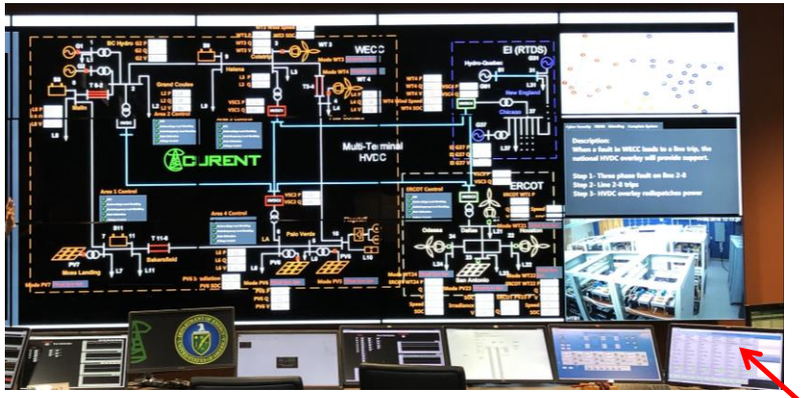
CYME INTERNATIONAL T&D
Eaton's CYME Power Engineering Software

ePHASORSIM

PowerWorld Corporation

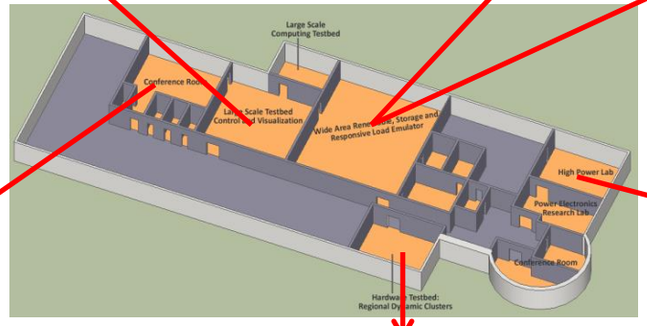
DSATools™

Facilities – Headquarters and UTK Labs



Visualization and Control Lab

Low and Medium Power Lab



Conference Room

Grid Emulation Lab

High Power Lab

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Northeastern University

Power System Computer Simulation Software

- Industry-grade state and parameter estimator
- P.E.T: Educational software developed at Northeastern
- ETAP, PowerWorld, Matlab/Simulink and SimPower Toolboxes

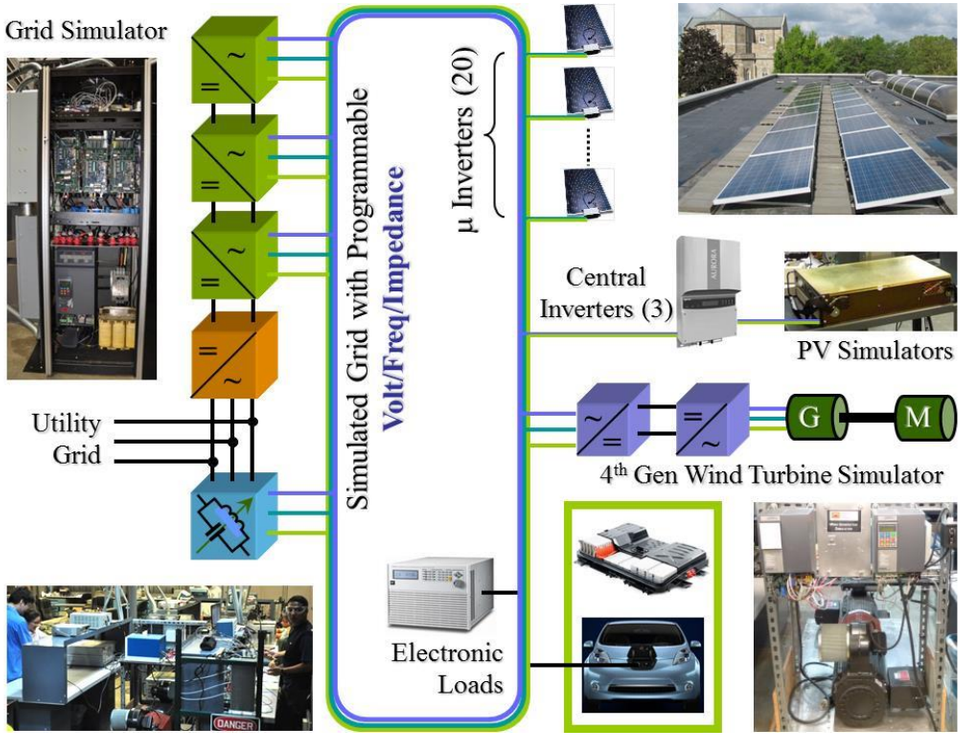
CURENT-ERC Computer Lab with PMUs

- PMU panel with GPS antenna and synchro-phasor visualization software. Digital programmable relays and associated software.

Rensselaer Polytechnic Institute

- **Distributed Generation and Smart Grid Test-Bed**
  - Grid Simulator, Wind, Solar, Programmable Loads

- **ALSETLab**
  - The “Digital” Grid Laboratory



Tuskegee University

Power Systems Laboratory

- Six (6) Hampden work stations equipped with motor/gen sets, transmission lines, loads

Power Systems/Power Electronics Research Lab

- OPAL-RT OP8660 HIL Controller and Data Acquisition Interface
- OPAL-RT P5700 RCP/HIL FPGB-based Real –Time Simulator
- Lab-volt Electromechanical Training System
- DS1104 R&D Controller Board, Electric Machines/DC-DC, DC-AC Converters

Other Supporting Facilities

- Two supercomputer workstations for modeling and simulation
- Modeling and simulation software PSCAD, Matlab/Simulink, OPNET, PowerWorld

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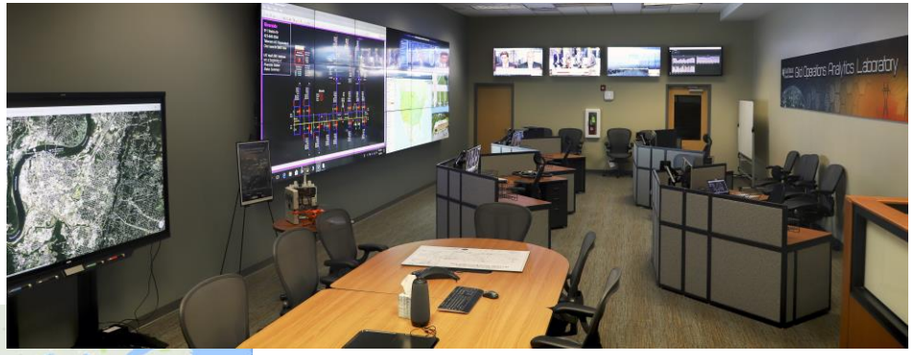
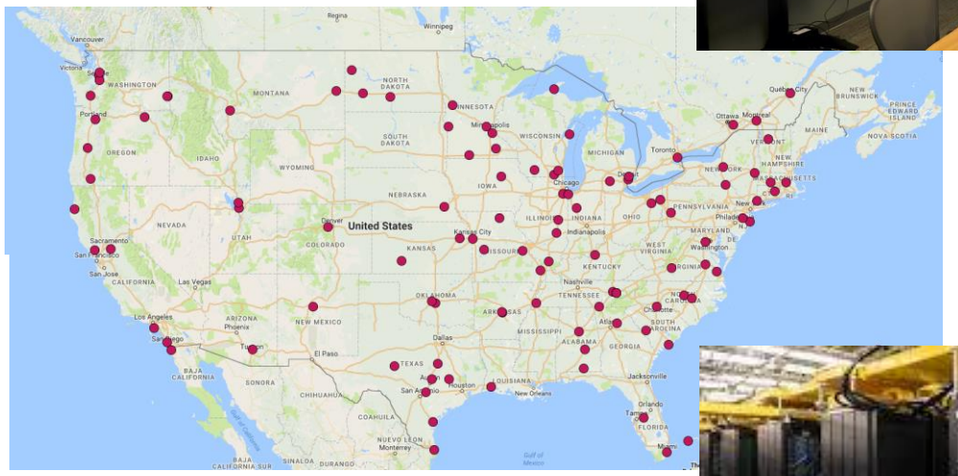
Access to ORNL Facilities

- DECC Lab
- FNET/GridEye
- ORNL GRID-C Facility
- Eagle-I
- IACMI – 3D printing
- Summit supercomputer





The Institute for iacmi Advanced Composites Manufacturing Innovation

CURENT

Functional Budget

Table 8: Current Award Year Functional Budget					
Function	**Direct Support**		**Direct Support Total**	**Associated Projects**	**Total Budget**
	Unrestricted Cash (Core Projects)	**Restricted Cash (Sponsored Projects)**			
Actuation	$400,000	$0	$400,000	$1,620,000	$2,020,000
Control	$700,000	$0	$700,000	$560,525	$1,260,525
Modeling	$500,000	$0	$500,000	$455,000	$955,000
Monitoring	$400,000	$0	$400,000	$255,000	$655,000
Testbeds	$700,000	$0	$700,000	$0	$700,000
Research Total	**$2,700,000**	**$0**	**$2,700,000**	**$2,890,525**	**$5,590,525**
Educational Program Total	$570,000	$0	$570,000	$0	$570,000
General Shared Equipment	$125,000	$0	$125,000	$0	$125,000
New Facilities/New Construction	$0	$0	$0	$0	$0
Leadership/Administration/Management	$650,000	$0	$650,000	$0	$650,000
Industrial Collaboration/Innovation Program	$300,000	$0	$300,000	$0	$300,000
Center Related Travel	$100,000	$0	$100,000	$0	$100,000
Indirect Cost	$846,463	$0	$846,463	N/A	$846,463
Functional and Educational Budget Total	**$2,591,463**	**$0**	**$2,591,463**	**$0**	**$2,591,463**
Support Reserved for Future Years	N/A	N/A	$0	N/A	$0
Residual Funds Remaining	$0	$0	$0	N/A	$0
Total	**$5,291,463**	**$0**	**$5,291,463**	**$2,890,525**	**$8,181,988**

ASSESSMENT

Formative Assessments

Evaluation and Assessment	Frequency	Objective	Implementation
Research thrusts and project meetings	Weekly teleconference	Ensure continual progress and address any significant roadblocks to projects	Students present progress on research projects. For some projects, such as the test beds, a student lead has been assigned who organizes the presentations and presents the task schedule.
Center administration	Weekly teleconference	Coordinate planning of overall Center activities and address any administrative issues	Agenda set by leadership team but open meeting where any issues can be brought up. All Center faculty are invited.
Education activities	Bi-weekly teleconference	Coordinate planning of outreach and education activities and provide forum to share materials and results	Agenda set by education and diversity director. Campus education leaders participate.
Other research tasks	As needed	Investigate more in-depth research discussions.	Faculty, students or industry members prepare detailed technical descriptions and invite commentary/suggestions
Center wide project review	Monthly webinar	Coordinate results across research thrusts and ensure systems approach to research. Bring in broader points of view in assessing progress.	Faculty and students presentations to entire Center. Two approaches have been used: a) Brief overview from thrust leaders covering all project tasks; b) In depth presentation for a single thrust.
Industry and scientific advisory board review	Monthly webinar	Bring in industry and scientific advisory board perspectives on research. Provide value to industry members.	In depth presentation by faculty representing most recent research results.
Scientific advisory board	Monthly teleconference	Engagement of SAB in overall Center activities.	Independent meeting of SAB members to discuss Center.
Culture of inclusion	Continuous	Feedback from staff, students, and faculty through surveys and consultants.	External consultancy and coaching; feedback from Slack and Officevibe.

Summative Assessments

Evaluation and Assessment	Frequency	Objective	Implementation
Center retreat	Semi-annual meeting	1: Discussions to revise research roadmap and prepare call for proposals 2: Present revised research roadmaps and proposed proposals.	Spring: Meeting at company or area of interest with selected advisory invites and all Center faculty members Late Summer: Combined meeting with IEEE PES GM open to all industry members and all Center faculty
Formal reports	Annually	Evaluate research project accomplishments. Provide input to new research directions. Review resource allocations.	NSF annual report and collected publications
SLC SWOT	Annually	Obtain student feedback on the Center programs.	SLC lead survey with discussion groups each fall.
Industry SWOT	Annually	Obtain industry feedback on the Center programs.	IAB chair lead survey with follow up teleconference each fall.
Site visit	Annually	Thorough review of all Center programs by SVT. SVT report with responses provides continual guidance throughout year.	Site visit each fall.
Review of Center culture of inclusion	Annually	Review inclusivity in Center through survey mechanisms, interviews and focus group.	Internal survey and external consultancy report.

Assessment of University Programs

Program Activities	Qualitative Measure	Quantitative Measure
Summer REU **Undergraduate research**	▪ Feedback from mentors, students and faculty during and after programs ▪ Intention to stay in the engineering fields	▪ Pre/post survey assessment; developing solid measurement in learning outcomes ▪ Final projects (posters, presentations) ▪ Degree earned ▪ Employment status and fields ▪ Internship ▪ Recognitions/awards
Graduate programs	▪ Feedback from students during program ▪ Improved IMPACT program ▪ Feedback on shared courses or research projects	▪ Pre/post survey assessment; developing solid measurement in learning outcomes ▪ Improved IMPACT program ▪ Degree earned ▪ Publications ▪ Employment and fields ▪ Recognitions/awards
Seminars and trainings	▪ Feedback from students and faculty and staff ▪ Evaluating during and after the semester based on logic model	▪ Number of events ▪ Number of attendants

Assessment of Pre-College Programs

Program Activities	Examples of Formative Assessments	Examples of Summative Assessment
High School Summer Programs (YSP, RPI Smart Grid camp)	▪ **Feedback** from mentors, student workers, and faculty during and after programs	▪ **Pre/post survey assessment** for students with open-ended questions ▪ **Final projects** (posters, presentations, etc.)
Middle school summer programs (Adventures in STEM)	▪ **Feedback** from students during program	▪ **Pre/post survey assessment** for students with open-ended questions ▪ **Final projects** (posters, presentations, etc.)
Classroom presentations	▪ **Feedback** from students and teachers during/after the presentation	▪ Longitudinal study: **classroom data – assignments, final products, and so on.**
Community out-of-school-time events (Family Engineering Night)	▪ **Feedback** from students, parents, teachers, and volunteers during/after the event	▪ **Survey data** from parents, students, and teachers about the event

Some ERC Benchmarks

Table 1a: 2019 Average Metrics Benchmarked Against All Active ERCs and the Center's Tech Sector					
Metric	**Average All Active ERCs FY 2019**	**Average Energy, Sustainability, and Infrastructure Sector FY 2019**	**Average Class of 2011 FY 2019**	**Tennessee-CURENT Total**	**Tennessee-CURENT Total**
	(14 ERCs)	**(6 ERCs)**	**(4 ERCs)**	**FY 2019**	**FY 2020**
Organizations Within Non-Industry Sectors	**27**	**30**	**43**	**28**	**29**
Industrial/Practitioner Member Firms	**19**	**22**	**28**	**36**	**35**

Publications	**Average**	**Average**	**Average**	**Total**	**Total**
In Peer-Reviewed Technical Journals	30	31	36	27	29
In Peer-Reviewed Conference Proceedings	15	15	23	41	18
Multiple Authors: Co-Authored With ERC Students	32	34	42	55	33
Multiple Authors: Co-Authored With Industry	4	5	6	11	7

Intellectual Property	**Average**	**Average**	**Average**	**Total**	**Total**
Invention Disclosures	4	4	4	8	14
Patent Applications (Provisional and Full)	5	4	5	10	6
Patents Awarded	1	0	0	1	4
Licenses (patents, software)	0	0	0	0	2

Industrial/Practitioner Member Firms	**19**	**22**	**28**	**36**	**35**
Total Membership Fees Received	**$242,280**	**$289,167**	**$189,777**	**$571,000**	**$613,000**

SUSTAINABILITY

CURENT Industry Sustainability Planning Group (CISP)

- **Purpose for CISP**
  - Determine methods to retain existing relationships and explore other opportunities to sustain the center.
  - Help center build a sustainable model by providing guidance for financial support and facilitation of its programs.
- **Objectives**
  - Increase the likelihood of a successful transition so Center is able to sustain itself and continue to operate after graduation.
  - Identify key changes that can be expected for the Center. The goal is to positively manage these changes and develop approaches to augment the core programs of the Center in other ways.

CISP	
Name	Affiliation
Industry	
Tom King (chair)	UT/ORNL
Hongming Zhang	Peak Reliability
Dejim Lowe	Tennessee Valley Authority
Xiaoming Feng	ABB/IAB Co-chair
Dave Bertagnolli	Scientific Advisory Board
Matthew Gardner	Dominion/IAB Chair
Faculty	
Ali Abur	NEU Campus Director
Joe Chow	RPI Campus Director
Fran Li	UTK Campus Director
Greg Murphy	TU Campus Director
Staff	
Lisa Beard	Industry Liaison Officer
Ex Officio	
Gil Bindewald (invited)	DOE Office of Electricity Delivery and Energy Reliability

Sustainability Plan
Four Key Components

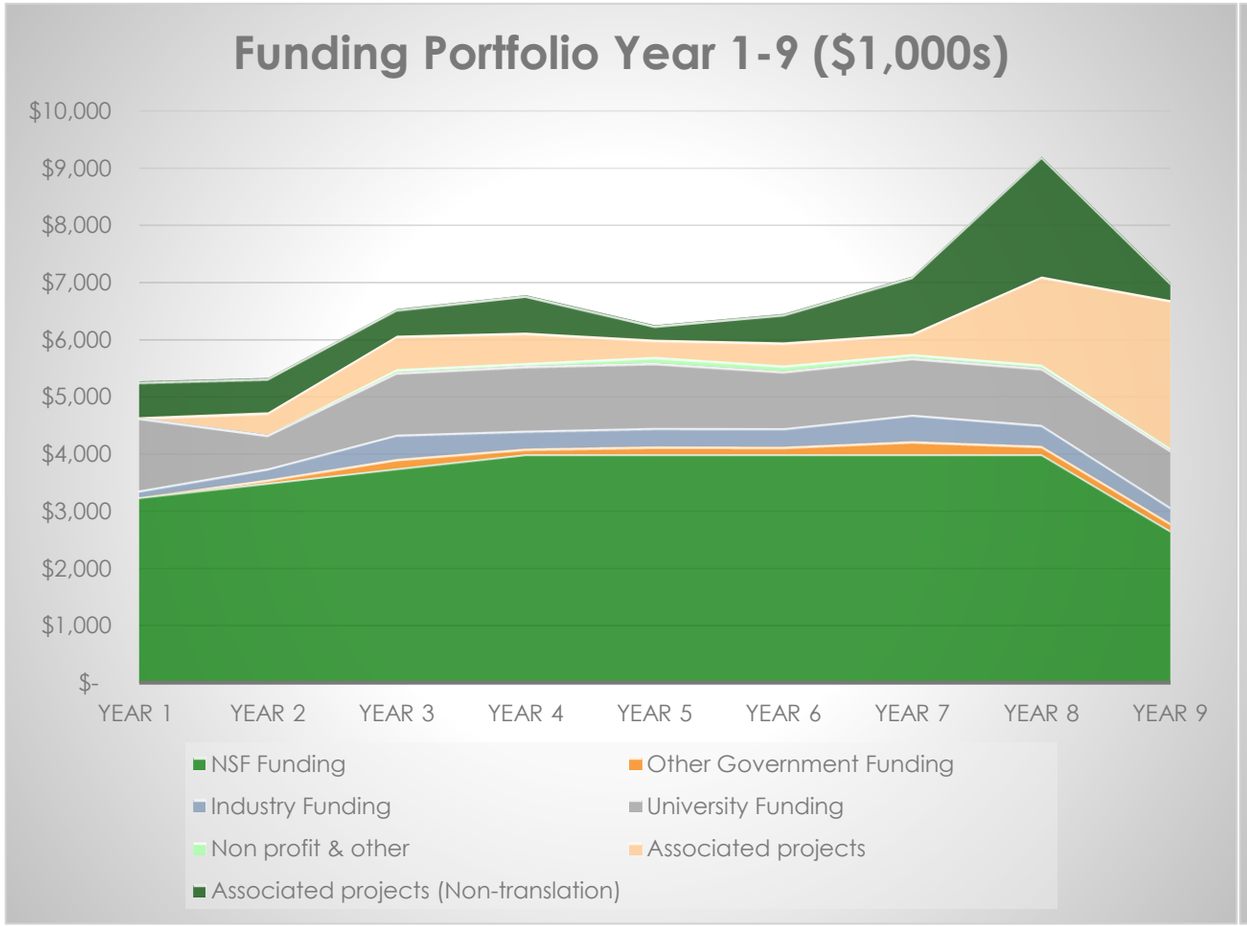
1. **Programmatic**
   - Define post-graduation mission & goals
2. **Financial**
   - Secure university support
     - Institutional support (financial) – existing written commitments from deans
   - Research and education
     - Interdisciplinary research grants obtained from Federal and State agencies
     - Innovation partnerships – education grants and start-up companies
   - Continue to increase industry engagement
     - Regular site visits to member companies
     - 36 members in Year 8 – goal is 40
   - Capitalize on technology transfer
3. **Cultural**
   - Develop future workforce of students who are prepared to work on teams, to be entrepreneurs, and are cross-trained in power electronics and power systems
   - Center approach of innovation through group research and valuable applications
   - Institutionalize Culture of Inclusion
4. **External**
   - Communication plan
   - Conduct outreach/workshops

Changing Research Portfolio

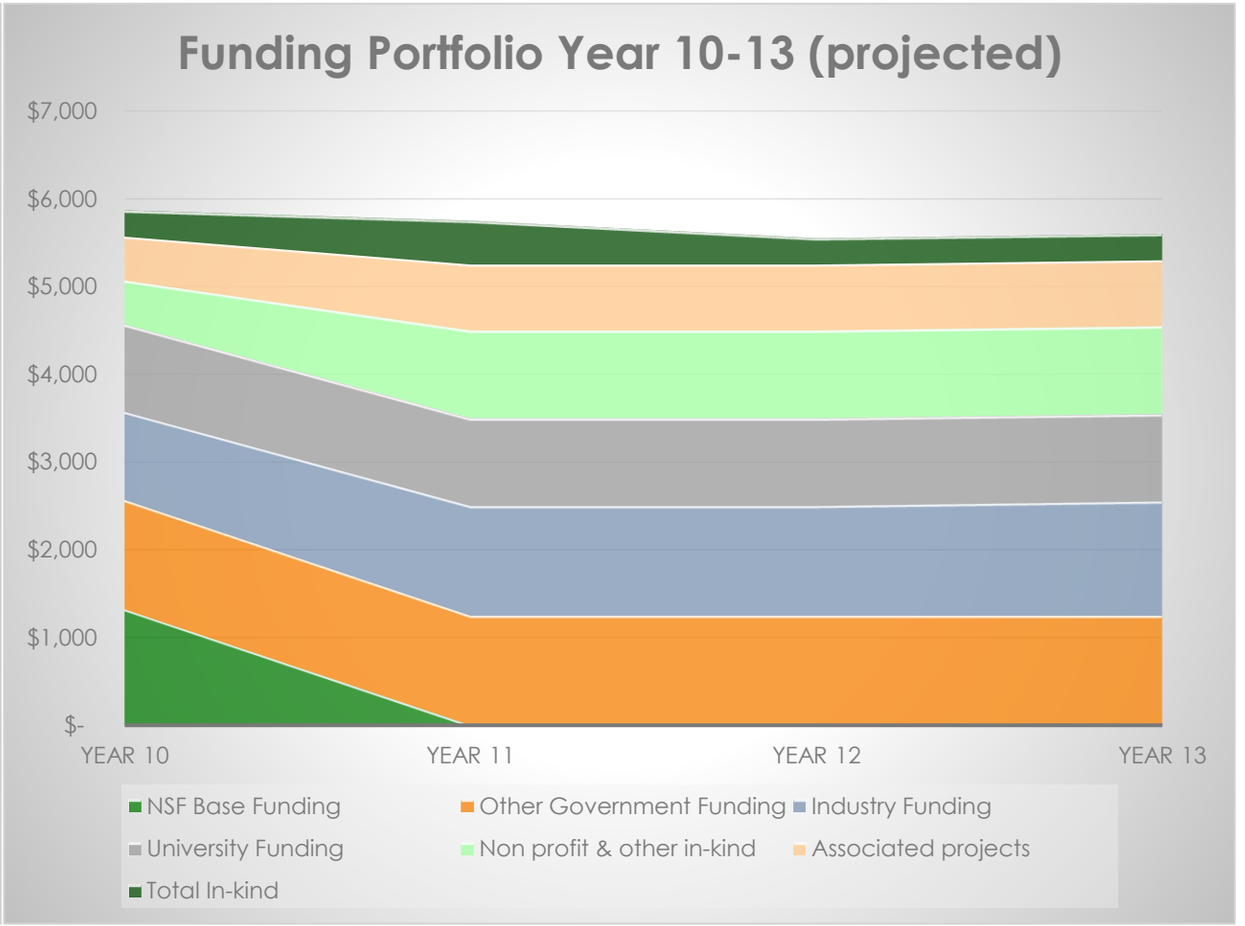
- **Research portfolio**
  - Responsive to industry members and other funding sources
  - Maintain identity and build on research strengths
- **Process**
  - Expertise in power systems and power electronics.
  - Center-wide project on developing future research thrusts begun in Year 7
    - Continent-wide system with HVDC overlay
    - Fully inverter based microgrids
    - Distribution system modeling as it impacts transmission system operations
    - Increased emphasis on cybersecurity and other resilience issues

    ➔ Create foundation for projects beginning in Year 9 and 10 that extend beyond year 10
  - Balance new research directions without losing focus
    - Operation of fully inverter based systems, such as, aircraft power
    - Power system interfaces to other infrastructures – e.g., buildings, transportation

Post-Graduation Business Plan



Funding Portfolio Years 1-9



Funding Portfolio Including Years 10-13 Projection

Post Graduation Functional Budget

- Income per year – $5.75M
  - $1M State/University
  - $1M Industry (memberships, service fees, licensing)
  - $3.25M Government grants and other associated projects
  - $500K F&A return and other university in-kind support; other foundations
- Expenditures per year – $5.75M
  - $750K – Director, Campus Leads, Administration and staff support, travel, materials/equipment
  - $500K – Labs and facilities
  - $1M – Core center research projects
  - $3M – Sponsored research

Summary of Actions/Status

- CURENT Sustainability Plan – living document
- Research funding is more than double core funding
- Commitments from deans for continued support of Center
- Outreach programs and staff positions begun integration into College
- Extended CURENT research roadmap beyond year 10
- Increased emphasis on technology transfer and licensing software and IP
- Workable financial plan
- Pursuing multiple avenues for new core funding
  - State level initiatives
  - Newly formed Oak Ridge Institute
  - Leveraging testbeds for several research grants

Acknowledgements

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