Office of Electricity Perspectives
Kerry Cheung, PhD
Advanced Grid R&D Division

July 17, 2018
The Office of Electricity (OE) provides national leadership to ensure that the Nation’s energy delivery system is secure, resilient and reliable. OE works to develop new technologies to improve the infrastructure that brings electricity into our homes, offices, and factories, and the federal and state electricity policies and programs that shape electricity system planning and market operations.

**OUR MISSION**
OE drives electric grid modernization and resiliency in the energy infrastructure. OE leads the Department of Energy’s efforts to ensure a resilient, reliable, and flexible electricity system. OE accomplishes this mission through research, partnerships, facilitation, and modeling and analytics.
Advanced Grid Research and Development

**Electric Power Grid**

- **RTO/ISOs**: Coordinates, controls, and monitors transmission grid and wholesale market.
- **Electric Utilities**: Monitor and operate distribution network.
- **Energy Storage**: Central component.
- **Wide Area Sensors Measurement and Monitoring**: Monitors states/territories and communities.
- **Distribution Automation and Management**: Controls and monitors transmission grid and wholesale market.
- **Transformers, Protection, Power Control Devices**: Connects electricity producers and consumers.
- **Microgrids**: Energy storage units for communities.
- **States/Territories**: Distributed energy resources for wide area sensors.
- **Electricity Consumers**: End users of electricity.
- **Electricity Producers**: Sources of energy.

**Distributed Energy Resources**

- Advanced Grid Research and Development
- Office of Electricity, US Department of Energy
## Advanced Grid R&D Portfolio

<table>
<thead>
<tr>
<th>Grid Controls and Communications</th>
<th>Transmission Reliability and Resilience</th>
<th>Synchrophasors</th>
<th>Advanced Grid Modeling</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resilient Distribution Systems</strong></td>
<td>Advanced Distribution Systems</td>
<td>Advanced Microgrids</td>
<td>Dynamic Controls and Communications</td>
</tr>
<tr>
<td><strong>Energy Storage Systems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Role of Government in R&D

Convening Stakeholders:
- Bring together diverse perspectives, align disparate efforts across various organizations, and foster partnerships between public and private entities

Catalyzing Innovation:
- Support cutting edge R&D, de-risk technologies for the public good, and promote the adoption of new technologies, processes, and approaches

Capacity Building:
- Build human capital and capabilities to sustain innovation, provide technical assistance, and share information on best practices and R&D results
Grid Modernization Initiative (GMI)

https://gridmod.labworks.org/
2018 GMI Peer Review

SAVE THE DATE!

September 4–7, 2018
Sheraton Pentagon City Hotel

GMI Peer Review activities include:

– Reviewing DOE’s grid modernization portfolio
– Listening to industry leaders discuss the future grid during a panel discussion
– Hearing from leadership at the national laboratories discuss future grid activities
– Reflecting on the updated Grid Modernization Multi-Year Program Plan
– Engaging with other GMI projects in the portfolio during the poster session

Look out for an email with more information and registration details.

Not on our distribution list? Contact us at gmi@hq.doe.gov

SAVE THE DATE!
Transformer Resilience and Advanced Components

To ensure the electric grid remains reliable and resilient, next-generation transmission and distribution hardware will need to better withstand physical and cyber-threats, facilitate rapid recovery and restoration, and provide new capabilities that meet future grid requirements. Improvements in the materials used in these components and the way they are designed and built will enhance their performance, reduce their costs, and enable more flexible and efficient grid operations.

- Increased energy efficiency
- Improved operations and new architectural paradigms
- Enhanced asset utilization and management
- Increased system resilience
- More domestic manufacturing and jobs
# Overview of TRAC Program Areas

<table>
<thead>
<tr>
<th>Program Areas</th>
<th>Objective</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market &amp; System Impact Analysis</td>
<td>• Understand system impacts of new technologies and functions</td>
<td>Reduces the uncertainty and costs of technology integration</td>
</tr>
<tr>
<td></td>
<td>• Techno-economic analysis for costs/benefits of advances</td>
<td>Reduce the risk and cost of next-generation components</td>
</tr>
<tr>
<td>Component Design &amp; Development</td>
<td>• Design and prototype components with enhanced features/functions</td>
<td>Implies knowledge of component operations and accuracy of models</td>
</tr>
<tr>
<td></td>
<td>• Field validations to demonstrate and evaluate new capabilities</td>
<td>Foundational to improved performance and costs</td>
</tr>
<tr>
<td>Monitoring, Modeling &amp; Testing</td>
<td>• Develop embedded sensors and intelligence to improve reliability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Testing and model validation to understand limits and performance</td>
<td></td>
</tr>
<tr>
<td>Applied Materials R&amp;D</td>
<td>• Evaluate and develop new materials and devices that underpin advanced components</td>
<td></td>
</tr>
</tbody>
</table>
Future Scenarios and Improved Simulation

- Explore costs/benefits and assess reliability of future scenarios with more PE
- Improve models and methods for simulating converters and multi-terminal DC
- Advance co-simulation capabilities to increase model fidelity
Next-Generation Transformers – Flexible Designs

<table>
<thead>
<tr>
<th>Primary Design Attributes</th>
<th>Secondary Design Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Efficiency</td>
<td>Transportability</td>
</tr>
<tr>
<td>Variable High Side Voltage</td>
<td>Manufacturability</td>
</tr>
<tr>
<td>Variable Low Side Voltage</td>
<td>Power Flow Controllability</td>
</tr>
<tr>
<td>Variable Impedance</td>
<td></td>
</tr>
<tr>
<td>Cost Effective</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Company</th>
<th>High Efficiency</th>
<th>Variable High Side Voltage</th>
<th>Variable Low Side Voltage</th>
<th>Variable Impedance</th>
<th>Cost Effective</th>
<th>Transportability</th>
<th>Manufacturability</th>
<th>Power Flow Controllability</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABB Inc. *</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>General Electric Company *</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>●</td>
<td>○</td>
<td>●</td>
</tr>
<tr>
<td>NextWatt, LLC **</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Georgia Tech Research Corp. *</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>●</td>
</tr>
<tr>
<td>North Carolina State University **</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

LEGEND:
* Near-term Market Potential (0-10 years)
** Long-term Market Potential (> 10 years)
● Strong Attribute
○ Moderate Attribute

New Funding Opportunity Announcement

In early June, OE released a $7.5 million FOA to spur the innovative design of large power transformers (LPTs) that will be more flexible and adaptable, thereby increasing the resilience of the Nation’s power grid.

Prototypes must demonstrate high efficiency, variable/controllable impedance, and the ability to accommodate a range of high-side and low-side voltages. Sensors, communications, and analytics that enhance the operation and performance of the final LPT should also be integrated into the prototype and assessed.

Application due date is July 25, 2018.
# Additive Manufacturing of Silicon Steel

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Model</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Max: 5.846 2.348 11.196 10.481

**Core**

**Shell**

A A1 A2

Fe-3Si

B A1 A2

Fe-6Si

![实验模型](image1)

![实验模型](image2)

![实验模型](image3)

![实验模型](image4)
DOE Power Electronics Strategy

Generation
- Hydro
- Nuclear
- Coal/Gas
- Photovoltaics
- Wind

Transmission
- Wind
- Battery
- High Voltage DC

Sub-transmission
- Battery

Distribution
- Electric Vehicle Charger
- LED Drivers
- Commercial End-Use
- Residential End-Use
- Industrial End-Use

LEGEND
- Power Electronics System
Power Electronics R&D Framework

Components
- Materials are combined together to form components
- Basic building blocks circuit
- Includes switches, capacitors, inductors, etc.

Subsystems
- Multiple components together form subsystems
- Perform a specific task within the PES
- Includes subsystem controls, sensors, thermal management, protection, power stage, etc.

Materials
- Bottom layer in the PE R&D spectrum (non-application specific)
- Foundation for other technological improvements
- Advanced semiconductor, magnetic materials, new capacitor dielectrics, etc.

Systems
- Multiple subsystems together form the system or Power Electronic System (PES)
- Self-contained, fully functional unit that performs the end-use application
- Includes DC/AC disconnects, system controls, final packaging, etc.

HVDC PES
Wind Energy PES
PV PES
Grid-tied Energy Storage PES
Electric Vehicle PES

Semiconductor Switches
Capacitor
Inductors and transformers

Capacitor Materials
Semiconductor Materials
Magnetic Materials

Power Converter Modules
Solid State Power Substations (SSPS)

SSPS: substations with the strategic integration of high voltage power electronic converters that provide enhanced capabilities and support evolution of the grid.
SSPS Vision for Grid Evolution
SSPS Technology Roadmap

End Goal: Scalable, adaptable, cost-effective, flexible AC/DC power router that spans all voltages

Converter Voltage Rating

- EHV
- HV
- MV
- LV

Functionality and Level of Sophistication

- Multiple Ports and Voltage and Frequency Control
- Integrated Communications and Coordination
- Fully Autonomous and Global Optimization

Advanced Grid Research
Office of Electricity
US Department of Energy
Questions?

Contact Information:

Kerry Cheung, PhD
Program Manager/Strategist
Office of Electricity
U.S. Department of Energy
(202) 586-4819
kerry.cheung@hq.doe.gov