Office of Electricity

Transformer Resilience and Advanced Components (TRAC) 2021 Program Review Report

February 2022

Acknowledgements

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List of Abbreviated Terms

A	ACCR	Aluminum Conductor Composite Reinforced
	ACSR	Aluminum Conductor Steel Reinforced
	AGD	Active Gate Drive
	AlOx	Alumina
	APS	Auxiliary Power Supply
B	BESS	Battery energy storage system
	BN	Boron Nitrate
C	CGI	Controllable grid interface
	CLTS	Core Loss Test System
	CM	Common-mode
	CT	Current transformer
D	DAB	Dual Active Bridge
	DESAT	Desaturation
	DGA	Dissolved gas analysis
	DLR	Dynamic Line Rating
	DOE	U.S. Department of Energy
	DSC	Differential scanning calorimetry
	DSP	Digital Signal Processor
E	EMF	Electromagnetic Field
	EMI	Electromagnetic interference
	EMT	Electro-Magnetic Transients
	EPRI	Electric Power Research Institute
F	FPGA	Field Programmable Gate Array

	F-V	Fussell Vesely
	FY	Fiscal Year
G	GD	Gate-drive
	GE	General Electric
H	HF	High Frequency
	HSST	Hybrid Solid State Transformer
	HV	High Voltage
	HVAC	High Voltage Alternating Current
	HVDC	High-Voltage Direct Current
I	ICS	Insulator Characterization Systems
	IEEE	Institute of Electrical and Electronic Engineers
	IP	Intellectual Property
	IPS	Intelligent Power Stage
L	LiDAR	Light Detection and Ranging
	LPT	Large power transformer
	LV	Low Voltage
	LVRT/ZVRT	Low-voltage ride through/zero-voltage ride through
M	MASTERRI	Modeling and Simulation for Targeted Reliability and Resilience Improvement
	Mbps	Mega bits per second
	MISO	Midcontinent Independent System Operator
	ML/AI	Machine learning / artificial intelligence
	MOF	Metal organic framework
	MOSFET	Metal-oxide field-effect transistor
	MPC	Model Predictive Control

	Msps	Mega samples per second
	MTdc	Multi-Terminal dc
	MV	Medium Voltage
	MVA	Mega volt ampere (transformer power rating unit)
N	NETL	National Energy Technology Laboratory
	NP	Nanoparticle
	NPI	New Product Introduction (a GE process for new products commercialization)
O	OC	Overcurrent
	OE	Office of Electricity
	OFDR	Optical Frequency Domain Reflectometry
P	PCB	Printed circuit board
	PCM	Production Cost Model
	P&D	Prognosis and Diagnosis
	PF	Power Flow
	PPM	Parts per million
	PT	Potential Transformer
	PTP	Precision time protocol
R	R&D	Research and Development
	ReEDS	Regional Energy Deployment System
	RF	Radio Frequency
S	SBIR	Small Business Innovative Research
	SC	Synchronous condenser
	SCADA	Supervisory control and data acquisition
	SCR	Short circuit ratio

	SEM	Scanning Electron Microscope
	SiC	Silicon-Carbide, semiconductor material
	SiOx	Silica
	SLR	Static Line Rating
	SMC	Soft Magnetic Composite
	SST	Solid State Transformer
	SUPER	Smart Universal Power Electronic Regulator
T	T&D	Transmission and Distribution
	TGA	Thermal gravimetric analysis
	TS	Transient Stability
U	UTS	Ultimate Tensile Strength
V	VSC	Voltage Source Converter
W	WBG	Wide Band Gap
	Wt.	Weight
X	XRD	X-Ray Diffraction
Z	Ztap	Position of the flexible impedance tap changer
	ZVS	Zero Voltage Switching
	%IACS	% International Annealed Copper Standard

Executive Summary

On February 1–3, 2022, the Transformer Resilience and Advanced Components (TRAC) program within the U.S. Department of Energy's (DOE's) Office of Electricity (OE) conducted its second program review virtually. The meeting brought together 111 participants, including representatives from utilities, equipment vendors, engineering associations, consultancies, academia, national laboratories, and government. The review included presentations representing 24 projects within the TRAC portfolio; each presentation was provided by a member of that project's research team. A panel of 10 formal peer reviewers evaluated the projects and provided feedback.

The TRAC program supports research and development (R&D) activities that aim to advance technologies and approaches that maximize the value and lifetimes of existing grid components and enable the next generation of grid hardware to be more adaptive, more flexible, more reliable, and more cost-effective than technologies available today. Next-generation grid components can improve equipment performance and lifetimes over current designs, simplify integration of advanced technologies, and provide new capabilities required for the future grid.

The program review solicited feedback from formal peer reviewers and attendees to ensure that program activities remain centered in high-impact focus areas, thereby optimizing the use of federal resources to fill critical R&D gaps. TRAC program management used the expert feedback to improve the program quality, and project principal investigators (PIs) reviewed the evaluations to improve project efforts. In addition, the review provided attendees with an opportunity to learn more about the TRAC program's vision, direction, and ongoing activities.

The TRAC program review also served as a mechanism to further solidify the advanced grid component research community. The program review included a keynote presentation from Dr. Andrew Philips, Vice President, Transmission & Distribution Infrastructure, EPRI, which focused on Transition to a Low Carbon Future. Having a forum for these interactions is critical to the advancement and adoption of innovative technology solutions, especially grid hardware. Lasting and effective change requires a diverse and engaged community; the TRAC program aims to catalyze and nurture this community, which spans diverse stakeholders from material scientists and system designers to equipment manufacturers and utility engineers.

The table below provides the current status for each of the 24 projects presented at the review.

Project Title	Status
SSPS 1.0 Hardware Prototype Development: Smart Universal Power Electronics Regulators (SUPERs) & Intelligent Power Stages (IPSs) for SSPS 1.0 – Madhu Sudhan Chinthavali	Ongoing
SSPS 1.0 Hardware Prototype Development: IPS Hardware Prototype Development – Hui Li	Ongoing
SSPS 1.0 Hardware Prototype Development: IPS Hardware Prototype Development – Yue Zhao	Ongoing
SSPS 1.0 Hardware Prototype Development: Intelligent Power Stages (IPS) – Rolando Burgos	Ongoing
SSPS 1.0 Hardware Prototype Development: Intelligent Power Stages (IPSs) – Jin Wang	Ongoing
SSPS 1.0 Hardware Prototype Development: Intelligent Power Stages (IPSs) – Babak Parkhideh	Ongoing
SSPS 1.0 Hardware Prototype Development: Intelligent Power Stage – Alex Q. Huang	Ongoing
SSPS 1.0 Hardware Prototype Development: Intelligent Power Stages (IPSs) – Fang Luo	Ongoing
SSPS Controller: Hardware in loop (HIL) validation – Radha Krishna Moorthy	Ongoing
SuperFACTS: Super-Flexible & Robust AC Transmission System – Vahan Gevorgian	Ongoing
Continuously Variable Series Reactor (CVSR) for Distribution System Applications – Sonny Xue	Ongoing
Multi-Port Modular Medium-Voltage (M3) Transactive Power Electronics Energy Hub – Madhu Sudhan Chinthavali	Ongoing

Design, Deployment, and Characterization of the World's First Flexible Large Power - Ibrahima Ndiaye	Ongoing
Demonstration of a 5 MVA Modular Controllable Transformer (MCT) for a Resilient and Controllable Grid - Deepakraj Divan	Ongoing
Modular Hybrid Solid State Transformer for Next Generation Flexible and Adaptable Large Power Transformer - Alex Q. Huang	Ongoing
Next-Generation Modular Flexible Low-Cost Silicon Carbide (SIC)-Based High-Frequency-Link Transformer - Sudip K. Mazumder	Ongoing
System Resiliency Evaluation Tool – Carol A. Reid	Complete
Scalable Hybrid Large-Scale dc-ac Grid Analysis Methods – Suman Debnath	Ongoing
Demonstration of Advanced Monitoring and Data Analytics of Power Transmission Lines – Jonathan Marmillo and Kristine Engel	Ongoing
Optical Fiber Sensors for Selective Detection of Acetylene Dissolved in Transformer Oil – Michael Buric	Ongoing
Al/Ca Composite Conductor Characterization – Iver Anderson	Ongoing
Enabling Soft Magnetics for Power Conversion Applications – Jagannath Devkota	Ongoing
High Temperature Ceramic Capacitor Development – Jonathan Anton Bock	Ongoing
Robust Insulation for Transformers and Power Electronics – Bjorn Vaagensmith	Complete

Introduction

Overview

To date, much of the "smart grid" transformation has focused on applying advanced digital information and communication technologies to the power grid to improve the system's reliability, resilience, efficiency, flexibility, and security. To realize the full potential of a modernized grid, advances in the grid's physical hardware are also needed. Next-generation grid components can improve equipment performance and lifetimes over current designs, simplify integration of advanced technologies, and provide new capabilities required for the future grid. The Transformer Resilience and Advanced Components (TRAC) program supports research and development (R&D) activities that aim to advance technologies and approaches that maximize the value and lifetimes of existing grid components and enable the next generation of grid hardware to be more adaptive, more flexible, more reliable, and more cost-effective than technologies available today.

On February 1-3, 2022, the TRAC program within the U.S. DOE OE conducted its second program review virtually. Due to COVID-19 restrictions and the presence of the Delta and Omicron variants, this program review was held virtually. The program was initiated in fiscal year (FY) 2016 to fill a critical gap in DOE's R&D portfolio, drawing on opportunities identified during the 2015 Quadrennial Technology Review. Over several years, research projects across several focus areas were supported to build out a robust and diverse portfolio necessary to address program objectives. This program review was planned and executed under the direction of Andre Pereira (DOE), the current program manager for the TRAC research program.

The meeting brought together 111 participants, including representatives from utilities, equipment vendors, engineering associations, consultancies, academia, national laboratories, and government. The review included presentations of 24 projects within the TRAC portfolio; each presentation was provided by a member of that project's research team. For each presentation, a panel of 10 formal peer reviewers evaluated the project and provided feedback. Additionally, all attendees were given the opportunity to provide feedback on the research program through live questions and chats during the online event. This report presents the feedback received from attendees, including summaries of the research project peer evaluations. The report also details the process used for the TRAC program review.

A complete list of participants and the agenda can be found in Appendices A and B, respectively.

Purpose

The TRAC program aims to coordinate its portfolio to maximize benefits from interrelated activities. While each technology and project can provide value to the industry individually, a coordinated portfolio approach amplifies results by leveraging synergies. Program reviews are useful in assessing and evaluating a research portfolio and informing program improvements to ensure projects continue to provide value. In general, reviews are conducted routinely (e.g., every two years) to evaluate activities based on a range of criteria including scientific merit, likelihood of technical success, actual or anticipated results, and effectiveness of research management. Results from each project evaluation and program assessment feedback into program planning and portfolio management. This important process helps guide research directions, assess progress, and direct (or redirect, if necessary) resources toward the most promising technology pathways.

Program reviews also serve as a mechanism for interested parties to learn about the status and future directions of a research program. Lasting and effective change requires a diverse and engaged community; the TRAC program aims to catalyze and nurture this community, which spans stakeholders from material scientists and system designers to equipment manufacturers and utility engineers.

Program Review Process

Prior to the program review, a panel of peer reviewers was selected and trained to perform project and program evaluations. The project evaluations were based on presentations delivered by the project principal investigators (PIs) or their designated representatives. Peer reviewers attended the review virtually to observe each project presentation and established a preliminary assessment in a customized spreadsheet with notes in real time. Based on the information captured, reviewers submitted a final evaluation against pre-established criteria, along with supporting comments, within one week of the program review. The evaluation and feedback collected from peer reviewers and other attendees will be used to improve the quality of the program and individual projects.

This section provides more details about the process.

Project Presentations

Before the review, PIs of projects were given presentation templates to ensure consistency and were informed of the established evaluation criteria via a training webinar. The PIs used the templates and criteria when developing their project presentations. During the review, the PI or a designated representative delivered the presentation to the review panel and other attendees who were present. After the conclusion of the review, DOE compiles the project evaluations for review and dissemination, and PIs use the feedback to improve their efforts.

Peer Reviewers

Preparing for the review involved identifying technical professionals with relevant experience and expertise to serve as reviewers for the selected projects. These reviewers were chosen based on their technical expertise in topics of relevance to the TRAC portfolio, their professional experience related to the management of technology projects, and the diversity in organizational perspectives. The final panel composition represented a broad spectrum of expertise and perspectives.

Each of the projects were evaluated by three peer reviewers, with assignments made to ensure diverse and balanced perspectives. Additionally, all assignments were investigated to ensure that no conflicts of interest existed between assigned peer reviewers and the projects that they evaluated.

Reviewers received training before the formal event to ensure complete understanding of the review objectives, consistent interpretation of the criteria, and consistent application of scoring.

Below are the 10 individuals who were selected as peer reviewers, along with their professional affiliations. Appendix C provides brief biographies of each reviewer.

- Dr. Sandeep Bala, ABB Corporate Research
- Dr. Vijay Bhavaraju, Eaton Corporate Research & Technology
- Dr. Sudipta Chakraborty, OPAL-RT Technologies
- Dr. Debrup Das, Hitachi Power Grids
- Mr. Stephen Kelley, Southern Company
- Dr. Michael Mazzola, University of North Carolina at Charlotte
- Dr. Fang Peng, Florida State University
- Dr. Maryam Saeedifard, Georgia Tech
- Mr. Mathew Stinnett, Knoxville Utility Board
- Mr. Ehab Tarmoom, Microchip Technology, Inc.

Project Evaluation Criteria

The reviewers evaluated each project against pre-established criteria, developed to capture the information needed for the review's purpose. These criteria included the project's relevance to DOE and OE missions, impacts on industry, accomplishments, and management. In each area of evaluation, reviewers were asked to provide a numerical score for each project, according to the following scale:

1-2	3-4	5-6	7-8	9-10
Poor/Not adequate	Fair/Significant weaknesses	Good/Modest/ Some areas to improve	Very good/Few areas to improve	Outstanding/Excellent

In addition, reviewers were asked to provide comments/findings, recommended actions, and any considerations the PI should evaluate. Descriptions for each criterion and associated weights are listed below.

Significance and Impact (40%)

- The degree to which the project, as presented, effectively delivers, or has the potential to deliver significant value beyond its research findings. Key points to consider included:

- The degree of impact or potential impact the project has on the electricity delivery system, energy markets, or society
- The likelihood that the technology or project outcomes will become a valuable, widely accepted solution for the electric power industry
- The extent to which research findings spur or enable further innovations
- The effectiveness of technology transfer or the dissemination of results
- The degree to which collaboration with the energy industry, universities, government laboratories, states, and/or end users is being, or has been, pursued

Approach and Execution (20%)

- The degree to which the project, as presented, includes a clear, technically sound, and effective approach for achieving the goals and outcomes presented. Key points to consider included:
- Quality of project approach, including research plan, project execution, and relevance of research team areas of expertise
- The degree to which the project approach is free of major flaws that would limit the project's effectiveness or efficiency
- The degree to which technical or market barriers are, or have been, addressed; the quality of the project design; and technical feasibility
- The degree to which technical accomplishments are being achieved and progress is being made toward overall project goals and milestones
- If this project is continuing, the degree to which the project has effectively planned its future, defined milestones, identified risks, considered contingencies to mitigate/manage risks, built in optional paths, etc.

Technical Productivity and Quality (20%)

The degree to which the project, as presented, represents a valuable and appropriate use of government financial support. Key points to consider included:

- The degree of innovation and risk associated with the project and the extent to which federal investments are justified
- The relative quality and quantity of technical accomplishments and research outcomes, realized or expected, given the amount of federal funding allocated to the project
- The extent to which project accomplishments and outcomes to date are appropriate given the resources utilized

Relevance and Alignment (20%)

The degree to which the project, as presented, aligns with the mission, goals, and objectives of the Office of Electricity, and the TRAC research program. Key points to consider included:

- Relevance to the OE mission and the TRAC program goals to modernize the electric grid; enhance the reliability, resilience, and security of the energy infrastructure; and improve the lifetime and performance of grid components
- The degree to which the project addresses an existing, impending, or critical problem, interest, or need in the electric power industry
- The degree of alignment to the TRAC program technology objectives

Project Evaluations

Project Information

Research projects within the TRAC portfolio are organized into three activity areas: *Advanced Grid Integration Technologies, Advanced Power Control Equipment, and Advanced Materials Based Components*. In accompaniment to this report, the TRAC "Program Overview and Project Fact Sheets"[1] document contains detailed information pertaining to the TRAC program, program activity areas, and an overview of each of the 24 projects evaluated. This section summarizes the results from the peer evaluations of the 24 presentations made.

Advanced Grid Integration Technologies Projects

Advanced grid integration technologies enable grid hardware to be adaptive, flexible, self-healing, resilient, reliable, and cost effective. During the peer review, the following advanced grid integration technologies projects were evaluated:

- SSPS 1.0 Hardware Prototype Development: Smart Universal Power Electronics Regulators (SUPERs) & Intelligent Power Stages (IPSs) for SSPS 1.0
    - Madhu Sudhan Chinthavali, ORNL
- SSPS 1.0 Hardware Prototype Development: IPS Hardware Prototype Development
    - Hui Li, Florida State University
- SSPS 1.0 Hardware Prototype Development: IPS Hardware Prototype Development
    - Yue Zhao, University of Arkansas
- SSPS 1.0 Hardware Prototype Development: Intelligent Power Stages (IPS)
    - Rolando Burgos, Virginia Tech
- SSPS 1.0 Hardware Prototype Development: Intelligent Power Stages (IPSs)
    - Jin Wang, The Ohio State University
- SSPS 1.0 Hardware Prototype Development: Intelligent Power Stages (IPSs)

[1] Link to the OE Website for this document can be found: INSERT LINK WHEN DOCUMENT IS LIVE

    - Babak Parkhideh, University of North Carolina at Charlotte
- SSPS 1.0 Hardware Prototype Development: Intelligent Power Stage
    - Alex Q. Huang, University of Texas at Austin
- SSPS 1.0 Hardware Prototype Development: Intelligent Power Stages (IPSs)
    - Fang Luo, Stony Brook University
- SSPS Controller: Hardware in the loop (HIL) Validation
    - Radha Krishna Moorthy, ORNL

Below are summarized results from the reviews of these projects.

Average Score	8.5
Score Range	7.7 - 9.2

Advanced Power Control Equipment Projects

Advanced power control equipment will help meet the needs of the future grid with electronic/electrical power conversion and control products. The following advanced power control equipment projects were evaluated:

- SuperFACTS: Super-Flexible & Robust AC Transmission System
    - Vahan Gevorgian, NREL
- Continuously Variable Series Reactor (CVSR) for Distribution System Applications
    - Sonny Xue, ORNL and Aleksandar Dimitrovski, University of Central Florida
- Multi-Port Modular Medium-Voltage (M3) Transactive Power Electronics Energy Hub
    - Madhu Sudhan Chinthavali, ORNL
- Design, Deployment, and Characterization of the World's First Flexible Large Power
    - Ibrahima Ndiaya, General Electric
- Demonstration of a 5 MVA Modular Controllable Transformer (MCT) for a Resilient and Controllable Grid
    - Deepakraj Divan and Joseph Benzaquen, Georgia Tech
- Modular Hybrid Solid State Transformer for Next Generation Flexible and Adaptable Large Power Transformer
    - Alex Q. Huang, University of Texas at Austin

- Next-Generation Modular Flexible Low-Cost Silicon Carbide (SIC)-Based High-Frequency-Link Transformer
    - Sudip Mazumder, NextWatt

Below are summarized results from the reviews of these projects.

	Average Score	8.3
	Score Range	7.2 - 9.0

Advanced Materials Based Components Projects

To support a modern resilient, reliable, and secure electric grid, advanced materials-based components are needed to meet the many demands and expectations of the electric grid of the future. The following advanced materials-based components projects were evaluated:

- Optical Fiber Sensors for Selective Detection of Acetylene Dissolved in Transformer Oil
    - Michael Buric and Dr. Jeff Wuenschell, NETL
- Al/Ca Composite Conductor Characterization
    - Iver Anderson, AMES
- Enabling Soft Magnetics for Power Conversion Applications
    - Jagan Devkota, NTEL
- High Temperature Ceramic Capacitor Development
    - Jonathan Anton Bock, SNL
- Robust Insulation for Transformers and Power Electronics
    - Bjorn C. Vaagensmith, INL

Below are summarized results from the reviews of these projects.

	Average Score	7.82
	Score Range	6.9 - 8.9

Other Projects

Throughout the program, there are a few projects that did not fall into one of the three main technology areas, but still accelerates modernization of the grid by addressing challenges with large power transformers (LPTs), Solid State Power Substations (SSPS), and other critical grid hardware components. The following other projects were evaluated:

- System Resiliency Evaluation Tool
  - Dr. Bjorn Vaagensmith and Carol A. Reid, INL
- Scalable Hybrid Large-Scale dc-ac Grid Analysis Methods
  - Suman Debnath, ORNL; Marcelo Elizondo, PNNL; and Jiazi Zhang, NREL
- Demonstration of Advanced Monitoring and Data Analytics of Power Transmission Lines
  - Jonathan Marmillo and Kristine Engel, Linevision

Below are summarized results from the reviews of these projects.

Average Score	7.9
Score Range	6.7 - 8.6

Appendix A. List of Participants

A	Abdul Basit Mirza, Stony Brook University
	Aleksandar Dimitrovski, UCF
	Alex Q. Huang, UT-Austin
	Ali Ghassemian, DOE
	Andre Pereira, U.S DOE
	Andrew Barbeau, The Accelerate Group
	Andrew Fellon, Alliance Advisory Services
	Andrew Phillips, EPRI
	Anita Peterson, ICF Next
B	Babak Parkhideh, UNC Charlotte
	Benjamin Shrager, DOE
	Bjorn C. Vaagensmith, INL
	Brian Rowden, Oak Ridge National Laboratory
C	Carol Reid, INL
	Chen, University of Texas at Austin
	Chondon Roy, UNC Charlotte
	Chunlei Liu, Hitachi Energy
	Cullin Brown, BCS LLC
D	Daniel Evans, UNC Charlotte
	David Porras, University of Arkansas
	David Wells, DOE
	Debrup Das, Hitachi ABB Power Grids
	Deepakraj Divan, Georgia Tech
	Denise Gnipp, ICF
	Diane Michault, Sidem LLC
	Dongwoo Han, Florida State University
	Dr. Jeff Wuenschell, NETL
	Dustin Hickman, Iowa State University
E	Ed Chambers, NETL
	Ehab Tarmoom, Microchip

	Enrique Betancourt-Ramirez, Prolec GE Internacional
	Eric Hsieh, USDOE
F	Fang Luo, Stony Brook University
	Fang Zheng Peng, Florida State University
G	Graham Messick, CBS News
H	Hamed Pourgharibshahi, Florida State University
	Hui Li, Florida State University
I	Ibrahima Ndiaye, General Electric (GE)
	Icf Support, ICF Next
	Imre Gyuk, DOE
	Iver Anderson, AMES
J	Jacob Mueller, Sandia National Laboratories
	Jagan Devkota, NETL
	Javier Iglesias, Hitachi Energy
	Jayne Faith, Office of Electricity
	Ji Liu, Stony Brook University
	Jiazi Zhang, NREL
	Jim Gafford, UNC-Charlotte
	Jin Wang, OSU
	Jonathan Anton Bock, Sandia Labs
	Jonathan Marmillo, LineVision
	Jongchan Choi, Oak Ridge National Laboratory
	Joseph Benzaquen, Georgia Tech
	Joshua Novaceck, NREL
	Juan Balda, University of Arkansas
K	Keith Dodrill, US DOE
	Kristine Engel, LineVision
	Kushan Choksi, Stony Brook University
L	Liqi Zhang, Hitachi Energy
M	Madhu Sudhan Chinthavali, ORNL
	Marcelo Elizondo, Pacific Northwest National Laboratory
	Mark Gifford, Sidem LLC

	Maryam Saeedifard, Georgia Tech
	Mathew Stinnett, Knoxville Utilities Board
	Matt Scallet, ICF Next
	Meredith Braselman, ICF Next
	Merrill Smith, US DOE
	Michael Buric, NETL
	Michael Mazzola, University of North Carolina Charlotte
	Michael Pesin, DOE
	Molly Roy, US DOE
	Murali Baggu, NREL
N	Namwon Kim, University of North Carolina at Charlotte
P	Paromita Mazumder, NextWatt LLC
R	Radha Sree Krishna Moorthy, Oak Ridge National Laboratory
	Rafal Wojda, ORNL
	Rahul Choudhary, University of Texas at Austin
	Rajendra Prasad Kandula, ORNL
	Ray Byrne, Sandia National Laboratories
	Ray Long, DOE-AMO
	Raymundo Carrasco, Prolec GE Internacional
	Richard Zhang, Virginia Tech
	Richrd Raines, UT-Battelle
	Rob Schulberg, ICF Next
	Roderick Gomez, University of Arkansas
	Rolando Burgos, VT
	Ronke Luke, ICF
S	Sandeep Bala, IEEE
	Sandra Jenkins, DOE
	Sanghun Kim, Florida State University
	Sanjay Rajendran, The University of Texas at Austin
	Sari Fink, American Clean Power Association
	Sean Bishop, Sandia Labs
	Sonny (Yaosuo) Xue, ORNL

	Stan Atcitty, Sandia National Laboratories
	Stephen Kelley, Southern Company
	Sudip Mazumder, NextWatt LLC
	Sudipta Chakraborty, OPAL-RT
	Suman Debnath, ORNL
T	Thomas King, ORNL
	Tom Weaver, American Electric Power
	Trevor Riedemann, Ames Laboratory
V	Vahan Gevorgian, NREL
	Vijay Bhavaraju, Eaton Corporate Research & Technology
	Vinod Siberry, DOE
W	Whitney Muse, DOE
	Wim Dhondt, Roland Berger
X	Xiaofeng Dong, Florida State University
	Xin Sun, ORNL
Y	Yue Zhao, Uark
Z	Zibo Chen, The University of Texas at Austin

Appendix B. Program Review Agenda

DAY 1 – TUESDAY, FEBRUARY 1, 2022

Time	Agenda
12:00 – 12:05 pm	**Welcome and Introductions** Andre Pereira
12:05 – 12:10 pm	**Purpose, Agenda, Logistics** Meredith Braselman
12:10 – 12:40 pm	**Keynote Speaker** Andrew Philips, Vice President of Transmission and Distribution Infrastructure, EPRI
12:40 – 1:05 pm	**TRAC Program Overview** Andre Pereira, TRAC Program Manager, U.S. Department of Energy
1:05 – 1:20 pm	**BREAK**
1:20 – 3.00 pm	**Group 1 — Advanced Grid Integration Technologies** Madhu Sudhan Chinthavali, ORNL *SSPS 1.0 Hardware Prototype Development* Hui Li, Florida State University *SSPS 1.0 Hardware Prototype Development* Yue Zhao, University of Arkansas *SSPS 1.0 Hardware Prototype Development* Rolando Burgos, Virginia Tech *SSPS 1.0 Hardware Prototype Development* Jin Wang, The Ohio State University *SSPS 1.0 Hardware Prototype Development*
3:00 – 3:15 pm	**BREAK**
3:15 – 4.30 pm	**Group 2 — Advanced Grid Integration Technologies** Babak Parkhideh, University of North Carolina at Charlotte *SSPS 1.0 Hardware Prototype Development* Alex Q. Huang, The University of Texas at Austin *SSPS 1.0 Hardware Prototype Development*

	Fang Luo, Stony Brook University *SSPS 1.0 Hardware Prototype Development* Radha Krishna Moorthy, ORNL *SSPS Controller: Hardware in the loop (HIL) validation*
4:30 pm	**Adjourn**

DAY 2 – WEDNESDAY, FEBRUARY 2, 2022

Time	Agenda
12:00 – 12:05 pm	**Welcome and Introductions** Andre Pereira
12:05 – 1:15 pm	**Group 3 — Advanced Power Control Equipment** Vahan Gevorgian, NREL *SuperFACTS: Super-Flexible & Robust AC Transmission System* Sonny Xue, ORNL and Aleksandar Dimitrovski, University of Central Florida *Continuously Variable Series Reactor (CVSR) for Distribution System Applications* Madhu Sudhan Chinthavali, ORNL *GMLC 2.4.2 Multiport Hub*
1:15 – 1:30 pm	**BREAK**
1:30 – 2:50 pm	**Group 4 — Advanced Power Control Equipment** *Flexible, Adaptable LPT – Prototypes (FY18 FOA)* Ibrahima Ndiaye, General Electric (GE) Deepakraj Divan, Georgia Tech and Joseph Benzaquen of Georgia Tech Alex Q. Huang, University of Texas at Austin Sudip Mazumder, Nextwatt
2:50 – 3:05 pm	**BREAK**

3:05 – 4:00 pm	**Group 5** Dr. Bjorn Vaagensmith and Carol A. Reid, INL *System Resiliency Evaluation Tool* Suman Debnath, ORNL; Marcelo Elizondo, PNNL; and Jiazi Zhang, NREL *Scalable Hybrid Large-Scale dc-ac Grid Analysis Methods* Jonathan Marmillo and Kristine Engel, Linevision *Linevision - Dynamic Line Rating (DLR) field validation*
4:00 pm	**Adjourn**

DAY 3 – THURSDAY, FEBRUARY 3, 2022

Time	Agenda
12:00 – 12:05 pm	**Welcome and Introductions** Andre Pereira
12:05 – 1:05 pm	**Group 6 — Advanced Materials Based Components** Michael Buric and Dr. Jeff Wuenschell, NETL *Optical Fiber Sensors for Acetylene Detection* Iver Anderson, AMES *Al/Ca Composite Conductor Characterization* Jagan Devkota, NTEL *Enabling Soft Magnetics for Power Conversion Applications*
1:05 – 1:20 pm	**BREAK**
1:20 – 2:00 pm	**Group 7— Advanced Materials Based Components** Jonathan Anton Bock, SNL *High Temperature Ceramic Capacitor Development* Bjorn C. Vaagensmith, INL *Robust Insulation for Transformers*
2:00 – 2.45 pm	**Group 8** Madhu Sudhan Chinthavali, ORNL *GRID-C*
2:45 – 3:00 pm	**Conclusion** Andre Pereira

Appendix C. Peer Reviewer Bios

Dr. Sandeep Bala, *ABB Corporate Research*	Sandeep Bala (Senior Member, IEEE) received the B.Tech. degree from the Indian Institute of Technology Bombay, Mumbai, India, in 2003, and the M.S., and Ph.D. degrees, working on the control of power electronic converters in microgrids, from the University of Wisconsin-Madison, Madison, WI, USA, in 2005 and 2008, respectively, all in electrical engineering. He is currently a Research Department Manager with ABB Research Center, Raleigh, NC, USA. At ABB, he was responsible for research on low- and medium-voltage power electronics technologies for applications in the future electrical grids. He worked on and led a number of research projects on the power electronics-based volt–VAR control devices for the distribution grid, distributed energy storage units, and grid integration of offshore wind and marine renewable energy. His current research interests include on using wide bandgap devices in power converters for a variety of applications, including photovoltaics (PV) inverters, uninterruptible power supply (UPS) systems, electric vehicle (EV) chargers, power supplies, and motor drives.
Dr. Vijay Bhavaraju, *Eaton Corporate Research & Technology*	Vijay Bhavaraju received the B.S. degree in electrical engineering from the Indian Institute of Technology Madras, Chennai, India, in 1976; the M.S. degree in power system operation and controls from Sri Venkateswara University, Tirupathi, India, in 1988; and the Ph.D. degree in power electronics from Texas A&M University, College Station, TX, USA, in 1994. He was in the oil industry designing and commissioning offshore and land rigs. He was with Tech Power Systems, Carrabelle FL, USA (later acquired by NOV), where he developed three important products: the mud-pump synchronizer, the auto-drill, and block controller. He was with Ford-Ecostar, Detroit, MI, USA, from 1998 to 2004, researching inverters for microturbines, photovoltaics, and fuel cells. Since 2005, he has been with the Corporate Research and Technology Group, Eaton Corporation Innovation Center, Menomonee Falls, WI, USA. He has been involved in different projects related to inverters for solar, batteries, and microgrids. He led a team that released the 250 kW PV inverter. Dr. Bhavaraju was a Member of the IEEE 1547 Standard from 2000 to 2004. He is currently a Member of the IEC Project Team of the Microgrid for Disaster Preparedness and Recovery.
Dr. Sudipta Chakraborty, *OPAL-RT Technologies*	Dr. Sudipta Chakraborty, Director of Energy Systems of OPAL-RT, is currently leading US R&D activities related to real-time simulation and hardware-in-the-loop for power systems and power electronics applications. Dr. Chakraborty has more than 11 years of experience in power converters and grid

	integration of PV, more than 9 years of experience in HIL, and more than 16 years of experience in power electronics. Prior joining to OPAL-RT, Dr. Chakraborty was a principal engineer at the National Renewable Energy Laboratory where he was leading projects on grid integration of renewable such as development of high-power density SiC PV inverter, development of modular power electronics, developing new hardware-in-the-loop based methods for inverter testing and supporting grid interconnection standards such as IEEE 1547 and IEEE1547.1.
Dr. Debrup Das, *Hitachi Power Grids*	Debrup Das (S'06-M'12) received the B.Tech. degree in Energy Engineering from Indian Institute of Technology, Kharagpur, India, in 2006, and the M.S. and PhD degree from Georgia Institute of Technology, Atlanta, in 2009 and 2012 respectively. Since 2011, he is with the US Corporate Research Center of ABB at Raleigh, NC, where he is presently a Senior Scientist. His research interests are mainly in the area of utility and industrial applications of power electronics including HVDC systems, low-cost FACTS devices, and wind energy integration.
Mr. Stephen Kelley, *Southern Company*	Stephen Kelley is a research engineer at Southern Company where he supports Research & Development's Power Delivery group. In this role, Stephen's primary responsibility is developing technologies that enable Southern Company's electric system to be more flexible, efficient, reliable, and resilient, enabling a net-zero energy future. Stephen's primary technical focus areas are grid applications of power electronics and system power quality. Stephen began his career with Southern Company in 2014 in Power Delivery R&D as a co-op student. Upon graduation in 2016, he joined the Transmission organization where his focus was implementing policy to facilitate interconnection of distributed energy resources on the bulk electric system. Shortly thereafter, Stephen returned to R&D as a research engineer in 2017, managing Southern Company's Distribution-related research portfolio. In 2019, Stephen was provided the opportunity to specialize in power quality and power electronics and is now building Southern Company's vision for a power electronics enabled grid while maintaining superior power quality. Stephen is an advisor to EPRI's power quality program and PowerAmerica. Stephen attended the University of Alabama at Birmingham receiving his BSEE in 2016 and Georgia Institute of Technology where he is anticipating receiving his MSEE in 2022.

Dr. Michael Mazzola, *University of North Carolina at Charlotte*	Dr. Michael Mazzola is the Director of the Energy Production and Infrastructure Center (EPIC) and the Duke Energy Distinguished Chair in Power Engineering Systems at UNC Charlotte. After three years in government service at the Naval Surface Warfare Center in Dahlgren, Virginia, in 1993, he joined the faculty at Mississippi State University, where he became known for his research in the areas of silicon carbide power semiconductor device prototyping and semiconductor materials growth and characterization. For 10 years, he served at the Mississippi State University Center for Advanced Vehicular Systems as the associate director for advanced vehicle systems, where he led research in high-voltage engineering, power systems modeling and simulation, the application of silicon carbide semiconductor devices in power electronics, and the control of hybrid electric vehicle power trains. In addition, he served two years as the chief technology officer of SemiSouth Laboratories, a company he co-founded. Dr. Mazzola holds a Ph.D. in electrical engineering from Old Dominion University.
Dr. Fang Peng, *Florida State University*	Fang Z. Peng (Fellow, IEEE) received the B.S. degree from Wuhan University, Wuhan, China, in 1983, and the M.S. and Ph.D. degrees from the Nagaoka University of Technology, Nagaoka, Japan, in 1987 and 1990, respectively, all in electrical engineering. From 1990 to 1992, he was a Research Scientist with Toyo Electric Manufacturing Co., Ltd., Midori, Japan. From 1992 to 1994, he was a Research Assistant Professor with the Tokyo Institute of Technology, Tokyo, Japan. From 1994 to 1997, he was a Research Assistant Professor with the University of Tennessee, Knoxville, TN, USA. From 1994 to 2000, he was a Staff Member with the Oak Ridge National Laboratory, Oak Ridge, TN, USA. From 2000 to 2018, he was a Professor with Michigan State University, East Lansing, MI, USA. In 2018, he joined, as a Professor with the Department of Electrical and Computer Engineering, Florida State University, Tallahassee, FL, USA.
Dr. Maryam Saeedifard, *Georgia Tech*	Maryam Saeedifard received the B.S. and M.S. degrees from Isfahan University of Technology, Isfahan, Iran, in 1998 and 2002, respectively, and the Ph.D. degree from the University of Toronto, Canada, in 2008, all in electrical engineering. From 2007 to 2008, she was with ABB Corporate Research Center, Dattwil-Baden, Switzerland, working in the power electronic systems group. She joined Purdue University in January 2010, where she served as an assistant professor in the School of Electrical and Computer Engineering. Since January 2014, she has been on the ECE faculty at the Georgia Institute of Technology. Her main research focus has been in the area of Power Electronics and Applications of Power Electronics in

	Power Systems and Transportation Systems. She has served on the technical program committees of the IEEE Power Electronics Society, IEEE Applied Power Electronics Conference and Exposition (APEC), and IEEE Industrial Electronics Conference (IECON). She is an editor for IEEE Trans. on Sustainable Energy, IEEE Trans. on Power Delivery, and IEEE Trans. on Power Electronics.
Mr. Mathew Stinnett, *Knoxville Utility Board*	Mathew Stinnett is the Manager of Electric Systems Engineering at Knoxville Utilities Board (KUB) in Knoxville, TN. He joined KUB in 2015 as a distribution design engineer. He is an IEEE member and a registered Professional Engineer in the State of Tennessee. He is a graduate of the University of Tennessee Knoxville with a BS in Electric Engineering.
Mr. Ehab Tarmoom, Microchip *Technology, Inc.*	Ehab Tarmoom is an applications engineer and subject matter expert (SME) on silicon carbide solutions at Microchip Technology Inc. He has over 20 years of experience designing and developing automotive electronics. His focus on electrification began in 2009 with supporting the development of the battery charging system for the Chevy Volt. He has since designed and developed electrification products, including on-board chargers, EVSEs, battery disconnect units, and a BISG inverter. His current focus is on modeling and simulation of power electronics circuits and systems using silicon carbide technology. Ehab earned his bachelor's and master's degree in electrical engineering at the University of Michigan – Dearborn.