EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Transmission Operations & Planning Research Area Review

January 2020

Contents

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Introduction and 2019 Research Area Highlights

The Electric Power Research Institute's (EPRI) Grid Operations and Planning (GO&P) research area spans both transmission and distribution across four research programs. The Transmission Operations and Planning (TO&P) portion of the research area comprises three research programs – Transmission Operations (P39), Transmission Planning (P40), and Bulk System Renewables/DER Integration (P173). Distribution Operations and Planning (DO&P) research is conducted from a single program (P200). Except where specifically noted otherwise, this review document focuses on the TO&P research programs. We have separately published a similar, but separate review document summarizing the DO&P activities.

Following are highlights from 2019 for each of the five performance indicators tracked across the TO&P research area.

Member/Industry Engagement and Leverage

- Significantly increased the number of member and industry SMEs engaged through our seven topical R&D Task Force meetings, webcasts, and workshops with engagement of 864 SMEs (up 279 from 2018) from 113 companies (up 29 from 2018).
- Expanded the TO&P research collaborative by 5 additional participants to a total of 72 and grew total research funding 3.3%.

R&D Strategy and Action Plans

- Revised TO&P action plans using a new simplified format and vetted near final drafts of action plan content with advisory committee prior to finalizing in early January 2020 with the relevant task forces.
- Developed government proposals and awarded 3 projects that will provide additional leverage to member research funding for achieving strategic research objectives from the action plans:
  - $4.1M TO&P-led effort to develop, validate, and commercialize solar PV models for dynamic, electromagnetic transient, and short circuit evaluations
  - $3M TO&P-supported effort to develop methods for delivering grid services from Distributed Resources
  - $1.5m TO&P-led effort to develop advance solar forecasting methods for system operations and end-use applications.

R&D Results and Deliverables

- Created short-term and long-term R&D value through 105 ARP deliverables that include new and updated models, algorithms, software tools, and reference guides (see each program Deliverable summaries for detailed descriptions).

Member Technology Transfer/Value Realized

- Worked with members to apply many deliverables including applications of the Alarm Management Philosophy and EMS Human Machine Interface reference guides, the DynADOR tool for improved operating reserve determination, Grid Strength Assessment Tool for identifying potential weak grid interconnections, the Optimal Blackstart Capability tool for restoration planning and Voltage Control Area and Reactive Power Assessment Software (VCA Studio).
- Documented 20+ member R&D value statements and EPRI Technology Transfer Award nominations resulting in 2 award winners.

Research Program Operational Processes

- Developed new software trial license process allowing for temporary evaluation of select R&D software tools.
- Began delivering a quarterly newsletter that aggregates project progress updates, deliverable information, meeting notices, and other R&D area information.

The remainder of this review dives deeper into the 2019 TO&P projects, associated deliverables, and examples of how members have applied these results. We look forward to working with you in 2020 to increase collaboration and value that you derive from our research.

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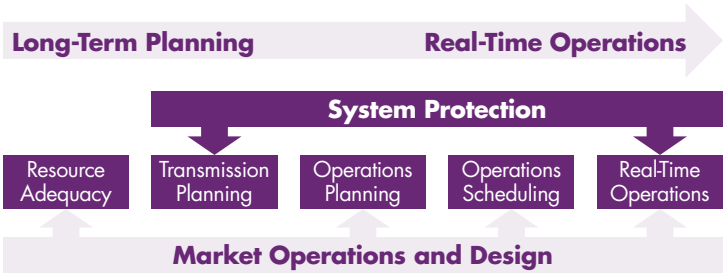
EPRI Transmission Operations and Planning Research Scope

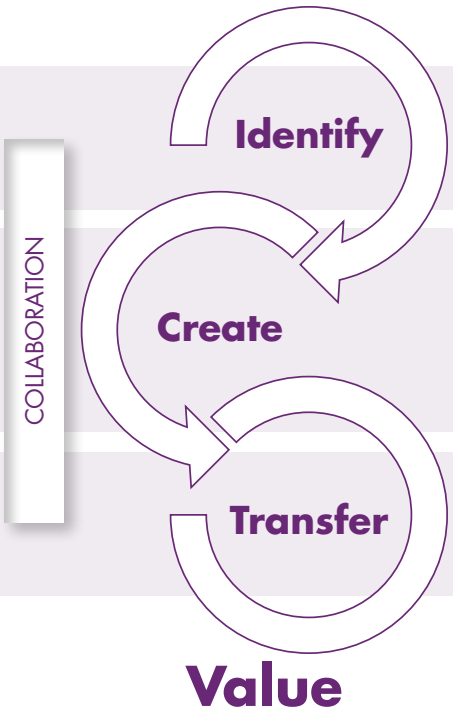
Conducts research, development, and demonstrations projects to support transmission owners and independent system operators (ISOs) in planning and operating the bulk power system reliably and economically to provide a safe and environmentally responsible source of electric power for society.

Transmission Operations & Planning Research Programs:

P39 – Transmission Operations
P40 – Transmission Planning
P173 – Bulk System Renewables Integration



Research Strategy and Approach



- We continually engage our utility and ISO members leveraging their shared experiences and understanding along with EPRI's TO&P staff engagement in industry standards and practitioner forums to ***Identify*** desired future needs, existing gaps, and a research ***roadmap*** with specific ***action plans*** to close the gaps and meet the needs.

- The EPRI TO&P team of subject matter experts and project management specialists structures and conducts specific projects that ***Create*** research results in a portfolio-based approach to provide deliverables addressing Near- and Long-Term needs for each planning and operations function:

Models	Algorithms	Software Tools	Reference Guides	Testing/Study Results	Technical Evaluations/ Benchmarking

- Finally, we ***Transfer*** the research ***Value*** to members through (1) deliverable vehicles such as technical reports, videos, and software; (2) collaborative task force interactions, topical workshops and user groups, and (3) by transferring results to commercial software vendors that supply and support member applications.

Resources

- There are forty-nine power systems modeling, simulation and analysis staff including world-class subject matter experts in Transmission and Distribution (T&D) planning and operations.
- A suite of commercial T&D system modeling, simulation, and analysis software comprising the planning, operation, and protection tools used by our members and our own EPRI-developed research platforms.
- Where internal resources are not available, we contract world-leading researchers and software developers.
- Sixty-eight utility and ISO advisors providing leadership and guidance from members around the world to ensure research results are practical and implemented.

Staff Experience

Years of Experience	#
5 or less	13
5-10	9
10-20	15
20+	12
Total	49

Staff Degrees/Certification

Degree	#
Doctorate	29
Masters	16
Bachelors	5
Professional Eng.	9
IEEE Fellow	2

Research Roadmap identifies drivers, desired future states, primary gaps and Action Plans comprising specific tasks required to bridge the current and future state. Action plans are reviewed and revised through EPRI member Task Force.

Action Plans & Primary Gaps

Modelling and Model Validation
Model Development
Model Validation

Scheduling, Forecasting and Active Power Control
Scheduling Applications for Variability and Uncertainty
Reserve Requirement Methods/Tools
Frequency Control and Performance
Energy Forecasting

Real Time Grid Monitoring and Control
Data Acquisition and Handling
Data Analytics
Automatic Control

Real Time Control Center Situational Awareness
The Data Model
Situational Awareness and EMS
Human Performance and Training
Buildings, Ergonomics and Hardware

Operations Planning and Engineering Study Support
Risk Assessment
Identifying Insightful Information
Study Tools and Analysis
Stakeholder Coordination

Voltage / VAR Management and Planning
Tools for Operations Support, Optimal Dispatch and Control
Tools for Reactive Power Investment Planning
Coordination with Distribution Systems

Flexibility & Resource Adequacy
Resource Modelling
Customer Demand Modeling
Scenario Generation
Standards and Guidelines
Simulation Tools

Transmission System Protection
Protection in Planning
Protection Settings and Studies
Protection in Grid Operations and Reliability
Reducing Misoperations and Post-Fault Analysis

Resiliency and Restoration
Extreme Event Analysis
Modelling for Extreme Events and Emerging Technologies
Restoration Under Extreme Events
Probabilistic Analysis
Operations Support

Transmission Planning Methods and Tools
Risk-Based Planning
Tools for Studying Inverter-Based Resource Integration
Advanced Power Flow Solutions and Analysis
HVDC Planning
Node-Breaker Modelling and Studies
Impact of Non-Wires Alternative

Market Operations and Design
Modelling Emerging Technologies
Reliability Service Assurance
Future Market Designs
Extreme Event Operations
Price Formation

Future States

Transition from centralized generation sources and predictable load to decentralized, variable resources and unpredictable load.

Proliferation in automated, power electronic-interfaced, devices with complex control systems in generation, transmission and load.

Electrification of society resulting in co-optimized transmission, distribution, generation, transportation systems planning and operations.

Risk and probability-based transmission system planning and operations decision making framework and tools, utilized by staff comfortable with these concepts.

Increased computational capabilities with validated system model and data that is coherently structured, so that artificial intelligence techniques can be used as part of the planning and operations engineer's toolkit.

Greater consumer participation and demand response in the markets with resulting price responsive behavior.

Reduction in transmission infrastructure may result in reduced resiliency of systems, and may lead to an increasing frequency of extreme, high impact low frequency weather events.

Annual research portfolio (ARP) and supplemental research efforts from across the three TO&P research programs aggregately contributed to progressing key system operations and planning cross-cutting initiatives in 2019.

System Modeling and Model Validation:

- Benchmarked the latest load model with DER representation, supported NERC load modeling efforts to help utilities implement the composite load model.
- Developed guidelines for modeling distributed energy resources (DER) for transmission planning studies, developed default parameters for the DER model, and performed case studies to illustrate use and value of the DER model (DER_A).
- Continued development and validation of High-Voltage Direct Current (HVDC) and wind/solar photovoltaic (PV) plant models, including providing guidelines demonstrating limitations of positive-sequence models compared to three-phase models when connected to weak portions of the grid.
- Initial insight obtained with T&D co-simulation of coupled transmission and distribution grids.

System Resiliency and Restoration:

- Examined Transformer Thermal Impact Assessments for DC Withstand Capability: Examining the Impacts of GIC on Transformer Thermal Performance.
- Released new GIC harmonic assessment tool (GICharm) and GMD Harmonic Assessment Guide: Geomagnetic Disturbance Harmonic Impacts and Asset Withstand Capabilities.
- Developed GMD Operating procedure guidelines.
- Continued development of technical basis for operating procedures for continued reliable control room operations with degraded or lost capabilities.
- Continued development and application of tools for evaluating resiliency investments, restoration planning and decision support for High Impact Low Frequency Events (HILF).
- Developed tools and methods to integrate variable generation in restoration plan & strategies.

Real Time Control Center Operations:

- Launched Human Factors Innovations workstream and delivered technical brief reports on High Reliability Organizations and Work Domain Analysis.
- Completed non-convergent case processor routine and launched the Automated Outage Coordination tool development.
- Implemented the Streaming Synchrophasor Data Quality (SSDQ) tool using GPA's OpenECA, and developed the Synchrophasor Based Machine Learning (SBML) tool.
- Delivered software "Voltage Control Areas (VCA) Studio v1.0 " for determining and analyzing voltage control areas of power systems and assessment of reactive power reserve adequacy.

Protection and Misoperations:

- Released updated versions of the Protection Setting Evaluation Tool (PSET) with visualization and analytics capabilities to assess protection coordination across whole grids and to proactively identify relay settings that may potentially result in misoperations and new spreadsheet-based tool to guide reporting of mis-operations.
- Released GridCOPS tool for ASPEN and CAPE to enable automatic protection assessment in outage scheduling and real-time ops.
- Continued coordination with commercial short-circuit platform vendors to integrate EPRI wind and PV plant short-circuit models into commercial tool model libraries.
- Released updated version of specific protection practice guidelines for high penetrations of renewables, underground cables, modeling protection in planning studies, and short circuit model validation.

Variable and Distributed Energy Resources Integration:

- Revised tools for estimating online frequency response and integrating renewable forecasts to better determine operating reserve requirement, including understanding risk and the use of probabilistic methods.
- Delivered updated guidelines for system flexibility adequacy assessment and the related InFLEXion tool, new guidelines for resource adequacy and a method for calculating the capacity contribution of hybrid hybrid renewables and storage plants.
- Delivered tools for assessing grid strength when interconnecting inverter-based resources and for screening transmission hosting capacity for renewables.
- Reviewed international experiences and practices in operating low inertia power systems and facilitated the development of new practices in this area.
- Published two DOE-funded reports on Tx/Dx planning interactions and TSO/DSO coordination with increasing amounts of distributed energy resources. Facilitated an industry-wide working group to specify DER group management functions for coordinated operations.
- Worked with ISOs/RTOs and utilities on adopting new DER ride-through standards in their reliability regions, and developed a DER Performance and Settings database for improved coordination of DER trip settings with distribution utilities.

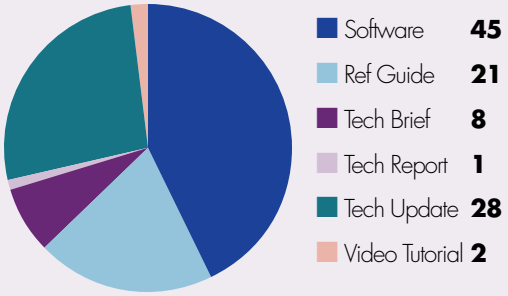
EPRI TO&P Area Tech Transfer Activities:
January - December 2019

13 Workshops/ Conference

67 Task Force/ Advisory Meetings/ Webcasts

18 Member Site Visits

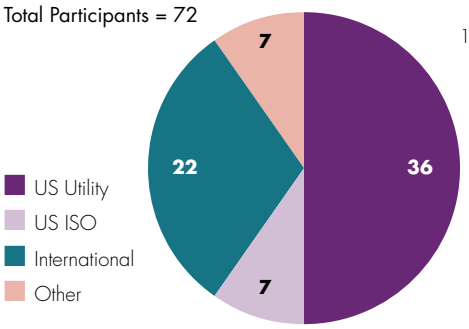
TO&P 2019 ARP Deliverables
Total Deliverables 105



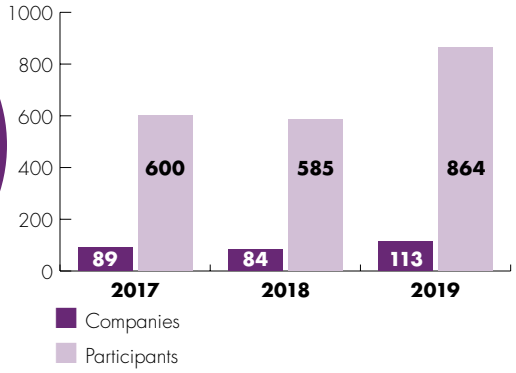
TO&P Collaboration and Member Engagement

TO&P Area Collaborative Funding Trend

TO&P Total Participation
(ARP + Supplemental)



TO&P Task Force Participation



2019 Member Satisfaction Survey

Overall Performance	94.4%
Technical Program Value	95.1%
Ease of Doing Business	91.0%
Overall Satisfaction	94.6%

TO&P Member Advisory Structure

Industry Issue Strategic Guidance

Transmission Sector Council (Transmission Executive Committee)

Research Area Strategic Guidance

TO&P Advisory Committee (TO&P Advisory Leadership Team)

- Transmission Ops (P39)
- Transmission Planning (P40)
- Bulk Renewables Integration (P173)

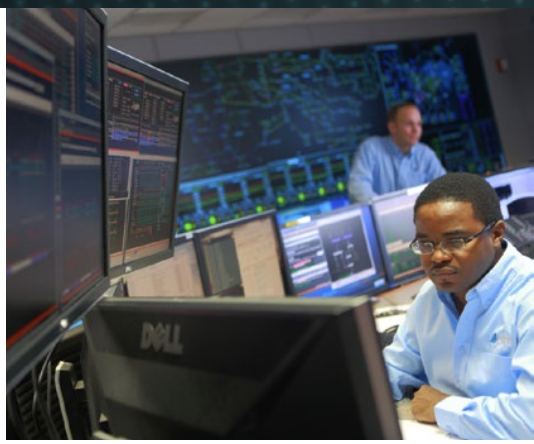
Project Level Tactical Guidance

- Transmission Planning TF
- Resiliency & Restoration TF
- Protection, PQ, & Transients TF
- Balancing & Uncertainty TF
- Modeling & Model Validation TF
- Real-Time Ops & Control Center TF
- Market Ops & Design TF

Task Forces provide EPRI project guidance and serve as primary vehicle for R&D technology transfer to members.

(Task Force Leadership Team per TF)

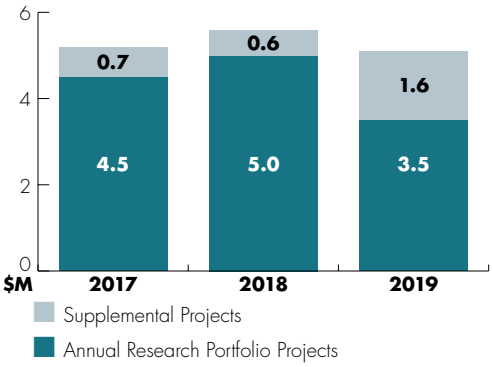
P39 - Grid Operations 2019 Accomplishments and 2020 Plans



EPRI's Transmission Operations research program is focused on providing operators and operations support engineers actionable information based on real-time data regarding the status of the system, decision-making support to respond to rapid changes that might occur in the near future, and improved visibility of system conditions, alarms and protection system implications. The program also provides operator tools for managing reactive power, controlling voltage, and planning/executing restoration actions. Examples of products delivered in 2019 include revised Voltage Control and Reactive Power Management Reference Guide, Wholesale Electricity Market Design, Decision Support Tools for System Resiliency and Restoration, and Non Convergent Power Flow Guidelines.

Project Number, Name & Manager	**2019 Accomplishments**	**2020 Plan**
39.011 **Real Time Operations Situational Awareness** Adrian Kelly	• Enhanced AVAT with more advanced visualization for alarm loading, including by location and analog alarms. Further upgrades to GridCops. • initiated human factors improvement work stream. Released tech briefs on high reliability organizations and metrics for measuring situational awareness and ecological interface design. • Continued initiative with distribution and generation on an industry standard best practice guide. Released first version of technical report. • 8 webcasts with members on a range of topics associated with situational awareness in control centers.	• Launch the control center of the future initiative with workshops in Europe and North America in April 2020. • Launch of the AI.EPRI data analytics workstream for control center alarms, protection and operational data with real control center data. • Continue collaborative project work on developing a control center digital assistant based on reinforcement learning. • Release an updated version of the industry best practice guidelines for generation, transmission and distribution control center HMI designs.
39.012 **Reactive Power Management and Voltage Control** Alberto Del Rosso	• Updated VVC Reference Guide to include considerations for operating at sustained high voltage conditions and actions to mitigate harmful effects. • Revised VCA algorithms and software tool based on member case studies and explore how to apply tools to create a strategy for optimal allocation and control of reactive resources.	• Update reactive power and voltage control (VVC) reference guide. • Develop guidelines for operating under high voltage conditions including assessment of risks and appropriate control actions. • Update the Voltage Control Area (VCA) Studio software to include capabilities for efficiently scheduling reactive resources.

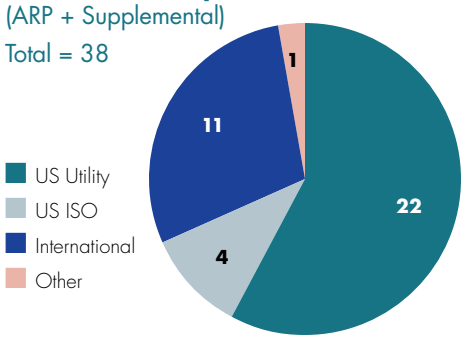
P39 Program ARP Funding Trend



P39 Total Participation

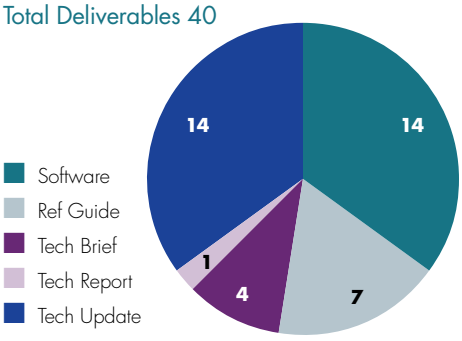
(ARP + Supplemental)

Total = 38



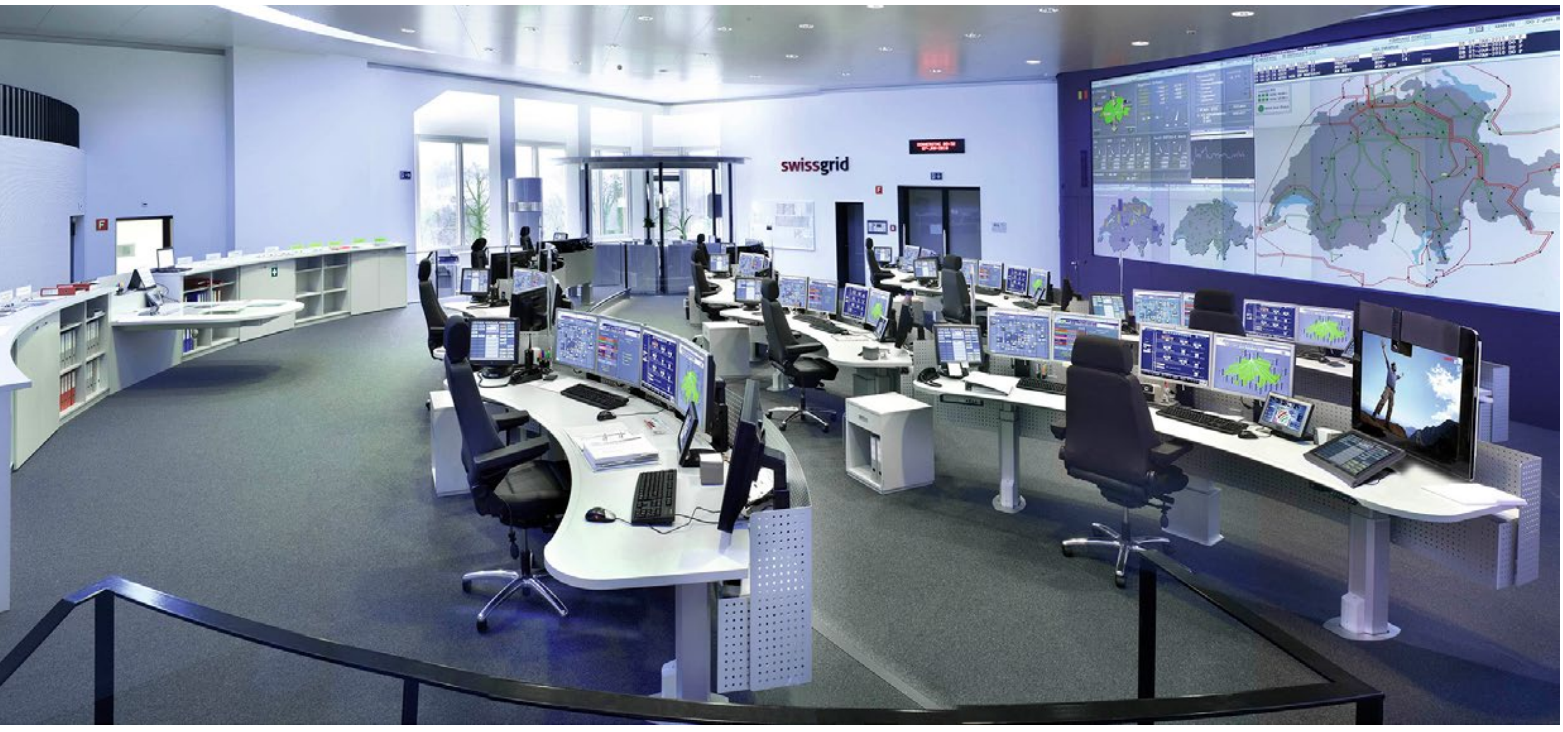
P39 2019 ARP Deliverables

Total Deliverables 40



Project Number, Name & Manager	**2019 Accomplishments**	**2020 Plan**
39.013 **Decision Support Tools for System Emergency and Restoration** Vikas Singhvi	• SRN was transitioned to a new python-based platform leveraging advance algorithms to better assess restoration needs resulting from High-Impact-Low-Frequency (HILF) events. • OBC tool was updated to improve convergence for large systems especially related to maintaining operating voltage within limits. • Updated Restoration Reference Guide. • Developed GMD Operation guide (joint deliverable with P40.23). • Updated guide to "Protection during System Restoration with and without renewable energy sources". This is a joint deliverable with 40.018.	• Initiate development of generic optimization framework for OBC that will allow automatic evaluation of minimum number of BSUs and calculate least-cost set of BSUs needed to restore a system. • Further develop SRN algorithms to support assessment of HILF events and explore feasibility of interface SRN with RTDS. • Assess the role of DER/Microgrid/renewables during restoration. • Update the Power System Restoration Reference Guide. • Conduct an industry workshop on power system restoration. • Further develop GMD Operating Procedure Guideline (Joint with 40.23). • Develop guidelines and tool to support reliable operation during extreme contingencies (loss of AGC, communication, etc.).
39.014 **Operations Planning & Engineering Support Studies** Eamonn Lannoye	• Developed software analysis platform to conduct automated outage coordination studies. • Demonstrated initial application of automated outage coordination analysis on host test system. • Updated Non-Convergent Power Flow guidelines based on case study experience. • Documented commonly used analysis tools in operational planning groups.	• Demonstrate initial application of automated outage coordination analysis on host test system. • Improve automated linking of dispatch tools with power flow tools. • Leverage commercial non-linear solvers to reduce time taken to solve difficult power flow cases. • Commence development of decision support tool to recommend contingencies based on context.

Project Number, Name & Manager	**2019 Accomplishments**	**2020 Plan**
39.015 **Advanced Monitoring, Control and Data Analytics Including Synchrophasor Applications** Evangelos Farantatos	• Enhanced SSDQ algorithms and revised online and offline software tools based on member case studies. • Extended machine learning synchrophasor algorithms to include early event warning and delivered SBML software tool. • Continued PMU Emulator vendor engagement with technical support for commercial implementation. • Analyzed PMU signal processing impact on measured grid dynamics and monitoring and control synchrophasor-based applications. • Updated Synchrophasor Apps Database. • White paper on Real Time Inertia Monitoring industry practices & R&D.	• Enhance SSDQ algorithms to consider practical implementation with streaming measurement in online environment and case studies. • Enhance machine learning synchrophasor algorithms for event identification and early warning and perform case studies based on historical data. • Develop method for online inertia estimation and monitoring using PMU data. • Design of wide-area control scheme for mitigation of forced oscillations. • Evaluate performance of synchrophasor-based closed-loop controls through hardware-in-the-loop experiments. • Update Synchrophasor Apps Database.
39.016 **Market Design and Operations** Erik Ela	• Expanded the understanding of options to manage state of charge of electric storage resources in electricity market operations in day-ahead and real-time markets. • Provided support to ISOs and surveyed the ISO changes to storage integration to meet FERC Order 841. • Initiated concepts on the ways in which hybrid resources (e.g., co-located storage + solar) participate and are modeled in electricity market clearing. • Updated North American Electricity Market Design Reference Guide with changes occurring in 2019. • Provided a detailed review of U.S. ancillary service market designs.	• Continue research on specific applications of electric storage resource integration into day-ahead, real-time, and ancillary service markets. • Conduct research and analysis on the four different participation models of hybrid resources through simulations. • Continue to follow initiatives by the ISOs on energy storage, hybrid resources, and DER aggregations. • Begin to conceptualize and survey the potential challenges of DER Aggregation participation in wholesale electricity markets. • Provide a detailed update of the North American Electricity Market Design Reference Guide with 2020 updates. • Explore ways in which operating procedures and market clearing can improve power system supply resilience.



P39 - Transmission Operations Deliverables

Key Deliverables

39
Situational Awareness

3002016167
Power System Dynamic Tutorial - 2019 Edition

39.011
Situational Awareness

3002016358
Control Center Human Machine Interface Reference Guide

3002016359
Alarm Management Philosophy Guide & Improvement Suggestions

3002016360
Human Machine Interface Philosophy, Style Guide & Improvement Suggestions
Guidelines and best practices on how to develop and maintain an transmission control center human machine interface philosophy and style guide.

3002016361
Human Factors Innovations and the Characteristics of High Reliability Organizations – Tech Brief

3002016362
Work Domain Analysis and Ecological Interface Design for Bulk Electricty System Operations Control Centers

3002016363
EPRI Major System Disturbance and Blackout Database

3002016654
Alarm Visualization and Assessment Tool (AVAT v3.2)

3002016655
Alarm Visualization and Assessment Tool (AVAT v3.3)

3002015664
Protection in Outage Planning Tool for Electrocon CAPE

3002015666
Protection in Outage Planning Tool for ASPEN Oneliner

39.012
Reactive Power Management / Voltage Control

3002016171
Voltage Control and Reactive Power Management: Reference Guide - Industry Practices and Tools for Voltage/VAR Planning and Management (VVPM) - 2019 Edition
This reference guide is a compendium of state-of-the-art VVPM tools and practices used by transmission planning and operations staff for planning and operating the bulk power system.

3002016168
Analysis of Volt/Var Control Challenges in Transmission Operation

3002016639
Voltage Security and Stability Assessment

3002016169
Voltage Control Areas for Power Systems

3002016170
Methodologies and tools for assessing reactive power reserve adequacy using the VCA concept

3002016265
Grid Analysis Toolkit v2.1

39.013
System Restoration and Resiliency

3002016400
Optimal Blackstart Capability Tool v6.0

3002016401
System Restoration Navigator v8.0

3002016402
Power System Restoration Reference Guide
This power system reference guide summarizes the principles and practices followed globally in developing and implementing plans for restoring a power system following a widespread blackout.

3002016403
Decision Support Tools for System Resiliency and Restoration – Algorithms and Case Studies

3002016213
GMD Operating Guidelines

3002015726
Protection during System Restoration with and without renewable energy sources

3002016265
Grid Analysis Toolkit v2.1

39.014
Operations Planning & Engineering Support Studies

3002016261
Automated Outage Coordination - Case Study

3002016260
Non Convergent Power Flow Guidelines - 2019
This practitioner's guide on the cause and mitigation of non-convergence in power flow analysis is updated with outcomes from the application of advanced solution techniques to case studies.

3002016262
Contingency Analysis: Gap Assessment

3002016265
Grid Analysis Toolkit v2.1

39.015
Synchrophasor Applications

3002016185
Streaming Synchrophasor Data Quality Tool (SSDQ), Offline v3.0

3002016188
Streaming Synchrophasor Data Quality Tool (SSDQ), Online v2.0

3002016189
Data Quality Conditioning of Streaming Synchrophasor Measurements - Algorithm and Case Studies

3002016190
Synchrophasor Based Machine Learning (SBML) Tool v1.0

3002016191
Synchrophasor Based Machine Learning Techniques for Advanced Situational Awareness

3002016192
Synchrophasor Based Closed-Loop Control Performance Requirements
Analysis of signal processing within a PMU and its impact on measured grid dynamics and performance of closed loop control applications.

3002016193
Synchrophasor Applications Database v.2.0

3002016195
Real-time Inertia Monitoring using PMU Measurements: Current Technology and Practices

39.016
Market Design and Operations

3002016226
Wholesale Electricity Market Design in North America Reference Guide: 2019 Review

3002016228
Incorporating Energy Storage into Electricity Markets and Energy Storage State of Charge Management Study Phase II: Real-time state of charge management for electric storage resource

3002016229
Integrating Hybrid Storage Plus X Resources into Electricity Market Operations

3002016759
Electricity Market Integration of Energy Storage and Hybrid Storage-Plus-Renewables Technologies: 2019 Update
A review of recent initiatives across North American markets regarding market integration of electric storage and hybrids.

P39 - Highlighted 2019 Member Value Statements

Below we highlight selected member statements summarizing value they have received from applying P39 research results or leveraging EPRI staff expertise and recognize P39 Technology Transfer awards and nominations.

	Value Obtained
Southern Company Shih-Min Hsu **39.012: Voltage Control Area (VCA) Tool**	
Use of Voltage Control Area and Reactive Power Assessment Software (VCA Studio) to evaluate reactive power reserve adequacy in various regions of Southern Balancing Authority Area.	• The VCA tool provides new insight into the local Volt/Var characteristics of the transmission system • It helps identify critical areas and locations for Var additional Var support • Useful for identifying mitigation actions to increase operation security margin.
ERCOT Sandip Sharma, John Adams **39.013: Optimal Blackstart Capability Tool**	
Support Blackstart service (BSS) procurement process. Used OBC to support 2017 Black Start Service (BSS) procurement and are using V5.0 for 2019 BSS procurement. Evaluate effectiveness of existing and new Blackstart resources.	• Improves identification of blackstart resources to efficiently meet restoration goals • Reduces time to evaluate blackstart capability offers • Replaces previously used heuristic methods
Southern Company Clifton Black **39.013: Application of EPRI Restoration Tools**	
Demonstration of EPRI's restoration tools on Southern Company System. Support development of alternate cranking paths and validate performance of existing transmission paths.	• OBC identified a path to a critical infrastructure that was not previously considered. • OBC allowed planners to validate the performance of the other paths that had been evaluated using our manual process • OBC provides a standardized and repeatable approach to selecting a primary path • Gained an improved understanding of the available restoration paths to address system emergencies and restoration
NYPA Atena Darvishi, Alan Ettlinger, George Stefopoulos, Bruce Fardanesh **Wide Area Oscillations Damping Controller – NYPA Case Study**	
The Wide Area Oscillations Damping Controller (WADC) was designed, implemented and tested under a simulation environment for NYPA's system. The performance of the WADC was demonstrated under hypothetical extreme contingencies.	• Demonstrated applicability of the WADC in NYPA's system and potential system security improvements by mitigation of low-damped or undamped oscillations.

Technology Transfer Award Nominations and Award Winners

Alarm Management and HMI Philosophy Development

American Electric Power Service Company, Ameren Services Company, Salt River Project Agricultural Improvement and Power District — Nominee

Application of EPRI Restoration Tools: Optimal Blackstart Capability (OBC) and System Restoration Navigator (SRN)

Southern Company Services, Inc., Dominion Energy, American Electric Power Company, Electric Reliability Council of Texas, Inc. — Nominee

Application of Robust Power Flow Solvers with EPRI's Grid Analysis Toolkit (GAT)

Southern Company — Nominee

Data Management and Analytics to Support Transmission Operations (Transmission Modernization Demo, Phase II)

New York Power Authority — Nominee

Synchrophasor-Based Wide-Area Oscillations Damping Controller

New York Power Authority, TERNA Rete Italia, Saudi Electricity Company — Nominee

Voltage Control Area and Reactive Power Assessment Software (VCA Studio)

Dominion, Entergy, Southern Company — **Award Winner**

Application of the VCA software to several planning power flow scenarios as well as EMS power flow cases to demonstrate its use and benefits.

Wide Area Damping Controller (WADC) Using Measurement Derived Transfer Functional Model, Phase I

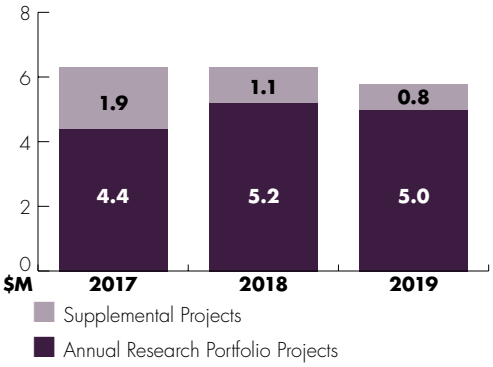
New York Power Authority — Nominee

P40 - Transmission Planning 2019 Accomplishments and 2020 Plans

EPRI's Transmission Planning research program supports the development and validation of planning study models, planning processes and frameworks, and reliability assessment analytics that will be required to build a reliable and economic transmission grid that integrates an evolving generation mix to supply an increasingly complex load that can also act as a system resource. Specific tools developed in 2019 include those for load model derivation, power plant parameter derivation, protection settings evaluation, contingency generation; screening and ranking, automated harmonic evaluations, GMD harmonic assessment, HILF cascading event analysis, and risk-based planning.

Project Number, Name & Manager	**2019 Accomplishments**	**2020 Plan**
40.016 **Model Development, Validation, and Management** Parag Mitra	• Investigated co-simulation techniques for load & DER research. • Continued dynamic load and aggregate DER modeling research and performed case studies. • Point-to-point HVDC model refinement, development of other HVDC models.	• Provide guidance on using the composite load model and DER model for transmission planning assessments. • Refine the composite load model and DER model based on the experience, and provide insights on parameterization of these models. • Explore use of co-simulation for assessing impacts of loads and DER on bulk system performance. • Benchmark VSC HVSC model across the major software platforms and explore modeling needs for hybrid SVC technology. • Provide guidance on new models of synchronous generators, turbines, and governors as they are developed. • Provide guidance on dynamic model reduction for performing stability and EMT studies.
40.16 / 173.003 **DER Model Development and Validation** Jens Boemer	• Improved Aggregate DER Model Integration (ADMI) tool to account for more than one DER at the same bus, and for presence of negative load. • Derived initial DER_A partial voltage trip characteristic along a preliminary prediction model based on type of feeder. • Derived a method to represent tripping of DER for unbalanced faults in positive sequence software. • Initial insight obtained with T&D co-simulation.	• Continue work on developing prediction model of DER_A tripping characteristic based on feeder characteristics. • Investigate development of more accurate DER dynamic models for use in RMS simulation software. • Continue development of ADMI to investigate use of feeder elements in the powerflow model.
40.018 **Transmission Protection Support Tools** Sean McGuinness	• Refinement of PSET and GridCOPS tools for transmission protection assessments based on member case studies. • Refinement of PIPS tool along with guidelines for helping transmission planners to incorporate protection behavior in planning studies. • New Short Circuit Model Validation and Error Detection Tool for ASPEN OneLiner. • New Protection Settings Peer Review Tool for ASPEN OneLiner. • Updated reference guides on various protection related topics.	• New versions of PSET and GridCOPS tools. • Refine Protection in Planning Studies (PIPS) tool for incorporating protection behavior in planning and update the related guidelines document. • Refine the Grid Consequences of Protection Status (GCOPS) tool for better understanding of the grid consequences of protection system behavior into outage planning and real-time analysis. • Continue to develop post-fault analysis & short-circuit model validation tools to identify protection mis-operations and near-misses, validate short circuit models, and identify the root-cause of discrepancies between simulated and measured values.

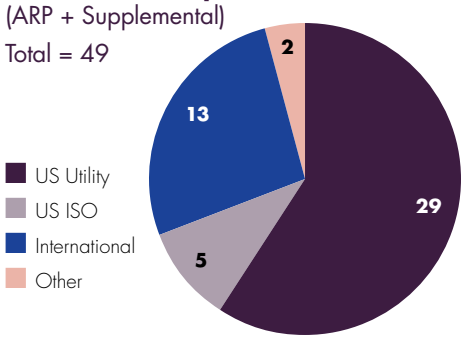
P40 Program ARP Funding Trend



P40 Total Participation

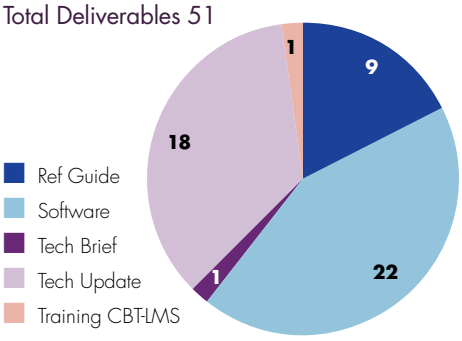
(ARP + Supplemental)

Total = 49



P40 2019 ARP Deliverables

Total Deliverables 51



Project Number, Name & Manager	**2019 Accomplishments**	**2020 Plan**
40.022 **Risk-Based Analysis into Planning and Resiliency Processes** Parag Mitra, Eknath Vittal and Miguel Ortega-Vazquez	• Development of the Resilient System Investment Framework (RSIF). • Tested RSIF using a utility system. • Demonstrated risk-based methodology for assessing transmission projects. • Refined the Scenario Builder framework to capture uncertainties in developing power flow cases. • Refined outage data analysis with emphasis on transformer and generator outage data. • Conducted a workshop to disseminate the research to utilities, industry engagement through IEEE, CIGRE, and NERC Task Forces and Working Groups.	• Further refine the scenario builder framework to capture uncertainties in building power flow cases. • Investigate tools/approaches to solve power flow scenarios for a broad range of system conditions. • Investigate tools/approaches to successfully solve a wide range of contingencies. • Develop a framework to assign probabilities to TPL contingencies. • Further refine the investment framework using risk-based planning concepts to more rigorously address increasing uncertainties and provide better insights to planners. • Further refine and test the RSIF for analyzing High Impact Low Frequency (HILF) events and compare various investment decisions to improve system resiliency. • Work on a generation and transmission coordinated expansion planning tool.
40.023-A **Planning for HILF events** Bob Arritt	• Benchmarked the GIC simulation of non-uniform electric fields across different platforms. • Developed GMD Operations Guideline. • Reviewed the impact of GMD on renewables	• Develop a road map for the next generation of GMD vulnerability assessment tools, define input data requirements and tool specifications, engage with vendors to disseminate the research. • Refine GMD guidelines for transmission planning and operations. • Refine GICHarm tool. • Assess equipment level impact of GMD harmonics on power delivery equipment.
40.023-B **Transmission PQ Modeling/Analysis** Bob Arritt	• Investigated power quality issues for weak grid interactions with inverter-based resources. • Investigated interactions of PV harmonic currents with capacitors and the grid impedance. • Developed EMTP-RV based models for predicting the behavior of inverter-based generating facilities before they connect to the network.	• Test and further refine time domain harmonics model for inverter-based resources. • Guidelines on performing transmission level harmonic studies in presence of inverter-based resources.
40.023-C **Transmission Transient Analysis** Bob Arritt	• Updated the ETRV tool with improved models and document applications. • Updated the TRV Application Guidelines.	• Update and test the TRV screening tool. • Develop modeling and simulation requirements guidelines for performing insulation coordination studies. • Develop and refine a set of application guides and investigative reports to support practical approaches to modeling, statistical switching, simulating and analyzing power system switching transients in general. • Refine EMT models for inverter-based resources (IBR).

Project Number, Name & Manager	**2019 Accomplishments**	**2020 Plan**
40.024A **Contingency Analysis Methods** Eknath Vittal	• Refined the Automated Contingency Analysis Tool (ACGT) and Contingency Screening & Ranking Tool (CSRT). • Developed screening indicators for voltage stability for different categories of contingencies. • Developed screening indicators for identifying vulnerable power flow scenarios from a stability perspective.	• Open source protection control group (PCG) identification logic in ACGT for commercial vendors to adopt. • Work with a member utility to demonstrate ACGT in parallel processing environment. • Investigate use of AI in contingency screening. • Refine CSRT to include voltage instability indicators. • Continue to enhance algorithms for screening power flow cases for stability issues. • Update signal damping analysis tool (SDAT) as needed. • Industry engagement on node-breaker modeling through NERC SAMS and potentially other forums.
40.024B **HVDC Planning Power Flow Control Integration** Alberto Del Rosso	• Completed the HVDC planning case study initiated in 2019. The case study intends to provide planners with examples of an initial feasibility study, including selection of topology and converter type, steady state and dynamic analysis. • Performed evaluation of the generic HVDC model implemented in the simulation software PSSE. • Completed joint white paper on Sub-Synchronous Oscillations in an Evolving Power System.	• Investigate the state of art of Multi-terminal HVDC and DC Grid technologies and prospective advancements. • Investigate alternatives to integrate remote renewable generation centers through VSC-HVDC technology. • Continue development of the HVDC planning reference guide with reference to the state of the art in the fast moving HVDC industry.
40.024C **Power Flow Controller Integration – Optimal Use among Other Transmission Alternatives** Alberto Del Rosso	• Delivered first version the software Controlled Transmission Expansion Planning (CPLANET) v0.1. EPRI's CPLANET is a software application for expansion planning of power systems considering power flow control devices. • Delivered Technical Update on power flow control integration, which includes a description of CPLANET capabilities and main characteristics and provides numerical examples on generic as well as real power system.	• Expand PFC reference guide with a framework for cost-benefit analysis of PFC-based solutions. • Further development of the software CPLANET for analysis and design of transmission reinforcement solutions that include optimal combination of power flow controllers and conventional transmission expansion projects.

P40 - Transmission Planning Deliverables

Key Deliverables

P40

3002016265
Grid Analysis Toolkit v2.1

3002016883
Transmission Planning Considerations for Energy Storage

40.016
System Modeling and Model Validation

3002015320
The New Aggregated Distributed Energy Resources (der_a) Model for Transmission Planning Studies: 2019 Update

3002016290
Technical Update on Load Modeling
The report provides an update on the continuing research on load modeling at EPRI. The report documents research results that enable planners and operators to develop better models of system loads for more accurate simulation studies.

3002016656
Update on HVDC Modeling

3002016684
Aggregate Distributed Energy Resource (DER) Model Integration (ADMI) - Version 3.0 - Beta, Pre-Software

3002016685
Detailed Distribution Circuit Analysis and Parameterization of the Partial Voltage Trip Logic in WECC's DER Model (DER_A): Improvements for Modern and Single Phase DER and Regional Default Settings for Unbalanced Fault Conditions

3002016688
DER Modeling Guidelines for Transmission Planning Studies

3002016689
Duke Energy Progress Distributed Energy Resources Case Study. Impact of Widespread Distribution Connected Inverter Sources on a Large Utility's Transmission Footprint

3002016686
T&D Co-Simulation for Transmission Planning Studies: Load Modeling Verification & Use Cases

40.018
System Protection Decision Support Tools

3002015667
Short Circuit Model Validation and Model-Error Detection Tool for ASPEN Oneliner

3002015668
Protection Relay Functional Testing and Reporting Tool for ASPEN OneLiner

3002015669
DER Area of Vulnerability Screening Tool for Siemens-PTI PSS/e

3002015717
Protection Dynamics Analysis Tool for Siemens-PTI PSS/e

3002015718
Protection Settings Evaluation Tool for Electrocon CAPE
This plugin for Electrocon CAPE applies multiple faults across all lines in a selected area or across an entire grid in order to identify uncleared faults, relay misoperation, inadequate protection performance and near-misses. Web browser, Access DB and Excel interfaces are provided to simplify the analysis of the results and flagging new protection issues as they appear over time.

3002017434
Protection System Evaluation Tool (PSET) For Electrocon CAPE 2019 v2

3002015716
Guide to Protection of Power Transformers

3002015719
Protection Settings Evaluation Tool for ASPEN OneLiner
This plugin for ASPEN OneLiner applies multiple faults across all lines in a selected area or across an entire grid in order to identify uncleared faults, relay misoperation, inadequate protection performance and near-misses. Web browser, Access DB and Excel interfaces are provided to simplify the analysis of the results and flagging new protection issues as they appear over time.

3002015720
Protection of Underground Transmission Systems

3002015721
Protection in Planning Studies Tool for Siemens-PTI PSS/e and GE PSLF
This is a grid and generator protection settings management tool for PSSE and PSLF. It can store protection settings for individual relays and automatically create and parameterize other relays based on user-defined settings rules. It allows distance protection, overcurrent, voltage, frequency, volts-per-hertz, power swing blocking, out-of-step tripping, and loss-of-excitation relays to be modeled as well as capturing inter-tripping and auto-reclosing.

3002015722
Guide to Short-Circuit Model Validation and Model Error Detection Using Fault Records

3002015728
Performance of Protection During Stable and Unstable Power Swings Considering Decreasing Grid Inertia

3002015729
Guide to Modeling Protection in Planning Studies

3002015730
Short Guide to Maintaining and Exchanging Relay Settings

3002015731
Protection Misoperation Reporting and Analysis Tool

3002015664
Protection in Outage Planning Tool for Electrocon CAPE

3002015666
Protection in Outage Planning Tool for ASPEN Oneliner

3002016198
Impact of IBR on ROCOF and Power Swings Protection

3002015726
Protection during System Restoration with and without renewable energy sources

40.022
Risk-Based Planning

3002016438
Risk-Based Transmission Planning Approaches

3002017569
The Resilient System Investment Framework: Case Study and Development Results

3002016439
Scenario Builder v6.0

3002017542
Scenario Builder v7.0
Risk Based Planning Scenario Builder tool is a GUI based tool that can be used by system planners to generate seasonal/hourly power flow models and associated contingencies for a given system based on historical profiles. Additionally, the tool provides the user means to perform preliminary data analysis on historical system data. Thus, providing user insights on potential system conditions to be considered for planning analysis and the supporting statistics.

3002016440
TransCARE

3002016224
Outage data analysis for Risk Based Planning update

3002017012
Outage File Creation Tool (OFCT), v2.4 - Beta

P40 - Transmission Planning Deliverables

Key Deliverables

40.023
Special Planning Studies

3002016208
GMD Non-uniform Field Benchmark Test Case

3002016209
Geomagnetic Disturbance Vulnerability Assessment and Planning Guide
EPRI GMD planning guidelines reference.

3002016213
GMD Operating Guidelines

3002016216
Planning for Harmonic Analysis of Utility-Scale PV Resources on Weak Transmission Systems
Provided tools for harmonic-system study at the grid and inverter-based resources levels.

3002016218
EPRI TRV (ETRV) Screening Tool
This screening tool that conducts TRV analysis was updated with a surge arrester model, more network equivalents models, improved transformer models, 3-winding transformer, added control switching study option, etc.

3002016220
Application Guide to Performing Circuit Breaker TRV Studies

3002016204
Sub Synchronous Oscillations in an Evolving Power System

40.024
Advanced Power Flow and Contingency Analysis

3002014959
Distributed Energy Resources: Impact on Bulk Power System Operation – Lesson 2

3002016167
Power System Dynamic Tutorial - 2019 Edition

3002016435
Automated Contingency Generation Tool v4.0.1
ACGT is a stand alone executable that automatically generates different categories of contingencies associated with the node-breaker topology of a given substation. This tool allows for automation based on any substation change or maintenance outage, efficiently allowing the user to assess steady-state and dynamic impacts of contingency events. V4.0.1 was released in 2019.

3002016436
Contingency Screening & Ranking Tool v4.0
CSRT is a fault screening algorithm that determines contingency event severity based on the first swing angular response of the system. The tool is a standalone executable that allows for the post-processing analysis of any set of dynamic contingency events. V4.0.1 was released in 2019.

3002016437
Technical Summary of EPRI Contingency Analysis Tools

3002015816
Signal Damping Analysis Tool (SDAT) 2.0

3002016165
PLANNING AND INTEGRATION OF HVDC TECHNOLOGY - Case Study on HVDC Planning
This report documents the case study of a HVDC project and illustrates, by means of an example, the process for conducting feasibility planning studies of HVDC installations, following the steps and overall process described in the EPRI HVDC planning guide.

3002016166
High Voltage Direct Current (HVDC) Planning Guide - 2019 Update

3002016163
Power Flow Control Integration - Technologies, Applications, and Solutions Design

3002016164
Power Flow Control integration software
This tool uses a mix-integer algorithm to identify the best location and optimal capacity of power flow control devices to solve overload conditions in a number of given scenarios. The PFC supported by this first version of the software includes phase-shifting transformers and impedance-change devices (i.e.: Smart Wires devices).

Technology Transfer Award Nominations and Award Winners

Blackstarting Scotland from HVDC

National HVDC Center UK, Scottish Power Energy Networks, SSE — Nominee

GridCOPS

American Electric Power Service Company — Nominee

HVDC Planning guide and HVDC generic models for system studies

Southwest Power Pool — Nominee

Protection System Evaluation Tool (PSET)

American Electric Power Services Company, Ameren Services Company, American Transmission Company, Duke Energy, Western Area Power Administration — Nominee

P40 - Highlighted 2019 Member Value Statements

Below we highlight selected member statements summarizing value they have received from applying P40 research results or leverageing EPRI staff expertise and recognize P40 Technology Transfer awards and nominations.

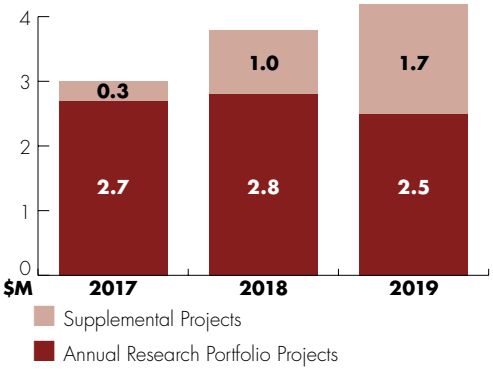
	Value Obtained
Sarawak Boniface Chia **Load Model Data Processing and Parameter Derivation** Measurement based parameterization of dynamic load model (CLOAD model) using EPRI Tool LMDPPD v3.0 as part of European Model & Model Validation Interest Group 2019.	• SEB team joined the EUMMVIG in August 2019 as an initiative to develop in-house expertise and improve load modeling capabilities • Used load event recorder data at distribution transformer at the 33kV level. Events selected include 3-phase response with voltage drop of at least 10% for duration of at least 3 cycle • Successful validation for a few events, results shared in EUMMVIG topical webcast 2 • Results derived are found similar to SEB experience.
Great River Michael Steckelbert **GMD Supplemental** • Research to meet the specific concerns of FERC Order 830. • Provide solid research to assist in any future revisions of TPL-007 (GMD Vulnerability Assessments)	• Able to actively participate in the FERC directed GMD research work plan • Aids in the understanding of the development of future revisions of TPL-007. • Ability to interface with researchers including geologist and space weather scientists through the EPRI GMD Workshops.
ISO New England Steven Judd **ISO-NE Risk-Based Planning Scenario Builder Tool Application** Data Analysis module (new) to assist system planners in determining the system conditions (load, renewable output levels) for planning analysis in Risk-Based Planning Scenario Builder tool.	• Data Analysis module helped verify existing solar PV output assumption during peak load conditions used in planning studies by using 7 years of historical output. • Previously tried to perform analysis in Excel, but reached the limits of the program due to the amount of data being analyzed.
Duke Bill Quaintance **Validating Aggregate DER Tripping** Validate aggregate tripping of distributed energy resources (DERs) following a three-phase transmission fault using DER_A model.	• Understanding impact of legacy DER and modern, IEEE Std 1547-2018 compliant DER, performance with regard to ride-through and voltage/frequency trip.
NERC Ryan Quint **SPIDER Working Group Support** • Technology transfer and thought leadership in NERC's System Planning Impacts from Distributed Energy Resources Working Group	• Maintain high levels of bulk power system (BPS) reliability with increasing deployment of DER • DER modeling guidelines and generic model parameters for aggregated DER model (DER_A) • Understanding impact of legacy and modern DER, recommendations on adoption of IEEE Std 1547™-2018

P173 - Bulk System Renewables and DER Integration 2019 Accomplishments and 2020 Plans

EPRI's Bulk System Renewables and DER Integration research program provides renewables/DER integration analytics and information and develops tools, methods and models to support transmission planning and protection; system operations, frequency control and balancing; and resource adequacy and flexibility assessment. These new approaches allow members to more reliably and economically integrate onshore and offshore wind, distributed and central solar PV, energy storage, and other emerging resources into the bulk system. Examples of work delivered in 2019 include an updated tool for estimating the ability of the transmission system to host wind and solar, enhancements of reserve determination methods and the associated tool to include probabilistic forecasts, an enhanced grid strength assessment tool, a review of low inertia operations and a first version of resource adequacy assessment guidelines.

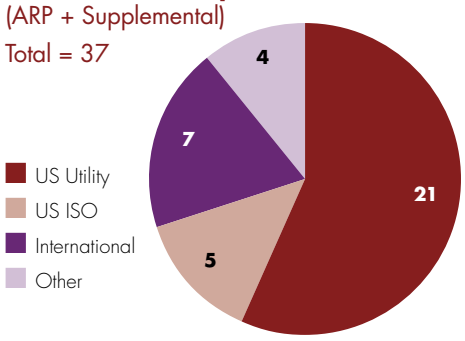
Project Number, Name & Manager	**2019 Accomplishments**	**2020 Plan**
173.003 PSET 173A **Model Development and Validation** Evangelos Farantatos	• Updated GSAT with enhanced algorithm for grid strength metric and case study. • Benchmarking and validation of REGC_C model. • Updated weak grid study guide. • Model benchmarking and validation of wind inertial based fast frequency response model. • White paper on fundamentals and study methodologies for sub synchronous oscillations • Updated Transmission Hosting Capacity tool including implementation in additional platforms and energy storage analysis.	• Modeling and study guidelines for IBR interconnection in weak grids. • Update GSAT to consider voltage stability in weak grids and explore use in operations environment. • Model benchmarking and case studies with REGC_C. • Grid forming inverters - modeling and interaction with grid following inverters. • Continue engagement with WECC for implementation and benchmarking of new features of RES models. • Update Transmission Hosting Capacity tool and explore vendor engagement.
173.003/40.16 **DER Model Development and Validation** Jens Boemer	• Improved Aggregate DER Model Integration (ADMI) tool to account for more than one DER at the same bus, and for presence of negative load. • Derived initial DER_A partial voltage trip characteristic along a preliminary prediction model based on type of feeder. • Derived a method to represent tripping of DER for unbalanced faults in positive sequence software. • Initial insight obtained with T&D co-simulation.	• Continue work on developing prediction model of DER_A tripping characteristic based upon rural, urban, commercial, or residential feeder. • Investigate development of more accurate DER dynamic models for use in RMS simulation software. • Continue development of ADMI to investigate use of feeder elements in the powerflow model.
173.009 PSET 173A **Impact of Renewables on System Protection** Evangelos Farantatos	• Updated wind/solar short circuit models with negative sequence fault current injection schemes. • Continued vendor engagement & technical support for wind/solar short-circuit model implementation in commercial platforms. • Updated protection studies guidelines document.	• Continue vendor engagement for wind/solar short-circuit model implementation in commercial platforms. • Engagement with members to test and apply the wind/solar short-circuit models on their systems. • Short circuit models for energy storage. • Pursue further model validation. • Scripts that calculate the entries of the voltage controlled current source model currently available in commercial platforms. • Update protection studies guidelines document. • IBR fault response performance requirements insights - coordination with P2800.

P173 Program ARP Funding Trend

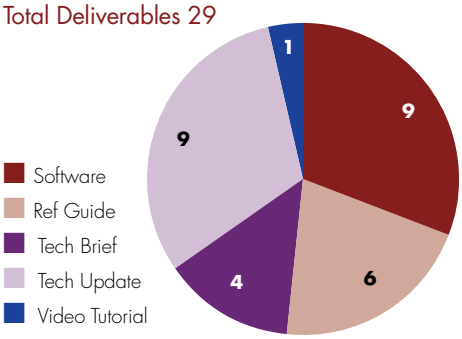


P173 Total Participation
(ARP + Supplemental)

Total = 37



P173 2019 ARP Deliverables
Total Deliverables 29



Project Number, Name & Manager	**2019 Accomplishments**	**2020 Plan**
173.005 PSET 173B **Operational Support Tools to Manage Variability and Uncertainty** Miguel Ortega-Vazquez	• Developed methods to utilize probabilistic renewables forecasts as input to reserve requirement calculation as part of DOE project. • Developed a method to assess risk in reserve procurement. Results show the benefits of risk-based reserve procurement. • Updated DynADOR (v3) for improved usability, data visualization and risk assessment.	• Extend dynamic reserve determination method used in DynADOR to accommodate probabilistic forecasts of wind and load, beyond solar. Improve clustering methods to better assess reserve needs. • Embed the risk-based reserve procurement process developed in the DynADOR tool. • Being research on contingency reserve determination during extreme weather and heavy cycling (TI project). • Explore other characteristics of reserve procurement and scheduling practices such as ramping needs and scheduling resolution.
173.011 PSET 173B **Frequency Control and Assessment** Vikas Singhvi	• Enhanced and validated Frequency Response Adequacy and Display Tool (FRADT), including ability to use at a BA level or an interconnection level for long study periods. • Published whitepaper - Online Inertia Estimation & Monitoring - Industry Practices and Research Activities. • Developed extended term dynamic simulation framework (joint project with NREL).	• Perform case studies using FRADT and improve tool accordingly. • Continue development of an extended -term dynamic simulation framework to study multi-timescale interaction of primary and secondary frequency performance (joint project with NREL). • Perform case studies to evaluate frequency performance with increased penetration of Emerging Technologies (DER, wind/solar, etc.). • Develop White Paper on using Nuclear Power Plants (NPPs) for Grid Frequency Control (joint deliverable with Nuclear sector).

Project Number, Name & Manager	**2019 Accomplishments**	**2020 Plan**
173.012 PSET 173C **Flexibility and Resource Adequacy** Eamonn Lannoye	• Updated Inflexion to version 5.2. • Updated flexibility assessment guidelines based on emerging industry practices and initiate resource adequacy assessment guidelines. • Commenced development of next generation system planning tools for advanced capacity and flexibility adequacy assessment. • Hosted flexibility and resource adequacy workshop. • Commenced study on estimating the capacity value of hybrid renewable and storage resources.	• Further development and refinement of flexibility guidelines and resource adequacy guidelines. • Methodology development and case studies for capacity contribution of new resources including demand contribution. • Development of new adequacy methods for next generation of planning tools, focusing on data and scenario development in 2020.
173.013 PSET 173D **Technology Transfer for Bulk System Renewables/DER Integration** Aidan Tuohy	• Provided short summary deliverables and webcasts on topics of interest, including frequency response with low inertia levels and DER market integration. • Developed first version of guidelines for operations with high levels of variable resources. • Published two DOE-funded reports on Tx/Dx planning interactions and TSO/DSO coordination with increasing amounts of distributed energy resources. Facilitated an industry-wide working group to specify DER group management functions for coordinated operations across the T&D interface. • Worked with ISOs/RTOs on adopting new DER ride-through standards in their reliability regions and developed a DER Performance and Settings database for improved coordination of DER trip settings with distribution utilities.	• Provide short summary deliverables and webcasts on topics of interest, including offshore wind, TSO-DSO interactions and other relevant topics. • Develop next version of guidelines for operations with high levels of variable resources. • Continue facilitation of an industry-wide working group to specify DER group management functions for coordinated operations across the T&D interface. • Continue working with ISOs/RTOs on adopting new DER ride-through standards in their reliability regions. Leverage learnings from ongoing supplemental projects for DER transmission. planning case studies

P173 - Bulk System Integration of Renewables and Distributed Resources Deliverables

Key Deliverables

173

3002016167
Power System Dynamic Tutorial - 2019 Edition

173 A
System Planning Methods and Tools with Renewables

3002015320
The New Aggregated Distributed Energy Resources (der_a) Model for Transmission Planning Studies: 2019 Update

3002015723
Transmission Hosting Capacity Tool (PSLF version) v1.0

3002016199
Modeling and Study Guides for Integration of Inverter Based Resources in Low Short Circuit Grids
Documents metrics & screening methods that assess the need for detailed studies in weak grids using three-phase models, enhancements of positive sequence models and case studies

3002016200
Verification of the Generic Model for Inertial-Based Fast Frequency Response of Wind Turbine Generators

3002016203
Transmission Hosting Capacity (PSS®E) v2.0

3002017456
Grid Strength Assessment Tool (GSAT) v2.1
Updated version of the GSAT tool that automates the computation process of grid strength indexes

3002016204
Sub-Synchronous Oscillations – An Overview and Future Challenges Under High Penetration of Inverter Interfaced Devices and Weaker Grids

3002016684
Aggregate Distributed Energy Resource (DER) Model Integration (ADMI) - Version 3.0 - Beta, Pre-Software

3002016685
Detailed Distribution Circuit Analysis and Parameterization of the Partial Voltage Trip Logic in WECC's DER Model (DER_A): Improvements for Modern and Single Phase DER and Regional Default Settings for Unbalanced Fault Conditions

3002016688
DER Modeling Guidelines for Transmission Planning Studies

3002016689
Duke Energy Progress Distributed Energy Resources Case Study. Impact of Widespread Distribution Connected Inverter Sources on a Large Utility's Transmission Footprint

3002016883
Transmission Planning Considerations for Energy Storage

3002016686
T&D Co-Simulation Aggregate Active Distribution Grid, Load and Distributed Energy Resource Modeling Verification & Use Cases for Transmission Planning Studies
Explores the use of T&D co-simulation to verify and improve aggregate models of loads and DER, and identify use cases

3002016196
System Protection Guidelines for Systems with Inverter Based Resources
Updated guidelines for protection engineers for fault analysis and protection studies on systems with increased levels of inverter based resources

3002016197
Impact of Inverter-Based Resources on Protection Schemes Based on Negative Sequence Components

3002016198
Impact of IBR on ROCOF and Power Swings Protection

3002015726
Protection during System Restoration with and without renewable energy sources

173 B
System Operations Methods and Tools with Renewables

3002016310
Dynador v2.1

3002016311
Dynador v3
Software tool for forecasting reserve requirement upgrades with enhancements including improved usability, data visualization and risk based metrics.

3002016312
Probabilistic Dynamic Reserve Determination and Risk Assessment

3002017371
Video Tutorial: Illustrating Operating Reserve Needs and Methods - Operational Support Tools to Help Meet Variability and Uncertainty (2019 Update)

3002016195
Online Inertia Estimation & Monitoring - Industry Practices & Research Activities
Literature review of current industry practices and R&D activities for real-time inertia monitoring using PMU measurements and other online methods

3002016404
Frequency Response Adequacy Display Tool v3.0
Allows users to calculate frequency response related metrics based on resources online - updated to include new metrics and improve functionality

3002016406
Bulk System Frequency Performance and Assessment under High Levels of Variable Generation

3002016659
PRE-SW: Frequency Response Adequacy Display Tool (FRADT) v2.1 Beta

173 C
Flexibility and Resource Adequacy

3002016256
Inflexion v5.2
Update to assessment tool that helps planners understand whether a system has sufficient ability to meet expected variability and uncertainty

3002016257
Flexibility Assessment Guidelines - 2019

3002016258
Resource Adequacy Assessment Guidelines - 2019
Compendium of practices, tools and methods to assess power system resource adequacy. First version in 2019

3002016264
Assessing the Capacity Contribution of Renewables Plus Storage Resources
Demonstration of methods to calculate and analyze the capacity contribution from combined renewables plus storage (hybrid) resources.

173 D
Bulk Renewables Integration Technology Transfer

3002017540
Operator Guidelines for High Penetrations of Variable or Distributed Energy Resource (VER/DER)
These guidelines provide an overview of the major issues faced in integrating high shares of VER/DER. The issue is laid out, current leading practices are identified and future research described. This is the first version of the document.

3002016712
Transmission and Distribution Operations and Planning Coordination
This DOE-funded report catalogs the current state and gaps associated with existing processes and architectures and specifies examples for the data exchange across the T&D interface needed in the future.

3002016174
DER Group Management for Coordinated Operations Across the T&D Interface
Identifies control and monitoring interactions aimed at addressing the needs for coordination between TSO and DSO regarding aggregations/groups of DER.

3002017006
Distributed Energy Resources Performance and Settings Database, Version 1.0 - Beta, Pre-Software
A public, web-based repository for the settings that utilities require for interconnection of DER.

P173 - Highlighted 2019 Member Value Statements

Below we highlight selected member statements summarizing value they have received from applying P173 research results or leveraging EPRI staff expertise and recognize P173 Technology Transfer awards and nominations.

Value Obtained

Dominion Derek Kou, Kyle Thomas

Short-Circuit Models for Inverter Based Resources (IBR)

Use of IBR short-circuit models developed by EPRI in coordination with IEEE PSRC, and implemented by software vendors (e.g. ASPEN) through EPRI vendor engagement and IEEE PSRC.

- The ASPEN IBR model has been fully integrated for solar generation studies at Dominion Energy
- More accurate modeling of IBR fault response
- More accurate system protection and relay setting studies

Southwest Power Pool (SPP) Doug Bowman

Weak Grid Analysis for Interconnecting Inverter-Based Generation

Applied Grid Strength Assessment Tool (GSAT) to calculate various system strength indices (e.g. SCR) and identify potential weak locations in the SPP system.

- Grid Strength Assessment Tool (GSAT) to screen for potential weak grid issues for inverter based interconnections
- GSAT allows for identification of areas where more detailed three phase studies are required to support interconnection needs and controller settings

MISO Kun Zhu

Guideline for IEEE 1547-2018 Implementation

Support MISO in developing a reliability guideline for distributed energy resources (DERs) to comply with IEEE 1547-2018 requirements related to bulk power system (BPS) reliability.

- Maintain high levels of bulk power system (BPS) reliability with increasing deployment of DER
- Build relationships with distribution utilities to coordinate DER functional settings that can impact the BPS, e.g., voltage and frequency trip

Southern Company Manish Patel, Sylvester Toe

Interconnection Requirements for BPS-Connected Inverter-Based and Distribution-Connected Resources

Improve technical interconnection requirements for inverter-based resources to build up a stock with grid support capabilities.

- Support NERC's Inverter-Based Resource Task Force
- Leadership of IEEE P2800 Working Group Draft Standard for Interconnection and Interoperability of Inverter-Based Resources Interconnecting with Associated Transmission Electric Power Systems
- Review of technical interconnection requirements (TIRs) for distribution connected resources (DERs)

XM Carlos Mario, Correa Posada, Dilan Andres, Caro Barranco

Application of DynaDOR and FRADT tools

Applied DynADOR and FRADT tools from PS173B to support planning and operations with increased renewables in the Colombian system.

- DynADOR complements existing and proposed reserve determination methodologies
- Allows for improved reserve requirement calculations
- FRADT calculation of relevant variables in short time complements detailed planning studies
- Fast provision of system inertia and related data provides timely information to control center

Technology Transfer Award Nominations and Award Winners

Application of Transmission Hosting Capacity Tool

Southwest Power Pool, Midcontinent Independent System Operator, Inc. — Nominee

DER Energy Market Integration and Control

Australian Energy Market Operator — Nominee

Improving Bulk System Reliability with DER through Early Adoption of IEEE Std 1547-2018 and UL 1741 SA Certification.

First Energy, Baltimore Gas and Electric, Midcontinent ISO, Xcel Energy, ISO New England, PJM Interconnection — Nominee

Review of Implications of Reduced Inertia Levels on the Electricity System

Iberdrola, Tokyo Electric Power Company — Nominee

Studying the Integration of Variable Energy Resources and Energy Storage

Tennessee Valley Authority — Nominee

System Flexibility Assessment for Renewable Integration

California Independent System Operator, Electric Reliability Council of Texas — Nominee

Weak Grid Assessment using EPRI's Grid Strength Assessment Tool and Detailed Modeling Studies

American Electric Power Company, Southwest Power Pool — **Award Winner**

EPRI worked with members to investigate the need for more detailed three-phase modeling tools to be employed in areas with low transmission system strength. Learnings were used to demonstrate and inform development of the Grid Strength Assessment Tool. This tool assists with calculating metrics to assess system strength and characterize inverter stability performance.

TO&P Recent TI Accomplishments and Future Plans

The EPRI TI program is funded by leveraging 12% of the Annual Research Portfolio funds to: (1) Provide longer-term directional guidance to the industry, (2) Inform society as to future energy trends, and (3) Support longer-term, foundational research efforts. This section summarizes recent, on-going, and future TI program research conducted by the TO&P team and the additional value EPRI TO&P members may derive from these research efforts.

TI Project Description	Status/Deliverables and **Future Plans**
Probabilistic Outage Scheduling Eamonn Lannoye With changing demand profiles, increasing renewables and decreasing potential to expand transmission in certain areas, scheduling outages to occur without elevating risks to reliability in the future may be challenge using current methods. This project is focused on testing the use of probabilistic tools and methods to assess outage requests from generators and transmission facilities with increasing uncertainty in the power system. Results from an initial case study indicate the potential for scenarios not typically considered to present issues when scheduling outages.	Completed early 2019. Deliverables/Outcomes: Technical brief entitled Managing Uncertainty in Planned Outage Scheduling (3002009117) summarizing the outage scheduling process and identifying challenges for outage scheduling in future. Currently working on a case study application of methods. **Work will transition into the Operations Planning and Engineering Support Studies project (P39.14).**
Linking Grid Reliability and Energy Analysis Tools Aidan Tuohy The goal of this project is to develop and demonstrate a framework and associated tools for evaluating resource expansion and power delivery choices concurrently, including an assessment of grid reliability as part of the expansion process. This includes appropriate linking of tools, results, and data across temporal (seconds to decades), functional (electric, gas, transport, water), and spatial (transmission and distribution) scales.	Work was completed in 2019. Deliverables/Outcomes: Several white papers were finalized in 2019: (1) Integrating Energy Analytics and Grid Reliability Tools: Survey of Existing Work and Research Gaps (3002012301, forthcoming); (3) Energy Storage in Planning, Operations and Wholesale Markets: Part 1 - Trends (3002012300, forthcoming) and Part 2 - Resource Planning (3002017874, forthcoming); Value of Modeling Constraints in Generator Scheduling (3002016693). **Work was finalized in 2019 with publication of final deliverables, with transition to ongoing collaborative efforts in P173 and P201.**
Updated Resource Reliability Contributions Whitepaper Aidan Tuohy This project will update the 2015 white paper to include an assessment of utility-scale battery energy storage contributions, as well as discuss other existing contribution assessments in light of other recent related industry efforts.	On-going, to be completed Q2 2020. Deliverables/Outcomes: Revised whitepaper titled Contributions of Supply and Demand Resources to Required Power System Reliability Services (3002012299, forthcoming) will be published Q2 2020.

TI Project Description	Status/Deliverables and **Future Plans**
Screening of Hourly Power Flow Cases Eknath Vittal Given the transformational changes in generation mix, interdependency among electric and other sectors, demand-side generation and control technologies, looking at only a few system scenarios for transmission planning will no longer be sufficient. This project will develop a screening framework that can indicate which hourly dispatch scenarios need more detailed analysis and which do not. Specifically, the aim of this project is to develop a methodology or methodologies that can identify potential transient stability issues (voltage stability, low short-circuit levels, inertial and frequency issues) and assess whether they are systemic or localized based on the results of steady-state simulation.	Needs clarification. In 2018, EPRI worked with a utility member to assess 8760 hourly power flow cases based on historical loads and generation dispatches to develop methodologies to assess and quantify potential voltage stability impacts based on network conditions were explored. Learnings were implemented as part of the voltage stability ranking algorithm in CSRT and the project will continue in the base research residing under P40.024-A. **Work into the development of the steady-state metrics will continue as planned into the second year of this project and will aim to develop a white paper summarizing the work completed.**
Linking Distribution and Transmission Models to Assess Impact of DER on Bulk System Vikas Singhvi & Jens Boemer The aim of this project is to link Transmission & Distribution hosting capacity tools to understand 1) how does DER hosting capacity calculated using both the tools compares with each other, 2) what information can be exchanged across the tools for more accurate T&D modeling, and 3) if there is a need for co-simulation for accurate DER hosting capacity assessment of a given region.	• Performed a case study to demonstrate need of coordinated T&D analysis for more accurate estimation of DER hosting capacity. •Published EPRI tech brief - "An Overview of Co-Simulation Platforms for Transmission Planning" (3002017494). **Explore co-simulation framework for accurate DER hosting capacity assessment as well for other use cases identified in EPRI DER modeling research.**
Coordinated Expansion Planning Miguel Ortega-Vazquez This project aims to account for the interdependencies between generation, transmission and emerging technologies such as DER and storage in the coordinated expansion planning (CEP) problem. Explicitly modeling these interdependencies will pave the way to develop coordinated generation and transmission, that would not only minimize net present value of the expansion plans and operation of the system, but also that would guarantee that these are sufficiently flexible and adaptable to respond to global and local uncertainties. These models will also feature a good balance between accuracy in the representation of operational planning aspects and computational burden of the solve. These efforts will result in tools that would bring forth the new generation of expansion tools, which undoubtedly will bring value to our members.	Completed late-2019. Literature review of existing methods for coordinated expansion planning has been completed: "Coordinated Expansion Planning: Status and Research Challenges (3002016661)". Project plan has been developed and technical development tasks will begin early 2020. **In 2020 this project will be part of the ARP under 40.22. The main tasks will include, familiarization with the CEP software, bring it to a greater readiness level, and research on increasing temporal resolution.**
Supply Resilience White Paper Erik Ela This project reviews the challenges of continuing to supply energy and power-related ancillary services during externally-driven high impact low frequency events. It reviews the definitions and metrics of reliability and restoration and compares and offers extensions to supply resilience. It also provides a framework for expanding the methods for ensuring supply resilience going forward. Finally, the report provide several detailed mechanisms for how different regions ensure supply resilience in planning, system operations, restoration ops/planning, and market operations.	White Paper Completed in 2019. 3002014963. **Evaluate joint research with Program 178 (Resource Planning) on ways that operating procedures and electricity market designs can improve power supply resilience and mitigate the impacts of externally-driven high impact low frequency events.**

Software

As part of the TO&P research efforts, we develop research software to implement, test and refine the planning, operations, and protection research results created. This section summarizes existing TO&P software that is still maintained for on-going research and application with members.

Product ID	Software Name	Description
	Transmission Operations (P39)	
3002016169	PRE-SW: Voltage Control Areas Studio (VCA) v1.0 Beta	This software identifies voltage control areas (VCA) in transmission systems, and determines if the reactive power reserve in each VCA is adequate to maintain operation security under the considered operating and contingency conditions.
3002016185	PRE-SW: Streaming Synchrophasor Data Quality Tool (SSDQ), Offline v3.0 Beta	SSDQ performs data quality conditioning of streaming synchrophasors with missing and bad data. Offline version 3.0 is Matlab-based for offline use.
3002016188	Streaming Synchrophasor Data Quality - Online - OpenECA Implementation (SSDQ Online OpenECA) v1.0	SSDQ performs data quality conditioning of streaming synchrophasors with missing and bad data. Online version 2.0 is OpenECA-based for online use.
3002016190	Synchrophasor Based Machine Learning (SBML) Tool v1.0	Software tool applying machine learning techniques using synchrophasor data for event identification
3002016193	Synchrophasor Applications Database v.2.0	Synchrophasor Applications Database provides a comprehensive overview of international use cases of synchrophasor technology with a user interface for search & filter options.
3002016265	PRE-SW: Grid Analysis Toolkit (GAT) v2.2 Beta	Python based steady state power system analysis toolkit. Provides engineers with a flexible, advanced and robust set of tools for optimization and power flow assessment.
3002016400	PRE-SW: Optimal Blackstart Capability Tool (OBC) v6.0 Beta	This software tool can assist in evaluating the blackstart capability of a power system. Users can use OBC to assess the effectiveness of existing blackstart units, or to identify potential locations to install new blackstart capability.
3002016401	PRE-SW: System Restoration Navigator Tool (SRN) v8.0 Beta	SRN is a stand-alone tool and is meant to be used primarily by restoration planners to develop, validate and update restoration plans.
3002016655	Alarm Visualization and Assessment Tool (AVAT v3.3)	AVAT enables analysis of alarms from multiple sources to filter, group, and prioritize alarms according to root cause and provides alarm performance monitoring and analytics to identify nuisance alarms and improve alarm handling in control centers.
	Transmission Planning (P40)	
3002015664	Protection in Outage Planning Tool for Electrocon CAPE	This plug-in for Electrocon CAPE identifies if the selected planned outages can potentially give rise to protection issues that could impact grid reliability. A web browser, Access database and Excel interfaces are provided in the tool for easier analysis.
3002015666	Protection in Outage Planning Tool for ASPEN Oneliner	This plug-in for Electrocon CAPE identifies if the selected planned outages can potentially give rise to protection issues that could impact grid reliability. A web browser, Access database and Excel interfaces are provided in the tool for easier analysis.
3002015667	Short Circuit Model Validation and Model-Error Detection Tool for ASPEN Oneliner	This tool enables validation of short circuit models using measured fault data. If any discrepancies are found, it provides guidance on potential issues related to the model and parameters.
3002015668	Protection Relay Functional Testing and Reporting Tool for ASPEN OneLiner	This tool performs off-line relay commissioning tests and reporting by assessing performance of each element within the relay - how far away each distance zone reaches, coordination margin with nearby devices, loadability checks etc.
3002015669	DER Area of Vulnerability Screening Tool for Siemens-PTI PSS/e	This tool provides an approximate but fast method for assessing DER tripping due to a voltage sag following a transmission fault. The tool can look across multiple faults for a given study area.
3002015717	PRE-SW:Protection Dynamics Analysis Tool (ProtDynamics) v1.0 Beta	This tool provides the capability to view and analyze protection performance during transient stability studies. It also enables the user to convert transient simulation data from PSS/e into the Comtrade file format which can be used for lab-testing or commissioning relays.
3002015718	PRE-SW: Protection System Evaluation Tool (PSET) For Electrocon CAPE version 2019 Beta	This plugin for Electrocon CAPE applies multiple faults across all lines in a selected area or across an entire grid in order to identify uncleared faults, relay misoperation, inadequate protection performance and near-misses. Web browser, Access DB and Excel interfaces are provided to simplify the analysis of the results and flagging new protection issues as they appear over time.
3002015719	PRE-SW: Protection System Evaluation Tool (PSET) 2019 For ASPEN OneLiner Beta	This plugin for ASPEN OneLiner applies multiple faults across all lines in a selected area or across an entire grid in order to identify uncleared faults, relay misoperation, inadequate protection performance and near-misses. Web browser, Access DB and Excel interfaces are provided to simplify the analysis of the results and flagging new protection issues as they appear over time.

3002015721	Protection in Planning Studies Tool for Siemens-PTI PSS/e and GE PSLF	This tool can populate PSSE and PSLF dynamic files with standard library relay models for distance protection, overcurrent, volts per hertz, power swing blocking, out of step tripping, and loss of generator excitation, and other protection functions. The tool populates models with default parameters which can be changed by the user.
3002015731	Protection Misoperation Reporting and Analysis Tool	This tool provides a simple and standardized method for logging protection misoperations.
3002015816	PRE-SW: Signal Damping Analysis Tool (SDAT) v2.0	This is a post-processing tool meant to analyze multiple signals for low damping and modal content. The tools can read PSSE and PSLF dynamic run output as well as actual signals recorded in the field.
3002016164	PRE-SW: Controlled Transmission Expansion Planning (CPLANET) v0.1 Beta	The tools uses a mix-integer algorithm to identify the best location and optimal capacity of power flow control devices to solve overloads conditions in a number of given scenarios. The PFC supported by this first version of the software include phase-shifting transformers and impedance-change devices (i.e.: Smart Wires devices)
3002016218	EPRI TRV (ETRV) Screening Tool	A screening Tool that conducts TRV analysis updated with surge arrester model, more network equivalents models, improved transformer models, 3-winding transformer, added control switching study option, etc.
3002016435	Automated Contingency Generation Tool v4.0.1	ACGT is a stand alone tool that automatically generates different categories of TPL contingencies associated with the node-breaker topology of a given substation. The tool allows for the automation based on any substation change or maintenance outage, efficiently allowing the user to assess steady-state and dynamic impacts of contingency events.
3002016436	PRE-SW: Contingency Screening & Ranking Tool (CSRT) v4.0 Beta	CSRT is a stand alone tool that can screen and rank contingencies based on firsts swing angular response of the system in a relatively short time using only a few cycles of dynamic simulation run.
3002017542	Scenario Builder v7.0	This tool provides a framework to capture uncertainties in renewable and hydro generation, as well as load, generation retirements to develop power flow cases for planning analysis. The tool also provides data analysis features for hourly profiles of load and generation.
3002016440	PEW-AQ: TransCARE v1.1.2017	A new release of TransCARE tool.
3002017012	PRE-SW: Outage File Creation Tool (OFCT), v2.4 - Beta	An easy-to-use, GUI-based tool for automatically creating circuit and generator outage files for PSS®E and TransCARE for performing risk-based analysis.
3002017434	Protection System Evaluation Tool (PSET) For Electrocon CAPE 2019 v2	

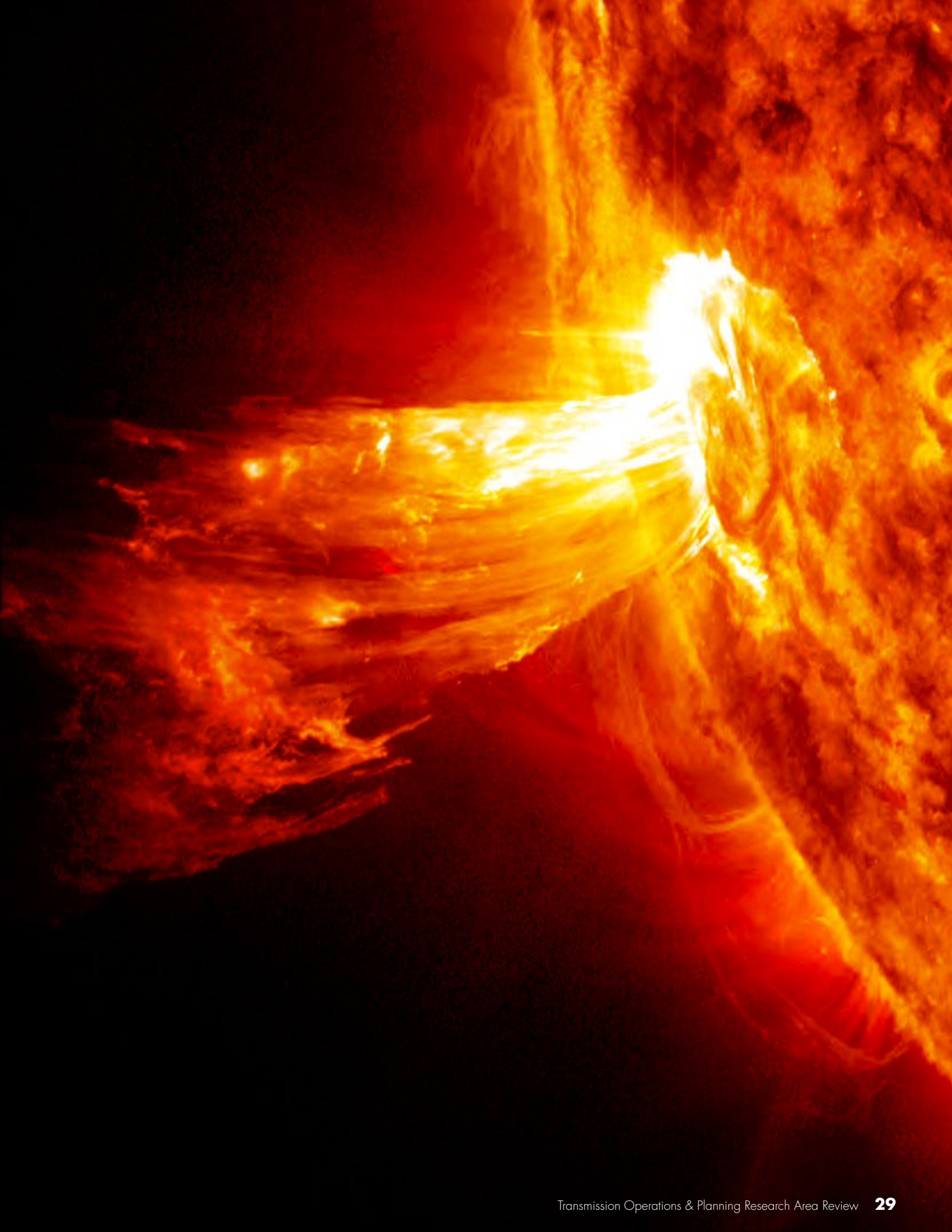
Bulk System Renewables/DER Integration (P173)

3002016256	Inflexion v5.2	Inflexion v5.2 includes new methods to determine flexibility requirements, use remote databases and resolves several performance issues.
3002016311	Dynador v3	This upgrade includes the major enhancements discussed throughout the year including improved usability of the software tool, data visualization and risk based metrics.
3002017456	PRE-SW: Grid Strength Assessment Tool (GSAT) v2.1	Updated version of the GSAT tool that automates the computation process of grid strength indexes
3002016684	PRE-SW: Aggregate Distributed Energy Resource (DER) Model Integration (ADMI) v3.0 Beta	Aggregate DER Model Integration Tool v3
3002016310	PRE-SW: Dynamic Assessment and Determination of Operating Reserve (DynADOR), v2.1 Beta	This Dynador Upgrade includes minor UI and bug fixes delivered during the year
3002016202	PRE-SW: Grid Strength Assessment Tool (GSAT) v2.0 Beta	Updated version of the GSAT tool that automates the computation process of grid strength indexes
3002016203	Transmission Hosting Capacity (PSS®E) v2.0	Tool to screen through varying load & generation scenarios to identify optimal transmission grid regions for renewables deployment/load growth -PSSE version
3002015723	PRE-SW: Transmission Hosting Capacity Tool PSLF Version (THCT PSLF), v1.0 Beta	Tool to screen through varying load & generation scenarios to identify optimal transmission grid regions for renewables deployment/load growth-PSLF
3002016404	PRE-SW: Frequency Response Adequacy Display Tool (FRADT) v3.0	This situational awareness tool displays anticipated frequency response looking ahead multiple hours or days and allows user to perform what-if analysis for mitigation strategies for inadequate frequency response

Reference Guides

As part of the TO&P research efforts, we develop guidelines for conducting planning, operations, and protection functions. This section summarizes existing TO&P reference guides that are maintained for on-going research and application with members.

Product ID	Reference Guide	Description
	Transmission Operations (P39)	
3002016358	Control Center Human Machine Interface Reference Guide	A guide to developing HMI interfaces with examples applicable to Transmission Generation and Distribution.
3002016359	Alarm Management Philosophy Guide & Improvement Suggestions	Guidelines and best practices on how to develop and maintain an transmission control center alarm management philosophy.
3002016360	Human Machine Interface Philosophy, Style Guide & Improvement Suggestions	Guidelines and best practices on how to develop and maintain an transmission control center human machine interface philosophy and style guide.
3002016171	Voltage Control and Reactive Power Management: Reference Guide - Industry Practices and Tools for Voltage/VAR Planning and Management (VVPM) - 2019 Edition	This reference guide is a compendium of state-of-the-art VVPM tools and practices used by transmission planning and operations staff for planning and operating the bulk power system.
3002016402	Power System Restoration Reference Guide	This power system reference guide summarizes the principles and practices followed globally in developing and implementing plans for restoring a power system following a widespread blackout. The technical issues typically encountered during restoration and the lessons learned during restoration following major global blackouts are also presented. In addition, an overview is provided for potential investigation of new restoration approaches to address emerging issues such as renewable generation, distributed energy resources and high-impact low-frequency (HILF) events.
3002016260	Non Convergent Power Flow Guidelines - 2019	Practitioners' guidance on the cause and mitigation of non-convergence in power flow analysis. Updated with outcomes from application of advanced solution techniques to case studies.
3002016226	Wholesale Electricity Market Design in North America Reference Guide: 2019 Review	The annual guide and update on electricity market design and market operations in North American electricity markets.
	Transmission Planning (P40)	
3002015716	Guide to Protection of Power Transformers	This guide presents an overview of all relevant aspects of power transformers for protection studies and analysis. This includes deriving short circuit models from factory tests, typical failure modes, protection approaches, and protection challenges.
3002015722	Guide to Short-Circuit Model Validation and Model Error Detection Using Fault Records	This is a concise guide on methods for validating short circuit models for protection studies and fault location calculations. It also provides guidance on further analysis if discrepancies are found between measured data and simulated models.
3002015729	Guide to Modeling Protection in Planning Studies	This guide presents an overview of the relay modeling capabilities of common planning tools and identifies where they can be used to identify potential protection misoperations. In 2019 particular emphasis is given to identifying how decreasing grid inertia affects protection performance and how these can also be assessed in transient stability studies.
3002015730	Short Guide to Maintaining and Exchanging Relay Settings	This short guide presents an overview of how EPRI members have used methods, processes, and tools to simplify and support the maintenance of relay configuration databases and protection simulation packages such as ASPEN and CAPE.
3002016209	Geomagnetic Disturbance Vulnerability Assessment and Planning Guide	EPRI GMD planning guidelines reference.
3002016213	GMD Operating Guidelines	EPRI GMD operating guidelines reference.
3002016220	Application Guide to Performing Circuit Breaker TRV Studies	Updated Guideline document on performing circuit breaker transient recovery voltage (TRV) studies with additional case studies and incorporate ETRV tool usage.
3002016166	High Voltage Direct Current (HVDC) Planning Guide - 2019 Update	A concise guide for planners in identifying the types of studies and considerations they will need to reflect on when considering the integration of large HVDC projects. The first version of this reference guide was published in 2015, and updated in 2018.
	Bulk System Renewables/DER Integration (P173)	
3002016688	DER Modeling Guidelines for Transmission Planning Studies	Summary of research on modeling of distributed energy resources in transmission planning studies. Includes a review of transmission planning impacts of substation reverse power flows.
3002016196	System Protection Guidelines for Systems with Inverter Based Resources	Updated guidelines for protection engineers for fault analysis and protection studies on systems with increased levels of inverter based resources.
3002016257	Flexibility Assessment Guidelines - 2019	Compendium of practices, tools and methods to assess power system flexibility. Updated to include most recent applications of flexibility in systems around the world.
3002016258	Resource Adequacy Assessment Guidelines - 2019	Compendium of practices, tools and methods to assess power system resource adequacy. First version in 2019 .
3002017540	Operator Guidelines for High Penetrations of Variable or Distributed Energy Resource (VER/DER)	These guidelines provide an overview of the major issues faced in integrating high shares of VER/DER. The issue is laid out, current leading practices are identified and future research described. This is the first version of the document.
3002016199	Modeling and Study Guides for Integration of Inverter Based Resources in Low Short Circuit Grids	Report that documents metrics & screening methods to assess need for detailed studies in weak grids using three-phase models, enhancements of positive sequence models and case studies.
3002017371	Operating Reserve Video V3	Video Tutorial – Illustrating Operating Reserve Needs and Methods: Operational Support Tools to Help Meet Variability and Uncertainty.



Standards Organizations

IEEE Power Engineering Society (PES)

Leadership Roles

i. Standard 1547 – Vice-Chair and DER Ride-Through Requirements Group Lead, Jens Boemer
ii. Standard 1547.1 – DER Ride-Through Test Requirements Subgroup Lead, Jens Boemer
iii. EDPG Wind and Solar Power Plant Interconnection and Design Subcommittee Secretary, Jens Boemer
iv. EDPG Wind and Solar Plants Interconnection WG Chair, Jens Boemer
v. Secretary Power System Economics Subcommittee, Erik Ela
vi. IEEE P2800 Draft Standard for Interconnection and Interoperability of Inverter-Based Resources Interconnecting with Associated Transmission Electric Power Systems WG Chair
vii. SA Standards Coordination Committee 21 (SCC21) Secretary, Jens Boemer
viii. Flexibility Assessment WG Co-Chair, Eamonn Lannoye
ix. Distributed Resources Integration WG Secretary, Bob Arritt
x. Power Systems Relaying Committee C24 WG Vice-Chair, Evangelos Farantatos
xi. Power Systems Relaying Committee K11 WG Author, Bob Arritt
xii. Transactions on Power Systems Board Member, Erik Ela
xiii. Synchrophasor Conformity Assessment Steering Committee Member, Mahendra Patel
xiv. Wind and Solar Power Coordinating Committee, Secretary, Aidan Tuohy
xv. PSOPE Committee TF "Next Generation EMS for Advanced Future Bulk Power Systems: Challenges, Architecture and Concept", Secretary, Evangelos Farantatos
xvi. IEEE PSDP Committee - Liaison to PSRC, Evangelos Farantatos
xvii. IEEE Power Systems Relaying Committee D41 WG Vice-Chair, Evangelos Farantatos
xviii. IEEE PSDP Task Force on Modeling and simulation of large power systems with high penetration of inverter-based generation, Secretary, Deepak Ramasubramanian

Active Contribution

i. Power System Operations, Planning, and Economics (PSOPE) Committee, Erik Ela
ii. Standard 741–Protection of Class 1E Power Systems and Equipment in Nuclear Power Generating Stations, Bob Arritt
iii. Power System Restoration with Renewable Energy Sources TF, Navin Bhatt and Vikas Singhvi
iv. PSRC WG H-11 Synchrophasors for Power Systems–Measurement, Mahendra Patel
v. PSRC WG C-19 Phasor Data Concentrators for Power Systems, Mahendra Patel
vi. PSRC WG P-8 Recommended Mapping Between IEEE and IEC Std., Mahendra Patel
vii. PSRC WG C-28 Revising C37.242, Mahendra Patel
viii. PSRC WG TF H-36 Revision of Standard C37.118.2, Mahendra Patel
ix. PSRC WG C-18 Protection Systems of Transmission to Generation Interconnections, Mahendra Patel

CIGRE – International Council on Large Electric Systems

Leadership Roles

i. Irish National Committee Member, Sean McGuinness
ii. Irish Protection B5 Committee National Representative, Sean McGuinness
iii. U.S. Distribution System and Dispersed Generation C6 Committee National Representative, Jason Taylor
iv. C4/C6.29, Power Quality Aspects of PV WG Convenor, Jeff Smith
v. D2/C2.41, Advanced Utility Data Management and Analytics for Improved Operation Situational Awareness of Electric Power Utility Operations WG Convenor, Alberto del Rosso
vi. IEEE/CIGRE B4.82 ,Working Group on Use of Real Code in EMT Models for Power System Analysis, Secretary, Deepak Ramasubramanian

Active Contribution

i. C2/6.26 WG on TSO/DSO Coordination in Operations, Eamonn Lannoye
ii. JJWG A3-B5-C4 on Assessing Probability for and Consequences of Out of Step Conditions, Sean McGuinness
iii. JWG B4-C4.38 Network Modelling for Harmonics Studies, Sean McGuinness
iv. B4.67 WG on Harmonics from VSC, Sean McGuinness
v. B5.58 WG on Faster Protection and Network Automation Systems, Sean McGuinness
vi. C6.30 WG on Battery Electric Storage Systems, Jason Taylor
vii. B5C4-61 on Impact of Low Inertia Network on Protection & Control, Adrian Kelly
viii. C6.25 WG on Control and Automation Systems for Electricity Distribution Networks of the Future, Jason Taylor
x. JWG C4/C6.35/CIRED Modelling and Dynamic Performance of Inverter-Based Generation in Power System Transmission and Distribution Studies, Jens Boemer and Eknath Vittal
xi. C1.27 WG on The Future of Reliability, Aidan Tuohy
xii. WG 1.40, Planning Coordination between System Operators, Transmitters and Distributors: Frameworks, Methods, and Allocation of Costs and Benefits, Eamonn Lannoye
xiii. Regulation and market design barriers preventing to capture all the value from fast and high-location-freedom energy storage, Erik Ela
xiv. C2.39 WG om Operator Training in Electricity Grids at Different Control Levels and for Different Participants/Actors in the New Environment, Adrian Kelly
xv. C5.27 Market Design for Short Term Flexibility, Aidan Tuohy
xvi. B5.65 "Enhancing Protection System Performance by Optimizing the Response of Inverter-Based Sources", Evangelos Farantatos
xvii. C4.49 Multi-frequency stability of converter-based modern power systems, Jonathan Ruddy and Evangelos Farantatos
xviii. C5.28 Energy Price Formation in Wholesale Electricity Markets, Robin Broder Hytowitz
xix. C2.40 - TSO-DSO Co-Operation – Control Centre Tools Requirements – Eamonn Lannoye
xx. JWG C2.C4.41 - Impact of high penetration of inverter-based generation on system inertia of networks - Secretary, Papiya Dattaray
xxi. JWG 1N° C4/C2.58/IEEE - Evaluation of Voltage Stability Assessment Methodologies in Transmission Systems - Alberto Del Rosso
xxii. CIGRE Next Generation Network (NGN), Ireland - Chair, Papiya Dattaray

IEC – International Electrotechnical Commission

i. Study Committee 8A Renewable Integration U.S. Member- Aidan Tuohy; SC8A WG2 Renewable Energy Forecasting - Co-Convener, Aidan Tuohy
ii. SC8A/TC8 JWG5 – System issues regarding integration of wind and PV generation into bulk electrical grid, Member - Deepak Ramasubramanian

International Energy Agency (IEA)

i. Wind Task 36 on Wind Forecasting, Aidan Tuohy

Other Industry Organizations

North American Electric Reliability Corporation (NERC)

i. System Analysis and Modeling SC, Jens Boemer–Liaison IEEE 1547
ii. System Planning Impacts of DER (SPIDER), Anish Gaikwad, Deepak Ramasubramanian, Evangelos Farantatos, Kevin Dowling, and Jens Boemer
ii. Inverter-Based Resources Performance Task Force, Eknath Vittal, Deepak Ramasubramanian, and Jens Boemer
iv. Synchronized Measurement Subcommittee, Evangelos Farantatos
v. Load Modeling TF, Anish Gaikwad, Deepak Ramasubramanian, Parag Mitra
vi. Operating Committee/Planning Committee, Robert Entriken–Observer

North American Transmission Forum

i. Active Contributions to Modeling Practices Team

Western Electricity Coordinating Council (WECC)

i. Model Validation Working Group, Anish Gaikwad, Deepak Ramasubramanian, Parag Mitra
ii. Load Modeling Task Force, Anish Gaikwad, Deepak Ramasubramanian, Parag Mitra

North American SynchroPhasor Initiative (NASPI)

i. NASPI Leadership Team, Daniel Brooks and Paul Myrda
ii. Engineering Analysis Task Team Co-Leader, Evangelos Farantatos

Energy Systems Integration Group (ESIG)

i. Board of Directors (ex officio), Daniel Brooks
ii. System Operations and Market Design Working Group Chair- Aidan Tuohy

Research Organizations/Consortia

PSERC, Industry Advisory Board, Evangelos Farantatos

University College Dublin Energy Institute, Industry Advisory Board

University of Tennessee CURENT, Member

EU Horizon 2020 SmartNet Project, Advisory Board

EU Horizon 2020 MIGRATE Project, Advisory Board

EU Horizon 2020 SPINE Project, Advisory Board

Ireland DS3 Advisory Council, Mark McGranaghan

Rutgers Western Conference on Regulatory Economics– Organizing Committee, Robert Entriken

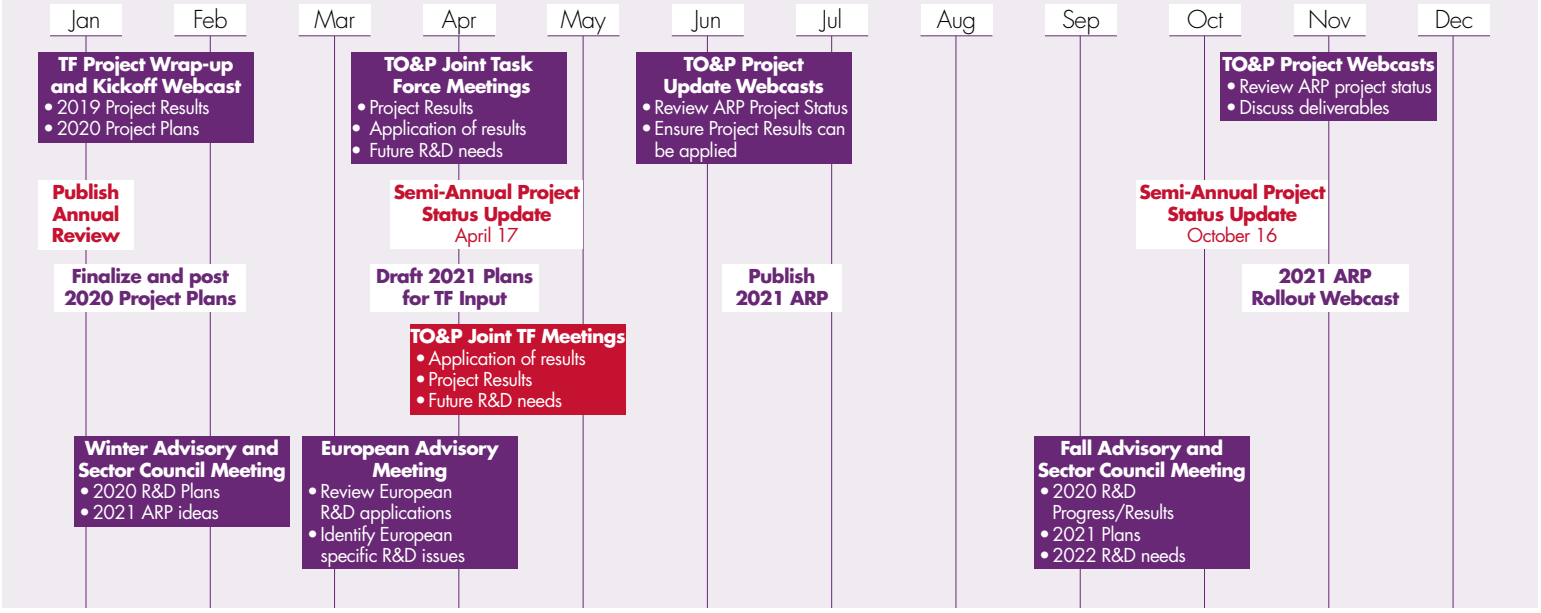
HELICS/GMLC 1.4.15/Transmission-Distribution-Communication, Technical Review Committee, Aidan Tuohy and Jens Boemer

EPRI Company Overview

Electric Power Research Institute (EPRI): Conducts research, development, and demonstration (RD&D) projects for the benefit of the public in the United States and internationally. As an independent, nonprofit organization for public interest energy and environmental research, we focus on electricity generation, delivery, and use in collaboration with the electricity sector, its stakeholders and others to enhance the quality of life by making electric power safe, reliable, affordable, and environmentally responsible.

In November 1965, the Great Northeastern Blackout left 30 million people in the United States without electricity, starkly demonstrating the nation's growing dependence on electricity and vulnerability to its loss. It marked a watershed for the U.S. electricity sector and triggered the creation of EPRI. Since 1972, EPRI has collaborated with the electricity sector and its stakeholders such that our membership has grown to represent approximately 90% of the electric utility revenue generated in the United States and extends to participation in more than 35 countries.

TO&P Area Operational Calendar



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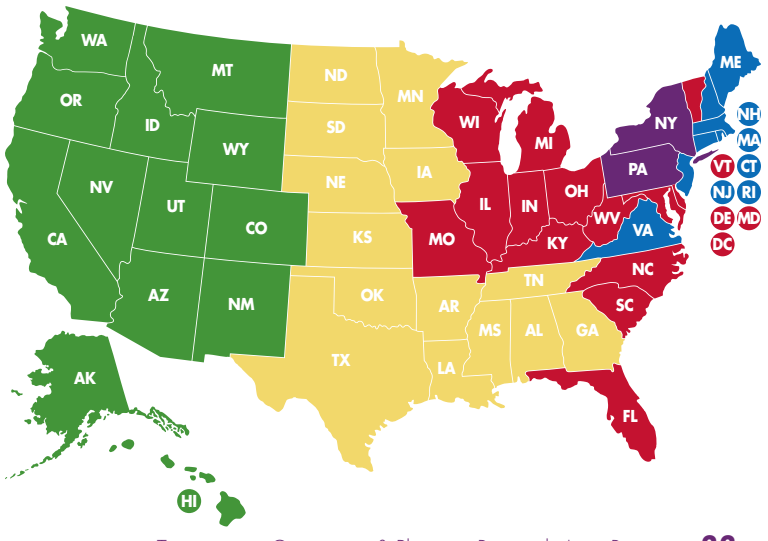

The Electric Power Research Institute (EPRI, www.epri.com) conducts research and development for the global electricity sector. An independent, nonprofit organization, EPRI brings together experts from academia and industry as well as its own scientists and engineers to help address challenges in electricity generation, delivery and use, including health, safety and the environment. EPRI also provides technology, policy and economic analyses to drive long-range research and development planning, and supports research in emerging technologies. EPRI's members represent more than 90 percent of the electricity generated and delivered in the United States, and international participation extends to 40 countries. EPRI's principal offices and laboratories are located in Palo Alto, California; Charlotte, North Carolina; Knoxville, Tennessee; and Lenox, Massachusetts.

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