The Information and Communication Technology (ICT) Program conducts research in the following areas:

- **Interoperability** – The program accelerates the industry’s migration towards interoperability by making technical contributions to standards development efforts; providing training to utilities; developing reference implementations and organizing interoperability tests of developing standards; and collaborating with utilities on the demonstrations of emerging standards.

- **Telecommunications** – The program provides leadership in communications standards development; provides tracking and analysis of communications technologies; develops the tools and techniques to effectively plan and design communications networks; and conducts laboratory and field tests to evaluate the performance of evolving and emerging technologies.

- **Enterprise and Grid Architecture** – The program creates tools that deliver the state of the art in enterprise architecture and develops guides to help utilities with standards-based systems integration and enable greater flexibility as grid operations evolve.

- **Advanced Metering** – The program leads an industry effort to develop open, interoperable advanced metering systems; develops best practice guides for the operations and maintenance of Advanced Metering Infrastructure (AMI) systems; and investigates approaches for maximizing the value of AMI systems.

- **Data Integration of Intelligent Field Equipment, Consumer Internet of Things (IoT) Devices, and Mobile Workforces with Utility Systems** – The program is developing the requirements and advancing the standards for integrating and managing edge devices with utility systems.

- **Data Management** – The program identifies and documents industry best practices for how data is acquired, validated, stored,
protected, and processed; and how accessibility, reliability, and timeliness is ensured to improve grid operations. The program also advances the Common Information Model (CIM) standard.

Program 161 consists of seven project sets:

161A – Emerging Technologies and Technology Transfer: Provides tracking and analysis of the rapid advances in smart grid standards so that members can minimize risk when planning and procuring equipment. It investigates new, ground-breaking ICT issues and technologies potentially impacting utility investments.

161B – Applied ICT for Transmission: Identifies the requirements for a robust communications infrastructure that effectively supports situational awareness and asset management for the transmission system; develops effective approaches for integrating, managing and analyzing internal and external data sources; and creates a standards-based approach for integrating sensors.

161C – Applied ICT for Distribution: Develops data visualization techniques, analytics, and technologies to enhance distribution operations and increase grid reliability; defines communications requirements, leading practices, and standards to achieve interoperability between devices, visualization systems, and back office systems; documents practices to enable intelligence at the grid edge; and creates algorithms and tools to improve GIS data quality.

161D – Applied ICT for DER and Demand Response: Addresses the multi-vendor control challenges found in renewable generation and enables integration of microgrids, transactive energy, and smart city applications. This research addresses barriers in the communications, control, and monitoring of smart solar, storage, and loads to enable a cross-functional architecture that supports advanced grids.

161E – Enterprise Architecture and Systems Integration: Puts the best tools and techniques into the hands of enterprise architecture to address the unique needs and operating environments of utilities. This research provides utilities with guides for developing IT/OT convergence and cloud integration strategies.

161F – Advanced Metering Infrastructure: Aids utilities in optimizing AMI systems and AMI-collected data; accelerates and guides emerging standards and architectures to enhance interoperability, innovation, and marketplace competition; and identifies best practices for system operations monitoring and support.

161G – Telecommunications: Provides utilities with tools and methods to plan scalable, multi-service communication networks for current and future needs. Identifies best practices for fiber deployment in Wide Area Networks; defines optimal wireless technologies and spectrum types for field area networks; determines best roles for commercial wireless and shared networks and evolution to 5G networks; and identifies best practices for network management, visualization, and planning.

In 2019, the ICT Program will:

• Promote interoperable advanced metering systems leveraging the Common Information Model
• Advance the development and harmonization of standards for DER integration
• Develop techniques and technologies to improve GIS data quality
• Assess approaches to optimize remote management of intelligent electric devices
• Advance the seamless integration of wearable computers to support a mobile workforce
• Develop the communications requirements for near-term applications of smart inverters
• Create guidebooks for Enterprise Architecture, Cloud Integration, AMI Analytics and Revenue Protection
• Evaluate and test various FAN technologies and open Software Defined Network systems
• Conduct interoperability testing of DER devices and DERMS
• Conduct testing and evaluation of new packet technologies for teleprotection and operational networks
• Evaluate performance, cost, and reliability factors for private wireless networks and commercial cellular

TO JOIN, CONTACT ANY OF THE FOLLOWING TECHNICAL ADVISORS:

West: Christine Hertzog, Senior Technical Advisor, 650.314.8111; chertzog@epri.com
East: Chris Kotting, Technical Advisor, 980.219.0146; cketting@epri.com
Annette Mosley, Technical Advisor, PDU, 972.556.6507; amosley@epri.com
International: Kevin East, International Director, +44 (1925) 450.207; keast@epri.com

For more information, contact the EPRI Customer Service Center at 800.313.3374 or askepri@epri.com

3002015123 January 2019

3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813, USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

©2019 Electric Power Research Institute (EPRI), Inc. All rights reserved. Electric Power Research Institute, EPRI, and TOGETHER...SHAPING THE FUTURE OF ELECTRICITY are registered service marks of the Electric Power Research Institute.
This project set tracks and analyzes the rapid advances in smart grid standards to help members minimize risk when planning and procuring equipment. It investigates new, ground-breaking information and communication technology (ICT) issues and technologies and their impacts on utility investments. The project set promotes technology transfer for the entire ICT program through webcasts and newsletters and coordinates high-level technology transfer activities related to ICT technologies supporting advanced grids.

FOCUS AREAS

Smart Grid Standards Tracking and Analysis

Issue: Utilities are making large investments in equipment and infrastructure that enable applications such as situational awareness, distribution automation, integration of distributed energy resource integration, and demand response. These investments are highly dependent on data and communications standards that are evolving quickly. Many utilities find it difficult to track this complex and dynamic landscape that can have tremendous impacts on their business.

Objective: EPRI’s Technical staff is actively involved in standards development activities and regularly shares updates and recommendations to inform utility plans and procurement decisions. The staff also interacts with the vendor community to encourage standards adoption and interoperability.

Target Audience: Utilities interested in understanding the evolution of standards and their impacts on product evolutions and investments.

Results: Updates and insights on standards development are presented on monthly webcasts. The presentation material from the webcasts is compiled and published at the end of the year.

- Key Past Accomplishments
  - Summary of Interoperability Tracking and Reporting by the Information and Communication Technology Program in 2017 (3002010237).
  - 2018 Deliverables
    - Summary of Interoperability Tracking and Reporting by the Information and Communication Technology Program in 2018 (3002013481).

Next Steps: The Project Set will continue to track and analyze the development of key standards in 2019.

White Papers on Emerging Information and Communication Technology Issues

Issue: Issues around ICT surface quickly and utilities need answers and solutions just as quickly. Utilities and the public want to understand if emerging technologies such as Blockchain or Artificial Intelligence will impact electricity service, and what those impacts might be.

Objective: This project develops white papers that investigate and analyze emerging ICT technologies to help utilities formulate appropriate plans. With input from program advisors, EPRI staff identifies topics for white papers at the beginning of each year.

Target Audience: Utilities seeking informed tracking and analysis of advanced technologies that may have positive or negative impacts to their grid infrastructure.

Results: Key Past Accomplishments

- The Value of Direct Access to Connected Devices (3002007825): This paper identifies the values of direct, standard, and open access to devices. These terms are defined and contrasted with alternatives.
- Distributed Intelligence: Current Industry Landscape and Next Steps (3002007842): This paper identifies potential impacts across the utility enterprise, summarizes the current landscape and challenges, identifies gaps, and provides research recommendations to aid utilities in developing plans that incorporate distributed intelligence architectures in their infrastructure.
o **Blockchain: Early Activity for Utilities (3002009889):** Blockchain is an emerging digital technology acting as a distributed ledger to record transactions. The paper explains what blockchain is, its associated capabilities and applications in the utility industry.

o **Artificial Intelligence: Concepts for Electric Power (3002010236):** This paper explores the past, present, and future of artificial intelligence applications with respect to the electricity industry.

- **2018 Deliverables**
  o **Mounting Importance of Communications to Monitor and Control DER (3002013480):** This paper explores the emergence of requirements for open protocols in DER communications. It analyzes requirements for DER—interconnection standards, industry specifications, and building codes—to identify what DER types and protocols are in-scope and assess the impact the requirements for open protocols may have on the industry.
  o **Light(ere)weight Protocols for Lower-Capability Edge IoT Devices (3002013478):** This paper presents options for reducing network complexity and message sizes and introduces examples of alternative application-layer messaging systems that leverage traditional Internet-based networks while reducing the burden on smaller devices at the grid edge.
  o **Leading Practices for Transmission Network Model Management (3002014082):** This paper summarizes how a utility or ISO might address the problems commonly found in the network model data management domain and provides the status of activities in the vendor and standard development communities.

Next Steps: The White Papers on the Emerging ICT Issues project will continue in 2019. White paper topics will be defined in January in consultation with project set members.

### Technology Transfer Activities

This project set provides technology transfer support for the entire ICT program through monthly webcasts, regular newsletters, and email updates.

**Target Audience:** All people interested in the results coming out of the ICT program.

**Results:**
- Program Newsletters with articles on key research results from the ICT program are published three times a year and are posted in the program cockpit on the EPRI website.
- Technology Transfer Webcasts are held each month. Recordings of past webcasts are available for download in the program cockpit.
- Research Updates are posted in the “announcement” section of the program cockpit.

Next Steps: Technology Transfer activities will continue in 2019.

**Project Set Lead:** Don Von Dollen, 650.855.2210, dvondoll@epri.com
The research identifies the requirements for a robust communications infrastructure that effectively supports situational awareness and asset management for the transmission system; develops effective approaches for integrating, managing and analyzing internal and external data sources; and creates a standards-based approach for integrating sensors. The results of this work advances high voltage data communications and management that could ultimately help utilities reduce O&M expenditures and improve system reliability and resiliency. The year 2019 will generally maintain the same research focus topics with an expansion of the Communications-Related Information and Tools area, specifically the remote device management, and begin investigating the impact of virtualization on ICT elements.

**RESEARCH FOCUS AREAS**

**Standardized Data Structures**

**Issue:** Data Analytics can increase situational awareness and asset management capabilities, but data needs to be in an easily integrated format for multiple applications.

**R&D Objective:** Develop standardized data structures to facilitate data integration.

**Target Audience:** Transmission System Performance Engineers, Asset Management Performance Engineers.

**Research Results:** This research provides guidance on standards in support of analytics and equipment performance metrics and enables utilities to create standardized platforms for analytics that are non-proprietary.

- Plans for 2019: Develop a Comprehensive Data Model that addresses the requirements needed by utilities for improved asset health/condition management in collaboration with industry stakeholders to promote interoperability at all “layers” for major transmission assets.
- Key Past Accomplishments
  - **Assessment of IEC 61850 Transformer Monitors (3002007476) (2016):** Determined the level of compliance from transformer monitors with Dissolved Gas Analysis (DGA) capabilities relative to the final version of the IEC 61850-90-3 standard. Standards gaps were documented and provided to IEC Technical Committee 57 Working Group 10.
  - **2018 Deliverables**
    - **Substation Data Management (3002012586):** This report investigates the benefits of extracting and preparing substation data for further analysis by transforming the data into useful structures.
    - **IEC 61850 Working Group Activity 2018 Summary (3002012589):** This report documents the yearly progress of Technical Committee 57 Working Group 10 in support of the IEC 61850 standard for Power Utility Automation.
  - **2017 Deliverables**
    - **IEC 61850 Working Group Activity 2017 Summary (3002009873):** This report documented the Technical Committee 57 Working Group 10 activities in 2017 in support of the IEC 61850 standard for Power Utility Automation.
    - **Assessment of Asset Monitors to IEC 61850-90-3 – Circuit Breakers (3002009872):** This report examined the data outputs for circuit breaker monitors and protective relays from several manufacturers. Recent standards activity created an opportunity for advancements in circuit breaker health monitoring and these are identified in the deliverable.

**High-Speed Precision Time-Stamped Data**

**Issue:** New streaming data from sensors and video cameras may have new applications of value to utilities.

**R&D Objective:** Develop effective approaches for integrating, managing and analyzing new internal and external data sources and create a standards-based approach for integration of this data into new and existing utility applications including precision time stamped data.

**Target Audience:** Transmission Protection Engineers, System Performance Engineers.
Research Results: This research identifies benefits of high speed data from new internal and external sources for precise alignment of data from events and actions.

- Plans for 2019: The intention with this research is to develop a resilient and secure end to end infrastructure that can provide operational asset information from a range of asset sensing systems into a common repository for utility applications.
- Time-Stamped Related Information and Tools
- Key Past Accomplishments
  - **Utility Precision Time Methods – Current State (3002007474) (2016):** Included utility survey results about requirements for precision time and how precision time is being implemented, and what alternative options are being considered.
  - **Synchronous Data Management Assessment (3002007473) (2016):** Summarized prior work and included detailed case studies of two utilities. The deliverables of this work established the foundation for further research conducted in 2017/2018.
- 2018 Deliverables
  - **Substation Data Mapping - Initial Assessment (3002012587):** The key to this project is the extraction and integration of data providing ease of analysis. Also, addressed is the importance to develop the “linking” parameters that can be used to “connect” disparate data during the integration.
- 2017 Deliverables
  - **Integration of Internal and External Data for Informed Decisions: 2017 Update (3002009871):** Consolidated the planning tools developed in previous years and provided recommendations for future data considerations.

Communications-Related Information and Tools (2017 September Roadmap)

Identify the requirements for a robust communications infrastructure that supports situational awareness and asset management for the transmission system.

**Issue:** Data needs to be transmitted for multiple real-time and historical analytics applications.

**R&D Objective:** Understand communications technologies and identify the tools requirements and performance guidelines to support transmission grid situational awareness and asset management.

**Target Audience:** Utility operations personnel involved with data analytics and networks.

**Research Results:** Develop unbiased information regarding communications technologies, associated performance metrics, and tools including requirements for technologies in the transmission system.

- **2018 Deliverables**
  - **Remote Device Management Assessment (3002012588):** This research assesses the current state of Remote Device Management as implemented by the leading suppliers in this area. Both architectures and functions are evaluated.
- **2017 Deliverables**
  - **Synchronous Communication Assessment – Advanced Synchronous Protocol (3002009870):** Developed an Advanced Synchronous Protocol to address the limitations of IEEE C37.118 for large-scale synchronous data system deployments. Called the Streaming Telemetry Transport Protocol, it includes strong access control and encryption.

Project Set Lead: Paul Myrda, pmyrda@epri.com

**TO JOIN, CONTACT ANY OF THE FOLLOWING TECHNICAL ADVISORS:**

**West:** Christine Hertzog, Senior Technical Advisor, 650.314.8111; chertzog@epri.com

**East:** Chris Kotting, Technical Advisor, 980.219.0146; ckotting@epri.com

Annette Mosley, Technical Advisor, PDU, 972.556.6507; amosley@epri.com

**International:** Kevin East, International Director, +44 (1925) 450.207; keast@epri.com

For more information, contact the EPRI Customer Service Center at 800.313.3374 or askepri@epri.com

©2019 Electric Power Research Institute (EPRI), Inc. All rights reserved. Electric Power Research Institute, EPRI, and TOGETHER...SHAPING THE FUTURE OF ELECTRICITY are registered service marks of the Electric Power Research Institute.
Remote Device Management

Remote Device Management (RDM) is a process for collecting and organizing information about managed devices installed on electric utility assets to remotely acquire and modify intelligent electronic devices (IEDs) behavior. IEDs can include microprocessor relays, smart inverters, routers, switches and more. These IEDs fulfill a critical function by monitoring utility assets to provide the utilities with the data needed to operate the grid reliably, securely and efficiently.

Currently at many utilities there is limited or no RDM capability deployed. Therefore, field personnel may be required to drive to the substation, possibly in remote areas, to retrieve IED event files for fault location and event analysis. This additional activity can hamper restoration efforts and ultimately affect overall reliability performance. Other challenges include the lack of standard protocols for some functions and the lack of industry consensus on requirements, leading to a wide range of approaches between suppliers, and even with a single supplier’s products. The business need within the industry is great for effective tools to remotely manage the IEDs.

As utilities deploy ever increasing numbers of IEDs across their systems with growing capabilities to capture, process, store, and communicate a wide range of data types, the challenge to effectively manage these devices is also increasing.
“EPRI’s work on Remote Device Management aligns with SRP’s vision in managing Intelligent Electronic Devices (IEDs). Salt River Project (SRP) sees the capabilities of remote device management as key in being able to achieve more productivity with less resources. The results of the work performed by EPRI will be utilized as SRP continues to work with vendors in addressing existing gaps in their solutions to provide true Remote Device Management (RDM) beyond Interactive Remote Access (IRA).”

Kyle Cormier, Manager – Control Engineering, Salt River Project

In 2018 the Applied ICT for Transmission project set performed a current state assessment of the available RDM products. This assessment includes the following evaluation categories:

- Enabling technologies:
  - Architecture
  - Communications
- Key functionality:
  - Asset discovery
  - Asset inventory
  - Configuration management
  - Firmware/patch management
  - Password management

The research identified that the supplier offerings for RDM partially support the evaluation categories that we addressed. While there has definitely been some good progress made by a few suppliers, additional work by EPRI to identify RDM requirements remains to be done to reach the definition of an ideal RDM; to fully manage, update, secure, monitor and analyze all the remote IEDs of all types at all locations.

TO JOIN, CONTACT ANY OF THE FOLLOWING TECHNICAL ADVISORS:

West: Christine Hertzog, Senior Technical Advisor, 650.314.8111; chertzog@epri.com

East: Chris Kotting, Technical Advisor, 980.219.0146; ckotting@epri.com

Annette Mosley, Technical Advisor, PDU, 972.556.6507; amosley@epri.com

International: Kevin East, International Director, +44 (1925) 450.207; keast@epri.com

For more information, contact the EPRI Customer Service Center at 800.313.3374 or askepri@epri.com
The research of 161C seeks to provide utilities with the methods to capture and maintain accurate data; techniques to access the right data in the right location at the right time; interoperable standards; the ability to integrate and connect legacy and modern devices; and requirements to enable a mobile workforce. This work complements research conducted in the Distribution Systems Program (P180), Distribution Operations and Planning (P200), and other ICT project sets. By collaborating with member utilities and other EPRI Programs, Applied ICT for Distribution provides guidance to the industry to increase workforce and operational efficiencies, improve the accuracy of data in utility systems, and enhance communication and data sharing standards.

RESEARCH FOCUS AREAS

Precise System and Data Models
Issue: The management of a progressively more multifaceted distribution system necessitates a comprehensive and accurate model that is constantly updated with timely data from grid-connected devices.
R&D Objective: Increase accuracy and transferability of data between devices and applications/systems.
Target Audience: GIS technicians and distribution systems engineers and managers.
Research Results: The research focuses on techniques and algorithms to maintain and enhance the quality of data, development of standards and data models, and cost-benefit methodologies to capture the impacts of increasing data quality and improving models.
• Plans for 2019: The research will explore automated methods to identify, catalog, and geo-locate above- and below-ground assets. Algorithms will be developed to assist in improving the quality of utility data. Standards development will continue.
  o Data Integrity Techniques for GIS
  o Platform Agnostic Asset Identification and Geolocation
• Key Past Accomplishments
• 2018 Deliverables

Connected Workforce and Devices
Issue: Mobile workforce devices and sensors can improve utility worker safety and productivity. These devices must be interoperable with other utility systems and devices.
R&D Objective: Achieve full connectivity and interoperability of wearable technologies.
Target Audience: Mobile workforce, safety, and communications engineers and managers.
Research Results: The research investigates the availability and applicability of wearable technologies to improve safety and operational efficiencies of the modern workforce and identifies communication requirements of grid-connected devices.
• Plans for 2019: The research will extend standards and usability of devices, wearable computers, augmented reality, and artificial intelligence as well as demonstrate cutting-edge technologies. Cost-benefit impacts of these technologies will also be explored.
  o IT/OT Guidebook to Augmented/Virtual Reality Applications
Increasing Intelligence Through Standards and Integration

Issue: Robust standards and seamless integration of systems and devices are linchpins of the integrated grid that permit the interconnection of increasing amounts of distributed energy resources and require intelligence at the edge of the grid.

R&D Objective: Data is processed and stored at an optimal location and easily shared with other systems and applications through enhanced standards and integration.

Target Audience: Distribution automation and systems engineers and managers as well as data scientists.

Research Results: The research seeks to document and adapt standards to meet the needs of distribution utilities and to determine the most advantageous location for distribution intelligence to reside to achieve greater operational efficiency and reliability gains.

• Plans for 2019: Enhance existing standards, document requirements to move intelligence to the edge of the grid, create algorithms to enable distributed management, and evaluate the cost benefit impacts of the intelligence migration.

• Key Past Accomplishments
  • A Guidebook for Advanced Distribution Automation Communications (3002006004) (2015); The guidebook has associated utility communications case studies – Hydro-Québec in 2015 (3002006577) and Duke Energy in 2016 (3002007924).
  • Connected Workforce Technology and Sensor Survey (3002007925) (2016).
  • Case Study: Using Augmented Reality to Improve Storm Damage Assessment (3002011041) (2017).

• 2018 Deliverables
  • EPRI Virtual Reality Web Application and Source Code (EPRI VR) v1.0 (3002014698).

TO JOIN, CONTACT ANY OF THE FOLLOWING TECHNICAL ADVISORS:

West: Christine Hertzog, Senior Technical Advisor, 650.314.8111; chertzog@epri.com
East: Chris Kotting, Technical Advisor, 980.219.0146; ckotting@epri.com,
Annette Mosley, Technical Advisor, PDU, 972.556.6507; amosley@epri.com
International: Kevin East, International Director, +44 (1925) 450.207; keast@epri.com

For more information, contact the EPRI Customer Assistance Center at 800.313.3374 or askepri@epri.com

3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813, USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

January 2019

©2019 Electric Power Research Institute (EPRI), Inc. All rights reserved. Electric Power Research Institute, EPRI, and TOGETHER...SHAPING THE FUTURE OF ELECTRICITY are registered service marks of the Electric Power Research Institute.
Ameren and EPRI evaluated an augmented reality (AR) tablet application to train line workers to install communications routers. Traditional training relied on in-person situational training and cutout cards with installation instructions. The paper method used in the past included step-by-step instructions of the workflow of installing or repairing a router. The paper instructions were typically available to the line worker during installation. The AR application overlaid 3-D models of the communications routers in the training that also utilized standards, videos of the job, best practices, and the necessary clearances on the pole.

While the installation times for the routers did not seem excessive, Ameren was experiencing elevated levels of installation errors requiring multiple truck rolls to complete the installation. A common reason for sending trucks out multiple times was that hardware fasteners were being overtightened thus decreasing the life of the router due to exposure to water and other environmental issues.

EPRI photographically documented the line worker as they moved through orientation, verbal in-person training, rehearsal, and final performance of the router maintenance task. Measurements comparing the paper method to the AR method showed that, on average, router installation or maintenance tasks could be completed in 77 minutes with traditional training and modified training using paper and in approximately 37 minutes using AR training. This translates into a 48% gain in workforce efficiency.

The research and demonstration showed that AR training was faster than traditional training for the installation of communications routers at Ameren. These findings show the benefits of immersive mobile experiential learning. The possibilities of this type of training, especially the ability to immediately access additional visual instructions may prove effective for other field worker tasks.

“AR/VR training and technologies demonstration shows ability to expedite training and thus workforce efficiency for Ameren.”

John Hughes, Ameren

Project Set Lead: Jared Green, jgreen@epri.com

Augmented Reality Training – Router Installation

Ameren and EPRI evaluated an augmented reality (AR) tablet application to train line workers to install communications routers. Traditional training relied on in-person situational training and cutout cards with installation instructions. The paper method used in the past included step-by-step instructions of the workflow of installing or repairing a router. The paper instructions were typically available to the line worker during installation. The AR application overlaid 3-D models of the communications routers in the training that also utilized standards, videos of the job, best practices, and the necessary clearances on the pole.

While the installation times for the routers did not seem excessive, Ameren was experiencing elevated levels of installation errors requiring multiple truck rolls to complete the installation. A common reason for sending trucks out multiple times was that hardware fasteners were being overtightened thus decreasing the life of the router due to exposure to water and other environmental issues.

EPRI photographically documented the line worker as they moved through orientation, verbal in-person training, rehearsal, and final performance of the router maintenance task. Measurements comparing the paper method to the AR method showed that, on average, router installation or maintenance tasks could be completed in 77 minutes with traditional training and modified training using paper and in approximately 37 minutes using AR training. This translates into a 48% gain in workforce efficiency.

The research and demonstration showed that AR training was faster than traditional training for the installation of communications routers at Ameren. These findings show the benefits of immersive mobile experiential learning. The possibilities of this type of training, especially the ability to immediately access additional visual instructions may prove effective for other field worker tasks.
Worker Health Monitoring Using Augmented Reality Enhances Safety

Research has demonstrated that heat stress is an underlying cause for many workplace accidents and injuries. Heat stress impairs mental function, dexterity, and coordination, physical performance, and productivity. Furthermore, the physical discomfort associated with elevated core temperature promotes irritability, anger, and other emotional states—often causing individuals to overlook safety procedures or become distracted while performing their duties. Additionally, working continuously under heat stress can lead to a decline in health, reduced physical capacity, and increased psychological distress.

New York Power Authority (NYPA) investigated whether or not an augmented reality heads-up display (HUD) could be integrated to an internet of things (IoT) device to monitor a worker’s vital signs (heart rate, breathing rate, etc.) and warn a foreman if one of these measurements exceeds a pre-set limit. Several devices from the health and fitness industry were used for the integration. The most successful device was integrated using Bluetooth to a HUD developed for industrial applications. This combination was used to monitor individuals and warn of high pulse or breathing rates. Ken Anderson, Senior Engineer of Research, Technology Development and Innovation with NYPA, states that “Digital worker technologies have the potential to help NYPA enhance worker safety and well-being.”

Substation Situational Awareness Proactively Improves Worker Safety

A substation is a challenging environment whose complexity is exacerbated by a lack of situational awareness. “Situational awareness” refers to an individual’s understanding of the situation he or she is dealing with and forms the basis for that person’s subsequent decision-making and performance. Communications is another critical factor for working safely inside substations. Inaccurate verbal communications have been found to be a contributing or causal factor in a very large portion of accidents in substations, including those involving switching operations.

Southern Company sought to determine if augmented reality could be used as a situational awareness and communications tool to reduce ambiguity in device status. The initial experiment involved the use of novel scanning and navigation technologies to ensure the hand-held computer with the AR application provided a precise location for the worker. Data was overlaid on a view of reality with the device. The application acted as a light-weight graphical interface to retrieve information and warn of potential hazards. As an example, the application warned the user if flame retardant clothing was required in their location within the substation. Because of the innovative tracking technology, the information could be displayed over the correct substation asset regardless of the orientation of the worker to the asset. Asset health metrics as well as open work orders or lock-out/tag-out situations for the substation were displayed for the asset.
Proliferation of Distributed Energy Resources (DER) such as energy storage, solar, demand response, and electric vehicles have the potential to provide utilities and customers with options for maintaining flexibility and reliability of the grid beyond operation of distribution system equipment. These solutions support use cases such as reducing impacts of intermittency from solar, maintaining grid stability in low-inertia systems, microgrid resiliency, and advanced analytics and resource optimization using Distributed Energy Resource Management Systems (DERMS). EPRI’s research addresses communications issues, specifically the control and monitoring of smart solar, storage, electric vehicles, and loads to enable an architecture that supports a variety of advanced applications in the grid.

RESEARCH FOCUS AREAS

Interoperable Distributed Energy Resources Including Demand Response

Issue:
Maturity in interconnection standards and their adoption in products increase the likelihood that DER, DR, and control systems are fully interoperable out-of-the-box, reducing integration complexity, costs, and time. Grid integration, deployment, and interoperability issues arise that can impact the efficiency and effectiveness of the utility investments and objectives in DER initiatives.

R&D Objective:
Encourage standards adoption by producing tools and collaborating with utilities and third-parties that are creating the utility systems or DER. This includes vendors of software, manufacturers of devices, and other industry stakeholders.

Target Audience:
Utility resources involved in the integration and deployment of DER including program managers, OT staff, system designers, communications/network architects, and IT teams supporting distribution operations.

Research Results:
This project identifies gaps in functionality, security risks, and barriers to interoperability. It produces tools to support validation and researches an approach to accommodate customer-owned technology that may include IoT independent DER systems.

• 2019 Plans:
  o Interoperability and Industry Evaluation of Inverter-based DER and Demand Response Technologies. This project will evaluate the adoption of open protocols and smart functionality in existing DER assets. EPRI will perform lab-based interoperability testing for functional and communication test plans. Results may help avoid costly and time-consuming issues through awareness and encourage vendor solutions.

• 2018 Project Highlights:

Validated Interconnection and Control Architectures for DER/DR

Issue:
As utilities explore methods for integrating DER in the distribution grid, the communications and control architectures must be designed to allow connection regardless of model, manufacturer, or type without significant modification or costs. Research is needed to understand methods for achieving scalability while supporting a range of utility needs to control DER, interfaces to aggregators, and localized control like buildings and microgrids.

R&D Objective:
Identify and fill gaps in protocols and standards related to management systems. Produce DER and DR management system reference designs and device simulations to support development and testing of architectures. Evaluate methods to maximize the utilization and scalability of these resources.

Target Audience:
Utility members involved in the integration and deployment of DER, OT staff, system designers, including solar, storage, and demand response technologies.

Research Results:
This project researches the capabilities needed in standards and DER to be grid ready. This includes evaluating communication architectures and validating these to meet requirements of utility applications.

• 2019 Plans:
  o Assessment of Communications Architecture Requirements for Near-Term Smart Inverter Use Cases. IEEE 1547 includes mandatory communications functionality in smart inverters as a tool to maintain
stability on the grid. As utilities explore deployment of smart inverters they are faced with decisions around the communications systems required to support smart inverter integration for grid stability. EPRI will assess the communications architecture requirements, such as protocol selection, uptime, redundancy and latency to meet near-term use cases.

• 2018 Highlights:
  o EPRI’s DER Integration Toolkit (3002013623): EPRI Tools for Testing and Implementing Open Protocols is a compilation of test tools designed to support the development and testing of control systems including DERMS, DRAS systems and DER assets. In 2018 new tools for IEEE 2030.5, IEEE 1815 (DNP3), IEC-61850, and simulating storage systems on communication networks where added. This can enable digital twins, inclusion of communications constrains in modeling, and protocol testing.

Optimized Practices for Integrating DER/DR Asset Communications

Issue: Protocols and standards regulate how some aspects of the communication architecture are developed. Some case studies exist for end-to-end architectures but approaches for managing the utilization and sharing of DER devices and/or systems of devices among business applications have not been fully explored.

R&D Objective: Research the different metrics that indicate business and technical impacts on the final architecture. Document case studies from utilities, identify key takeaways, best practices and significant barriers that may impact the adoption and long-term effectiveness of DER asset operations.

Research Results: Research different metrics that indicate business/technical impacts on the architecture. Document case studies from utilities and identify key takeaways, i.e. best practices and barriers that may impact the adoption of DER asset operations.

Target Audience: Utility members involved in the integration and deployment of DER, OT staff, system designers, including solar, storage, and demand response technologies.

• 2019 Plans:
  o DER.EPRI.COM Expansion. A repository of information related to DER and DERMS including use-cases, RFP requirements language, and other utility-based information. 2019 will include new analysis tools for viewing the data collected and investigate new information based on industry needs. This may include business justification for communicating with DER, information on currently deployed pilots and demonstrations, interoperability issues, or economic justifications for different communications and control decisions.

• 2018 Highlights:
  o The Economics of Interoperability (3002013624). Utilities are connecting customer-owned devices in increasing numbers to help provide flexibility to manage grids beyond traditional distribution system assets. EPRI found that benefits of interoperable connectivity can be difficult to quantify, because it is an applied technology and must be embedded in devices or systems. The research found that likely opportunities to quantify impacts will be around service quality or customer satisfaction.

Project Set Lead: Ben Ealey, bealey@epri.com

TO JOIN, CONTACT ANY OF THE FOLLOWING TECHNICAL ADVISORS:

West: Christine Hertzog, Senior Technical Advisor, 650.314.8111; chertzog@epri.com
East: Chris Kotting, Technical Advisor, 980.219.0146; ckotting@epri.com, Annette Mosley, Technical Advisor, PDU, 972.556.6507; amosley@epri.com
International: Kevin East, International Director, +44 (1925) 450.207; keast@epri.com

For more information, contact the EPRI Customer Assistance Center at 800.313.3374 or askepri@epri.com

©2019 Electric Power Research Institute (EPRI), Inc. All rights reserved. Electric Power Research Institute, EPRI, and TOGETHER...SHAPING THE FUTURE OF ELECTRICITY are registered service marks of the Electric Power Research Institute.
SUCCESS STORY

Applied Information and Communication Technology for DER and Demand Response (161D)

EPRI’s Protocol Reference Guide Organizes Information for Utility Use Now and In Future Editions

Utilities are exploring how distributed energy resources (DER)—including solar, storage, electric vehicles, and demand responsive loads—can be integrated into the electric grid as key components for maintaining a flexible, integrated grid. Communications capabilities and interoperability between DER are at the heart of many of these use cases because it allows for dynamic control, system analytics, and optimized dispatch —use cases of value to utilities. Utilities interested in deploying DER technologies are presented with a challenge of understanding the landscape of communication protocols that can be used to interact with DER in their territory. Information about what is in the scope of these protocols, where they are used in the overall utility communication architecture, and their maturity are important for utilities to decide next steps. However, the protocols for controlling DER are fairly new to the industry so industry stakeholders are working to expand their knowledge about them. Some like Modbus and IEEE 1815/DNP3 have been around for a long time and are well known. However, the information models that define parameters, setpoints, and monitoring points to be exchanged over the protocols are not. Education will be an important next step for the industry as vendors, utilities, and other stakeholders look to understand the landscape of DER.
EPRI’s Protocol Reference Guide is helpful in communicating and educating the various departments within SRP on the many different attributes of DER protocols. This information helps all stakeholders get on the same page to better define requirements and next steps for DER integration.

Kyle Cormier, Manager Engineering – Control Engineering
Salt River Project

protocols and make informed decisions.

The Protocol Reference Guide (3002013621/2018) is a reference document for stakeholders working with distributed energy resources and demand response technologies who want to learn more about the different options for application-layer protocols. Each protocol is described through a three-page brief containing a concise but informative overview of the protocol to help researchers understand the protocol, maturity, current state, and where it should be used. The briefs are structured to highlight key topics so readers can quickly find the material they need while making it easy to compare protocols. Each brief highlights adoption, governance and maintenance, devices and technologies, implementation, test tools and certification, cyber security requirements, regulatory framework, and relevant EPRI reports and current projects.

The methodology was created with the help of utilities. The team developed a list of common questions that industry stakeholders have about communications protocols and developed a framework to answer them. The Protocol Reference Guide is designed to be updated regularly to add new protocols and capture any changes to protocols already evaluated.

Salt River Project’s Experience
Salt River Project (SRP) is in an excellent location for photovoltaic generation and is seeing increases in the number of connected DER. Technologies like demand response, smart inverters, and storage systems are becoming an important part of their grid to help them manage changes in supply and demand. As SRP is evaluating their next steps, information about the communications protocols they can use to manage these systems is helpful for selecting which protocols they will use and when is the right time to deploy them. This requires communicating this information across the many teams involved within the utility including IT/OT, distribution system planning, customer programs, and others. The Protocol Reference Guides have been helpful in providing a mechanism to quickly convey information to different stakeholders within SRP. Defining this base knowledge makes conversations between the teams more productive because each team can come to the table more educated on the options for managing DER in their territory.
The project set aims to put the best tools and techniques into the hands of enterprise architecture practitioners, with an eye to the unique needs and operating environments of utilities. This research provides utilities with guides for developing architecture, digital transformation, cloud integration strategies, and resources for standards-based enterprise integration.

**RESEARCH FOCUS AREAS**

**Enterprise Architecture (EA) Maturity**

**Issue:** EA as a practice aligns IT structures with business operations. Mature practices help utilities hold down costs, mitigate risks, and increase agility. Enabling enterprise architecture maturity includes the following:

- Integrate operations to move beyond “successful silos”
- Arm utilities with reusable templates, reference models, and architecture patterns
- Promote and develop leading EA practices

**R&D Objective:** Improved Enterprise Architecture

**Target Audience:** Primary: Enterprise, solution, application, and data architects, Secondary: CIOs, Sr. IT Managers

**Research Results:** Identify the resources required to improve EA maturity.

- Plans for 2019
  - **EA Guidebook 3rd Edition** is now updated annually with the latest templates and leading practices.
  - **Common Information Model (CIM) Primer, 5th Edition.** CIM Primer with new CIM use case additions and compliance activities.
  - **Digital Transformation: Aligning IT and Operations.** Transitioning the IT/OT convergence topic to reflect digital transformation needs.

- **Key Past Accomplishments**
  - **2018 Utility Enterprise Architecture Guidebook, 3rd Edition (3002012476).**
  - **Information Technology – Operational Technology Convergence Guidebook: First Edition (3002012479).** Explores the complementary practices of both EA and ITIL and how concepts such as AGILE and LEAN apply to governance.

**Integration Maturity**

**Issue:** Lower the cost/effort of integration.

**R&D Objective:** Understand the architectural issues associated with utilizing cloud-based capabilities.

**Target Audience:** Primary: Enterprise architects, solution architects, application and integration architects, Secondary: CIOs, Sr. IT Managers

**Research Results:** While various parts of CIM are very mature, as new use cases continue to be identified, such as enterprise integration of DER, extensions for OpenFMB, these use cases need to be vetted and contributed into the respective Standards Development Organizations (SDOs). There is also an imperative to develop these use cases in accordance with international standards such as those specified by IEC technical committee TC8 WG5-6.

- **Plans for 2019**
  - **The Cloud Integration Guidebook** is annually updated to add use cases, architecture patterns and utility case studies.

- **Key Past Accomplishments**

- **2018 Deliverables**

**Business Efficiency IT/OT Convergence (Architectural Impacts of Disruptive Technology)**

**Business Capability Impact Assessment**

**Issue:** The pace of technology innovation is increasing and disruptive technologies (competence destroying changes as
opposed to normal life-cycle sustaining innovations) can wreak havoc on the invest-
maintain-retire roadmaps for utility application portfolios. Additionally, the practice of
developing business architecture, business capability models, and performing an impact
assessment are generally not well understood by architecture practitioners.

R&D Objective: Determine the most likely impacted areas of various disruptive technologies.

Target Audience: Sr. managers in both IT and Operations who want to better plan for disruption and
make timely reviews of their applications portfolios and business capabilities.

Research Results: Generalized impact assessment against a generic utility business capability model that
utilities can then compare to their own portfolios to better judge how their roadmaps may
need to be changed to reflect disruptive technology impacts.

Plans for 2019: 

Introductory Whitepaper: As a new research topic for 2019, EPRI will review some
of the recent disruptive technologies such as blockchain, IoT, Augmented Reality, and do
an example impact assessment on a utility business capability model. This will provide a
starting point for utilities own impact assessments of their application portfolios.

Standards and Certification

Need to close the "actionability" gap between standards on paper and referenceable, certifiable
integration. Details regarding Standards and Certification includes supporting the CIM Testing Compliance
Committee and the semantic test harness with a growing body of CIM test cases.

Issue: Implementation of CIM between and across vendors is inconsistent and limits the ability
of CIM to provide interoperability.

R&D Objective: Support the development of a CIM compliance community to advance the use of CIM
standards. Develop test scripts from standards documentation and identify modifications
that are required to make them actionable.

Target Audience: Primary: Enterprise architects, solution architects, integration architects and software
developers, Secondary: CIOs, Sr. IT Managers

Research Results: Closing the actionability gap with development of test scripts and a semantic test harness
that can be used to ensure compliance.

• Plans for 2019
  • CIM Compliance Event: Builds on the successful 2018 compliance workshop and expand it to include 61968-5 Distributed Energy Optimization (DERMS), 61968-6 Maintenance and Construction, 61968-8 Customer Support, and 61968-9 Meter Reading & Control, as well as testing for Outage Data Initiative exchanges.
  • Key Past Accomplishments
    o AWS-based Test Harness to support client/server testing
    o soapUI test case library
    o Test Scripts for compliance for:
      • IEC 61968-5 Distributed Energy Optimization (DERMS)
      • IEC 61968-6 Maintenance and Construction (Work Orders)
      • IEC 61968-9 Meter Reading and Control
      • Utilizing IEC 61968-100 for Application Integration

These test scripts can be used for system acceptance testing or RFPs requirements.

Project Set Lead: Gerald Gray, 865.218.8113, ggray@epri.com

TO JOIN, CONTACT ANY OF THE FOLLOWING TECHNICAL ADVISORS:

West: Christine Hertzog, Senior Technical Advisor, 650.314.8111; chertzog@epri.com
East: Chris Kutting, Technical Advisor, 980.219.0146; ckutting@epri.com,
Annette Mosley, Technical Advisor, PDU, 972.556.6507; amosley@epri.com
International: Kevin East, International Director, +44 (1925) 450.207; keast@epri.com

For more information, contact the EPRI Customer Assistance Center at 800.313.3374 or askepri@epri.com

3002014924

3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813, USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

©2019 Electric Power Research Institute (EPRI), Inc. All rights reserved. Electric Power Research Institute, EPRI, and TOGETHER...SHAPING THE FUTURE OF ELECTRICITY are registered service marks of the Electric Power Research Institute.
SUCCESS STORY

Do standards-based interfaces (SBI) reduce operations and maintenance costs? That was the question that the EPRI Enterprise Architecture Collaboration Group (EACG) sought to address. It seems like SBI should reduce costs. There are a couple of characteristics of Informational SBI that suggest that costs can be reduced, for example, using a common semantic standard such as the Common Information Model (CIM), and using a predefined method for application integration. However, while this notion seems intuitive, a literature review revealed that there was scant information that addressed this topic. References may give the reader information about a standard, or about a particular adapter, but there was no information that could be found that compared using a standard with using other integration means or to find how to quantify integration effort.

Think about how functional requirements are normally developed. A gathering of stakeholders will be organized, and these stakeholders will develop a use case. Included in the use case will be the requirements for information exchange. Instead of determining the data types, relationships, or other attributes of entities such as “customer”, “address”, “meter”, or “transformer”, with a common semantic standard such as the CIM, the group can skip this exercise and simply select the entities that they need, using the predefined...
This framework will provide a meaningful public benefit for architecture practitioners looking for tools to better understand where various integration techniques are cost effective, and help align the thinking of other interoperability efforts, such as the Grid Modernization Laboratory Consortium – Interoperability Project.

Ron Cunningham, Enterprise Architect at American Electric Power (AEP), one of the key contributors to this effort.

CIM attributes. Then they only need to examine these attributes for gaps. This saves a significant amount of time compared to defining this information from scratch.

Development time should also be saved when using a predefined standard for integration. Again, in the absence of a standard, a developer must puzzle out how to integrate two systems together. This includes not just passing the data as described above, but also determining what other constructs must be created to ensure smooth operation or recovery from faults. Additionally, having a consistent naming convention helps teams of developers work together because the naming will indicate the type of operation each interface supports, thus reducing the learning curve. With a predefined standard for integration, the developers need only to learn the integration patterns defined and associated with this method.

As the EACG explored this topic they also compared SBI against other types of integration techniques, such as proprietary point-to-point, or using “adapters”. One challenge the group found was that when a vendor claims that their product “has a database adapter”, this usually meant that the developer was still required to write their own database queries or otherwise do data transformation from one system to another. An additional challenge was the confusing use of terms such as “interoperable”, “adapter”, or “conformance”. To address this issue the EACG also reviewed several references and attempted to resolve the different interpretations and create a taxonomy of relationships between the terms in this domain to work toward a common interpretation.

Finally, because the development norms may vary by organization, the EACG did not seek to be definitive, but rather created a framework so that any utility could compare their own development costs, expectations, and patterns to compare the different integration approaches. A spreadsheet is included as part of the deliverable to facilitate users to make these side-by-side comparisons.
Advanced Metering Infrastructure (161F)

This project set helps optimize existing AMI system utilization and discover the full value of AMI-collected data; accelerates and guides the development of emerging standards and architectures to enhance interoperability, innovation, and marketplace competition; and identifies best practices for the support of system operations and monitoring of systems. Researchers will also investigate solid-state meters with regards to accuracy, reliability, and tamper resistance.

**RESEARCH FOCUS AREAS**

**Open, Interoperable AMI Systems**

**Issue:** The AMI marketplace is occupied by conflicting and proprietary systems and platforms. This reduces feature competition in the marketplace, limits benefits, and requires complex one-of-a-kind integration efforts if multiple suppliers are used.

**R&D Objective:** Standardize data and communications aspects of AMI systems. Helps design, select, integrate and deploy AMI systems based on standards via technical references, performance assessments and evaluation tools.

**Target Audience:** AMI system designers, utility telecom engineers, meter shop personnel

- **Plans for 2019**
  - Implement a sample mapping of DLMS/COSEM objects to IEC 61968-9 Metering and CIM – will describe the current state of metering protocols and how those protocols may be mapped to CIM IEC 61968-9.

**Research Results:** Encourage commercial availability of AMI products that are interoperable and interchangeable. Provide information of current implementations and evaluate gaps in the standards.

- **Key Past Accomplishments**
  - **Wi-SUN Meter Test Tool Software (3002010501).** This software tool works with the open reference implementation of the Wi-SUN radio specification to monitor and interact with Wi-SUN compliant devices using commonly available hardware.
  - **Reference Implementation of Open AMI Endpoints based on IEEE 802.15.4g and Wi- SUN (3002005587)** is the first edition of a reference implementation of the IEEE 802.15.4g/Wi-Sun communication standard. EPRI developed this reference software to provide a vendor-neutral implementation and a baseline for product evaluation.
  - **Opportunities and Hesitations Associated with Open Advanced Metering Infrastructure (3002006917)** examines non-technical considerations in implementing an open AMI system, including responsibility for integration of the system components, required maintenance expertise, and potential economic effects on the industry.

- **2018 Deliverables**
  - **Toward a World Standard Advanced Meter Application Layer Protocol: An Analysis of the Current and Possible Future State of the Industry (3002013398)** outlines the currently used application protocols in AMI and examines what would be required to create a single unified standard.

**Advanced Metering Systems Operation and Management**

**Issue:** Need for a comprehensive collection of AMI best-practices, each being broadly applied by utilities and iteratively improved.

**R&D Objective:** Assess and document utility best practices for AMI system operation and management including performance optimization, health management, end of life and replacement plans, and AMI-related storm recovery/restoration.

**Target Audience:** Utility meter operations, system architects, information technology personnel

- **Plans for 2019**
  - **AMI Summit Meeting** – This conference will bring utilities and vendors together and provide a forum to discuss our shared future.

**Research Results:** Documented best practices for a comprehensive breadth of utility applications.
Advanced Metering Infrastructure (AMI) (161F)

FUTURE STATES
(2018 Roadmap Update)

Open, Interoperable AMI Systems

Established and Proven Best Practices for AMI System O&M

Optimized AMI System Utilization and Value

Key Past Accomplishments

- Guidebook for AMI System Disaster Preparedness and Restoration, First Edition (3002010502) provides best practices for recovery plans for incidents that disrupt AMI system performance. This is part of a series to address all aspects of AMI system operation and management.

- Guidebook for AMI Prognostics and Health Management (3002002861). Understanding the useful remaining service life of AMI systems reduces risk and informs plans. This guidebook describes statistically sound means to determine the health of deployed AMI devices.

2018 Deliverables

- AMI Data Management Guidebook: First Edition (3002013399) documents the best practices for AMI data management. It catalogs current practices for handling, storing, accessing and interfacing AMI data after it has arrived at the head end system.

Optimized AMI System Utilization and Value

Issue: There is a broad and increasing range of AMI data applications that add value to AMI systems, while preserving customer flexibility and options. These applications and uses are not necessarily widely known and understood.

R&D Objective: Enable the full value of AMI systems and data to be realized. Utilities will have a clear understanding of the range of uses and applications that can be effectively supported by their AMI systems and AMI data. Specific guidance on how to employ these uses will be available.

Target Audience: AMI systems engineers, information technology personnel, distribution engineers

Plans for 2019

- Guidebook for AMI Data Analytics will explore the technical approaches to AMI data analytics, use case implementation and organizational strategies (both data and people).

- AMI Data Analytics Survey – The survey will gather data from vendors and operators, including evaluation of what tools exist; how they work and how they compare to each other.

Research Results: A curated collection of documented application use cases and guidance on what system types are suitable for each.

Key Past Accomplishments

- Advanced Metering Infrastructure Resource Center (AMI Status DB), Version 3.0 Software (3002010503). The AMI Resource Center has an AMI RFP language engine containing a hierarchically organized repository of utility AMI RFP language components.

- Preparing Smart Meter and AMI Systems for Solar Integration (3002009731) provides a summary of the features and capabilities that should be considered for AMI systems to prepare for the integration of DER.

2018 Deliverables


TO JOIN, CONTACT ANY OF THE FOLLOWING TECHNICAL ADVISORS:

West: Christine Hertzog, Senior Technical Advisor, 650.314.8111; chertzog@epri.com

East: Chris Kotting, Technical Advisor, 980.219.0146; ckotting@epri.com,

Annette Mosley, Technical Advisor, PDU 972.556.6507 amosley@epri.com

International: Kevin East, International Director, +44 (1925) 450.207; keast@epri.com

For more information, contact the EPRI Customer Assistance Center at 800.313.3374 or askepri@epri.com

©2019 Electric Power Research Institute (EPRI), Inc. All rights reserved. Electric Power Research Institute, EPRI, and TOGETHER…SHAPING THE FUTURE OF ELECTRICITY are registered service marks of the Electric Power Research Institute.
SUCCESS STORY

Advanced Metering Infrastructure (161F)

EPRI Wi-SUN Meter Test Tool Helps Xcel Energy and Ameren Test AMI Systems

The last time you purchased a computer or other device equipped with Wi-Fi™
• Did you conduct a multi-month study with vendor presentations of their proprietary radio frequency (RF) solutions?
• Did you hire an outside expert to assess and evaluate the device’s conformance to the Wi-Fi standard?
• Did you use proprietary software that you obtained under a non-disclosure agreement (NDA) to be able to operate the equipment?
• Did you bring the equipment to an RF lab and analyze the emitted signal of the device with a spectrum analyzer?

Chances are that you answered “no” to all these questions. When we buy a device with the Wi-Fi logo emblazoned on it, we expect that seconds after the device is powered on, it will be able to seamlessly join an existing network made up of equipment from different vendors and that all devices will be compatible.

Currently, this interoperability scenario is an unrealized ideal for the RF mesh devices used in Advanced Metering Infrastructure (AMI) networks. The Wi-SUN Alliance is trying to do for AMI communications what the Wi-Fi Alliance has done for Wi-Fi. Both are based on an underlying IEEE standard: IEEE 802.11 for Wi-Fi and IEEE 802.15.4g for Wi-SUN. EPRI has been helping to drive this effort through multiple projects. One

Project Set Lead: Ed Beroset, eberoset@epri.com
TO JOIN, CONTACT ANY OF THE FOLLOWING TECHNICAL ADVISORS:

West: Christine Hertzog, Senior Technical Advisor, 650.314.8111; chertzog@epri.com

East: Chris Kotting, Technical Advisor, 980.219.0146; ckotting@epri.com
Annette Mosley, Technical Advisor, PDU, 972.556.6507; amosley@epri.com

International: Kevin East, International Director, +44 (1925) 450.207; keast@epri.com

For more information, contact the EPRI Customer Service Center at 800.313.3374 or askepri@epri.com

“EPRI has long been a leader in promoting industry use of standards-based solutions for telecommunications. EPRI’s participation in the Wi-SUN Alliance and the development of the reference implementation of the Wi-SUN stack are two examples of EPRI’S leadership in this area as is the work to educate and lead the industry toward the use of electric meter communication standards that will lead to interchangeable field devices. These efforts in particular will lead to more efficient and cost-effective field systems for years to come. Someday we’ll be able to just plug in AMI communication devices with the same interoperability we enjoy with Wi-Fi today. Until then, the EPRI Wi-SUN Meter Test Tool fills an important function in improving AMI deployments and operations.”

Dan Nordell, Excel Energy

(Left to right) Dan Nordell of Excel Energy, Ed Beroset of EPRI, and Kirby Diller of Ameren

project is to create an open source reference implementation of the Wi-Fi stack—the software needed to drive the radios in a standards-compliant way. The other project is the EPRI Wi-SUN Meter Test Tool as shown on the previous page. It allows users to test other equipment and potentially diagnose communications problems by providing both software and detailed instructions for building your own low-cost (under $200) tool.

In early August 2018, Kirby Diller of Ameren, Dan Nordell of Xcel Energy and Ed Beroset of EPRI all met in Diller’s lab in Illinois as shown in the photo above. They successfully demonstrated two test tools communicating with each other and plan to meet again to try the tool against commercially available products. With the tool, both Diller and Nordell hope to learn more about what the various meter vendors have implemented and how one might troubleshoot potential communications problems. Information gained from this experience will also lead to improvements and enhancements in the Wi-SUN Meter Test Tool, which is also entirely open source software.
This research provides utilities with the tools and methods to plan scalable, multi-service communication networks for current and future needs. It identifies best practices for fiber deployment in Wide Area Networks (WANs), including teleprotection on packet networks; examines the optimal wireless technologies and spectrum types for Field Area Networks (FANs); assesses the best roles for commercial wireless and shared networks and the evolution to 5G networks; and recommends best practices for network management, visualization, and planning.

**RESEARCH FOCUS AREAS**

**Wide Area Networks:** Controlled-Latency Packet Networks, time synchronization, and fiber network operational priorities. Applications of Software Defined Networking (SDN).

**Field Area Networks:** Design and evaluation of reliability, resiliency, and capacity. Understanding performance and prioritization requirements in multi-service networks. Optimized operation in licensed or unlicensed spectrum.

**Systems and Management:** Network management, metrics, and network visualization. Optimizing the Telecom Planning process to improve resiliency.

**Communications Standards:** Enabling interoperability through standards development and guidance.

### Issue:
Utilities need to develop strategic telecommunications assets, to maintain current functions and support future network requirements:
- Reliable, resilient, flexible, and secure telecom networks to support advanced grids
- Tools to manage complex, mission-critical telecom networks
- Migration path from today’s networks and legacy equipment to future telecom networks
- Interoperable communication systems, through development and deployment of standards

### R&D Objective:
Development of telecommunication strategic architecture and roadmap for utilities.

### Target Audience:

### Research Results From Project Set 161G in 2018
- **Managing Timing and Latency in Packet WANs (3002013385).** Introduces the concept of Time Sensitive Networking (TSN) for low, bounded latency on packet networks. Includes insights to apply improved Precision Time Protocol (PTP) as a fiber backup for GPS.
- **Strategic Fiber in the WAN: Exploration of Synergistic Fiber Network Deployment for Utility Smart Grid/DA and 5G Mobile Network Operators (3002013389).** Researches expanded fiber deployment in distribution grids, based on leveraging and partnering with commercial wireless carriers.
- **FAN Technology Performance Evaluation (3002013393).** Provides results of the FAN Testing platform for assessment of network performance in peer-to-peer applications, and applying Quality of Service parameters for relative prioritization on multi-services FANs. Test results include a 700 MHz Upper A Block FAN technology and a Private Long Term Evolution (LTE) pilot.
- **Integration of GIS Visualization in Telecom Network Management (3002013394).** Building on the prior reports 3002009800 and 3002009803, documents the geographical capabilities of Network Management Systems (NMS) and gaps with NMS functionality, and considers the application of model management to telecom.
- **Zero-Touch Provisioning White Paper (3002013395).** Discusses the end goal of a “zero touch” provisioning process where devices are installed without manual configuration.
- **Evaluation of Software Defined Networking (SDN) in Utility Operational Networks (3002013403).** Examines the current state of SDN and its potential for the OT network and the WAN. Joint project with Cyber Security.
FUTURE STATES
(2018 Roadmap Update)

Interoperable and Reliable Field Area Networks
Optimal Use of Available Spectrum
Wide Area Networks Use Packet-Based Technology
Expansion of Fiber Backbone
Fully Integrated Network Management Systems
Interoperability of Telecommunications Systems Through Standards

Research Results From the Telecom Initiative

<table>
<thead>
<tr>
<th>Track</th>
<th>Product ID</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial to Packet</td>
<td>3002009783</td>
<td>Protection over MPLS Workshop, Test Plan, Results</td>
</tr>
<tr>
<td>Serial to Packet</td>
<td>3002009784</td>
<td>Serial/TDM replacement</td>
</tr>
<tr>
<td>Serial to Packet</td>
<td>3002009785</td>
<td>Leased circuit requirements for protection</td>
</tr>
<tr>
<td>Private Wireless</td>
<td>3002009786</td>
<td>Wireless Taxonomy and Architecture</td>
</tr>
<tr>
<td>Private Wireless</td>
<td>3002009787</td>
<td>Unlicensed Noise Floor Study</td>
</tr>
<tr>
<td>Private Wireless</td>
<td>3002009788</td>
<td>Private LTE – Options and Opportunities</td>
</tr>
<tr>
<td>Private Wireless</td>
<td>3002011195</td>
<td>IEEE 802.16S Overview (white paper)</td>
</tr>
<tr>
<td>Public Wireless</td>
<td>3002009790</td>
<td>Testing QoS on Commercial Cellular</td>
</tr>
<tr>
<td>Public Wireless</td>
<td>3002009791</td>
<td>Low Power WAN Technologies</td>
</tr>
<tr>
<td>Public Wireless</td>
<td>3002009792</td>
<td>Public Networking and Shared Networks – Architecture &amp; Operation</td>
</tr>
<tr>
<td>Strategic Fiber</td>
<td>3002009793</td>
<td>Strategic Fiber Handbook Phase 1</td>
</tr>
<tr>
<td>Strategic Fiber</td>
<td>3002009797</td>
<td>Strategic Fiber Handbook Phase 2 – Innovative Business Models Case Studies</td>
</tr>
<tr>
<td>Grid Edge Connectivity</td>
<td>3002009798</td>
<td>Persistent Secure Wi-Fi Connectivity at Grid Edge (WiFiAT): Overview and Operation</td>
</tr>
<tr>
<td>Grid Edge Connectivity</td>
<td>3002009799</td>
<td>Pilot Testing Results, next phase continuation and collaboration plan</td>
</tr>
<tr>
<td>Network Management &amp; Planning</td>
<td>3002009800</td>
<td>Manager of Manager Survey Results</td>
</tr>
<tr>
<td>Network Management &amp; Planning</td>
<td>3002009802</td>
<td>Software defined networking (SDN) Standards and Applications</td>
</tr>
<tr>
<td>Network Management &amp; Planning</td>
<td>3002009803</td>
<td>Creating Telecommunication Metrics for the Electric Sector</td>
</tr>
<tr>
<td>Network Management &amp; Planning</td>
<td>3002009805</td>
<td>Roadmap and Framework for Telecom Planning</td>
</tr>
</tbody>
</table>

Next Steps:
• In 2019, Project Set 161G will continue working in strategic telecommunications in four tracks: WAN, FAN, and Management and Systems.
  o The WAN track will continue work on applications and best practices for packet WANs, data isolation requirements for NERC-CIP, and develop an update to the strategic fiber handbook.
  o The FAN track will define the communications network requirements for DER applications, expand the performance evaluation of FAN technologies, and document best practices for design and deployment of Private LTE.
  o The Management and Planning track will evaluate telecom planning approaches for achieving redundancy and resilience, including “islanding” of telecom while maintaining functionality through distributed intelligence and field message bus, and continue development of the telecom planning framework and co-simulation platform.
  o The Communications Standards track will release two Comms Intelligencer newsletters and develop the first edition of the Communications Standards Guidebook to put the standards landscape in context.

Project Set Lead: Tim Godfrey, 650.855.8584, tgodfrey@epri.com

TO JOIN, CONTACT ANY OF THE FOLLOWING TECHNICAL ADVISORS:

West: Christine Hertzog, Senior Technical Advisor, 650.314.8111; chertzog@epri.com
East: Chris Katting, Technical Advisor, 980.219.0146; ckatting@epri.com, Annette Mosley, Technical Advisor, PDU, 972.556.6507; amosley@epri.com
International: Kevin East, International Director, +44 (1925) 450.207; keast@epri.com

For more information, contact the EPRI Customer Assistance Center at 800.313.3374 or askepri@epri.com
EPRI Research Helps Ameren with Private LTE Field Area Network

Ameren used results from the EPRI Field Area Network (FAN) Demo, the Assessment of Licensed Spectrum, the Telecom Initiative and Project Set 161G to plan, develop, and deploy a private LTE network pilot. The pilot outcomes would shape final plan/build/run plans. EPRI research identifies the importance of the FAN as a multi-services network instead of unsustainable single-purpose networks. The results provided insights into the use cases for field area networks, requirements, architecture options, technology choices, and options for acquiring spectrum. Ameren examined available FAN technologies, and after careful evaluation, selected private LTE as their optimal choice.

The private LTE FAN will provide Ameren with a wireless network supporting multiple applications like distribution automation, SCADA, DER integration (required communications for smart inverters), and AMI Backhaul. It will provide the bandwidth and scalable capacity to support increases in the number of communicating devices on the FAN. Leveraging equipment used by commercial cellular carriers provides benefits in cost and improved availability of devices. Compared to subscribing to commercial cellular carriers, a private LTE network offers benefits in terms of operational cost reduction, better control of performance, availability, reliability, and cyber security.

Project Set Lead: Tim Godfrey, tgodfrey@epri.com
EPRI participated with Ameren in the initial network deployment validation. The FAN testing platform developed in the Telecom Initiative and Project Set 161G was used to test and validate the LTE FAN performance at one of the first pilot sites. The testing platform provided data that verified performance support for Quality of Service, and enabled Ameren to identify and correct configuration issues.

Ameren’s Private LTE FAN is an example of the application of EPRI results in the design, development, and deployment of a multi-services FAN that will serve critical grid applications and provide a scalable network that will carry Ameren to the future Integrated Grid.

“EPRI’s in-depth research helped us not only to make a decision to pursue private LTE, but during our pilot provided above and beyond support for doing unbiased bandwidth and latency testing that was critical for us to understand.”

Emerging Technologies and Technology Transfer 161A

2018
- Mounting Importance of Communications to Monitor and Control Distributed Energy Resources, 3002013480
- Leading Practices for Transmission Network Management, 3002014082
- Lightweight Messaging Technologies for the Energy Internet of Things: An Introduction, 3002013478
- Smart Grid Communications Intelligencer - Issue 20, Winter/Spring 2018, 3002012471

2017
- Smart Grid Communications Intelligencer, Summer 2018, 3002012472
- Smart Grid Communications Intelligencer, Fall 2018, 3002012473
- Summary of Interoperability Tracking and Reporting by the Information and Communication Technology Program in 2018, 3002013481

2016
- Artificial Intelligence: Concepts for Electric Power, 3002010236
- Basics of the Internet of Things: What is it, Who’s Involved, and EPRI’s, Research?, 3002010235
- Summary of Interoperability Tracking and Reporting by the Information and Communication Technology Program in 2017, 3002010237
- Smart Grid Communications Intelligencer: Fall 2017, 3002010452
- Smart Grid Communications Intelligencer: Issue 18, Spring-Summer 2017, 3002010453
- Smart Grid Communications Intelligencer: Winter 2017, 3002009755

2015
- Evaluation of TV White Space for Utility Communications Networks, 3002007255
- Interoperability Tracking & Analysis Summary, 3002007841
- Precision Time Technology Overview, 3002007843
- The Value of Direct Access to Connected Devices, 3002007825
- Smart Grid Communications Intelligencer: Issue 14, Winter 2016, 3002007445
- Smart Grid Communications Intelligencer: Issue 15, Spring/Summer 2016, 3002007446
- Smart Grid Communications Intelligencer: Issue 16, Fall 2016, 3002007447

2014
- Information and Communication Technology (ICT) Interoperability Newsletter, June 2015, 3002005579
- Information and Communication Technology (ICT) Interoperability Newsletter, November 2015, 3002005580
- Opportunities and Hesitations with open AMI White Paper, 3002006917
- Smart Grid Communications Intelligencer: Issue 11, Winter 2015, 3002005094
- Smart Grid Communications Intelligencer: Fall 2015, 3002005096
- Smart Grid Communications Intelligencer: Spring 2015, 3002005095

ICT for Transmission 161B

2018
- IEC 61850 Working Group Activity: 2018 Summary, 3002012589
- Remote Device Management Assessment, 3002012588
- Substation Data Mapping: Initial Assessment, 3002012587
- Substation Data Management: An Initial Assessment, 3002012586

2017
- Assessment of Asset Monitors to IEC 61850-90-3: Circuit Breakers, 3002009872
- IEC 61850 Working Group Activity: 2017 Summary, 3002009873
- Integration of Internal and External Data for Informed Decisions: 2017 Update, 3002009871
- Synchrophasor Communication Assessment: Advanced Synchrophasor Protocol, 3002009870

2016
- Integration of Internal and External Data Sources for Informed Decisions: Data Simulation, 3002007475
- Synchrophasor Data Management Assessment: Status Report, 3002007473
- Utility Precision Time Methods: Current State, 3002007474

2015
- Electric Utility Guidebook on Integration of Internal and External Data Sources: Industry Risks, Technical Challenges, and Data Integration Methodologies, 3002005118
- Guidebook on Synchrophasor Communications, 3002005116
- Guidebook on Synchrophasor Data Management: Current State Update, 3002005117
- Electric Utility Guidebook on Using IEC Standards for Asset Health Data Management: Harmonizing Common Information Model (CIM) and IEC 61850 Asset Health Data Models, 3002005119

ICT for Distribution 161C

2018
- Evaluation and Demonstration Machine Learning for Asset Recognition: Utility Feature Extraction Using Terrestrial Photogrammetry, 3002013113
- A Guidebook to Centralized, Hierarchical, and Local Autonomous Intelligence for Distribution Systems, 3002013416

2017
- Detection and Geolocation of Power Distribution Infrastructure Using Public Domain Photographic Imagery, 3002011490
- A Guidebook to Centralized, Distributed, and Decentralized Intelligence, 3002010511
- GIS Leading Practices Guidebook – Data Cleanup Methods with Cost-benefit Analysis Guidance, 3002010509
- Line Impedance Evaluation and Calculation for Underground Mesh Networks, 3002010510
- Redesign of Common Information Model (CIM) Unified Modeling Language (UML) and Normative Message Profiles (XSDs) for IEC 61968 Part 3 Outage Management System (OMS) Messages, 3002010513
- Redesign of Common Information Model (CIM) Unified Modeling Language (UML) and Normative Message Profiles (XSDs) for the International Electrotechnical Commission (IEC) 61968 Part 3 Fault Location, Isolation, and Service Restoration (FLISR) Messages, 3002010512
- Storm Damage Assessment: Using Augmented and Mixed Reality, 3002011041
- A Quantitative Evaluation of Camera Resolution on Automatic Power Pole Location Algorithms, 3002011696
Information and Communication Technology (ICT) Program (161) Deliverables

2015

2016 European CIMug Meeting Summary, 3002009491

Connected Workforce Technology and Sensor Survey, 3002007925

Electric Utility Guidebook for Geographic Information Systems Data Quality: Metadata, 3002007921

Program on Technology Innovation: Redesign of CIM UML and XSDs for IEC 61968 Part 3 FISUR Messages, 3002007927

Geospatial Information System Data Cleanup: Building Out of Distribution Secondary Models, 3002007922

Innovations in GIS Technology: A 2016 ESRI User Conference Summary, 3002009490

Program on Technology Innovation: Redesign of CIM UML and XSDs for IEC 61968 Part 3 OMS Messages, 3002007926

Visualization Techniques for Distribution System Data, 3002007920

2018

Common Information Model Primer: Third Edition, 3002006001

Common Information Model (CIM) 2014 Update, 3002006002

Development of Outage Management Status Messages and Test Plan for Phase 1: Red Button, 3002006384

Electric Utility Guidebook for GIS Data Quality: Conflation, 3002006006


Telecommunications Solutions for a Distribution Network: A Hydro-Québec Case Study, 3002006577

ICT for Distributed Energy Resources 161D

2018

Assessment of Interoperability Achieved through IEEE Std 1547-2018 and IEEE P1547.1: Results from EPRI Interoperability Testing and Market Research, 3002013473

Assessment of Integrated Energy Technologies Research: Flexible Loads, Distributed Solar, Energy Storage, and Electric Vehicles, 3002012960

Consumer Devices Functional Specification for Photovoltaic Support, 3002013875

Common Information Model (CIM) Compliance Testing: November 2018 Summary of Results, 3002014800

EPRI’s Distributed Energy Resources Integration Toolkit: An Overview of EPRI Tools for Testing and Implementing Open Protocols, 3002013623

DERMS RFP Repository – epri.der.com (Joint deliverable P161D,P174,P161E)

Part of the ITC Security Architecture for DER SPNs, 3002012049

EPRI IEEE 2030.5 Client User’s Manual, 3002014087

Grid Integration with High PV Penetration: DERMS Decomposition, Control Architectures, Smart Inverter Functions, and Inertial Force of Power Grid, 3002013112

Grid Integration with High PV Penetration: Smart Inverter Standards and Uses, Coordination with Voltage Regulation Resources, and Operation in Low Inertia Power Systems, 3002014260

IEC 61850 Protocol Driver Agents: Open Source Software to Support Testing and Development of IEC-61850 in Smart Inverters, 3002013625

Integration of DER Technologies: Preliminary Test Results, 3002013484

Overview of EPRI’s DER Simulation Tool for Emulating Smart Solar Inverters and Energy Storage Systems on Communication Networks: An Overview of EPRI’s Distributed, 3002013622

Protocol Reference Guide: Understanding the Characteristics of Communications with Distributed Energy Resources, 3002013621

The Economics of Customer and Grid Connectivity and Grid Interoperability: Evaluation of the Potential Impacts of Interoperability in Utility Economic Analyses and Program Design, 3002013624

2017

Applying Standards-Based Demand Response to Support Solar Integration, A Summary of EPRI Testing at the National Renewable Energy Laboratory (NREL), 3002009841

Common Information Model Compliance Testing for Distributed Energy Resource Group Management: October 2017 Summary of Results, 3002011233

CTA-2045 UCM C++ Library (LIBCEA2045 – OPEN), Version 1.0, 3002009782


DER Grouping Dependencies and the Concept of Operations, 3002009857

Distributed Energy Resource Management System (DERMS) Master Station User Manual, 3002011482

EPRI’s Communication Protocol Reference Guide, 3002009850

EPRI’s DER Integration Toolkit: An Overview of EPRI Tools for Testing and Implementing Open Protocols, 3002009853


OpenADR 2.0 Open Source Virtual Top Node (VTN) User’s Manual, 3002011483

OpenADR 2.0b Open Source Virtual Top Node (OADR2.0b VTN) Version 0.9.7.0, 3002007431

Overview of EPRI’s Simulation Tool for Emulating Smart Water Heaters on Communication Networks: An Introduction to EPRI’s Smart Water Heater Simulator, 3002009852

Performance Test Results: CTA-2045 Water Heater: Testing Conducted at the National Renewable Energy Laboratory, 3002011760

Performance Test Results: CTA-2045 Electric Vehicle Supply Equipment Testing Conducted at the National Renewable Energy Laboratory, 3002011757

Performance Test Results: CTA-2045 Variable Speed Pool Pumps: Testing Conducted at the National Renewable Energy Laboratory, 3002011749

Performance Test Results: CTA-2045 HVAC Thermostat - Testing Conducted at the National Renewable Energy Laboratory, 3002011747

Performance Test Results: CTA-2045 Solar Inverter - Testing Conducted at the National Renewable Energy Laboratory, 3002011748

Simulation Tool for Emulating Smart Inverters on Communication Networks, 3002009851

Summary of Interoperability and Functionality Testing of SunSpec Inverters, 3002009854

2016

Common Functions for DER Group Management, Third Edition, 3002008215

Guidebook for Revenue Protection with AMI, 3002008943

IEC 61850 Working Group Activity 2016 Summary, 3002007477

Matching DER Application Requirements with Communications Performance, 3002007923

OpenADR 2.0b Virtual End Node C++ Library (OADR2.0b VEN) v0.7.0, 3002007432

Smart Inverter Testing Summary 2016, 3002009462

Telecommunications Solutions for a Distribution Network: A Duke Energy Case Study, 3002007924
### Information and Communication Technology (ICT) Program (161) Deliverables

**2015**
- Communications Challenges and Opportunities Associated With the Integration of DER, 3002005756
- Using Customer Internet Access to Manage Smart Meters and Other Demand Responsive Devices Connected to the Low-Voltage Grid: Connecting Demand Responsive Loads and Distributed Energy Resources on a Common Network, 3002005755

### Enterprise Architecture and Systems Integration 161E

**2018**
- Common Information Model (CIM) Compliance Testing: 2017 Activities, 3002013705
- Managing Integrated Distributed Energy Resources Programs: Communications, Cyber Security, and Architecture, 3002014321
- Measuring Business Performance Using Enterprise Architecture Metrics, cross-mapped to EACG SPN, 3002012483
- Procedings of Information and Communication Technology Security Architecture for Distributed Energy Resources Launch Meeting: Champaign, Illinois, December 2017, 3002013985
- Top Ten Indicators of EA Maturity, 2017 results, cross-mapped to EACG SPN, 3002012482
- What Utility Enterprise Architects (Should) Do, cross-mapped to EACG SPN, 3002012481

**2017**
- CIM Identities Web Services, Version 1.0, 3002011464
- CIM Identities Data Entry, Version 1.0, 3002009989
- Cloud Integration Guidebook, 2nd Edition, 3002009978
- Enterprise Architecture (EA) and Information Technology Infrastructure Library (ITIL): Aligning Governance, 3002009976
- Enterprise Architecture Practices for Utilities in Project Context, 3002009977
- EPRI Enterprise Architecture Workshop Summary: Review of Integration Costs and Architectures Project, 3002009986
- IEC 61850: More Than Meets the Eye, 3002012056
- Information Technology (IT)/Operational Technology: Cost-Benefit, 3002009979
- Point-to-Point Standards Integration Cost Framework, 3002009981
- Utility Business Architecture Service Repository, 3002011054

**2016**
- Utility Business Capability Archetype and Impact Analysis, 3002009987
- A Call to Action: Certification Testing for the Common Information Model, 3002007412
- Application Portfolio Assessment for Business Efficiency, 3002007877
- Enterprise Architecture Extension – Use Case Importer, 3002007875
- Service Oriented Architecture – Versioning and Maintenance, 3002007876
- Top Ten Indicators of Enterprise Architecture (EA) Maturity, 3002007400

**2015**
- Information Technology/Operations Technology Convergence Guidebook, 3002005249
- Business Architecture – Phase I, 3002005248

### Advanced Metering Systems 161F

**2018**

**2017**
- Advanced Metering Infrastructure Resource Center (AMI Status DB), Version 3.0, 3002010503
- Computer Modeling of AMI System Fast Data Use Cases, 3002011489 (2017/161F)
- Guidebook for AMI System Disaster Preparedness and Restoration, First Edition, 3002010502
- Home Area Network Issues and Architectural Alternatives, 3002011488
- Preparing Smart Meter and AMI Systems for Solar Integration, 3002009731
- Wi-SUN Meter Test Tool, 3002010501

**2016**
- Advanced Metering Infrastructure Resource Center (AMI Status DB), Version 2.0, 3002008944
- AMI Meter Reference Design and Evaluation Tool, 3002008942

**2015**
- Advanced Metering Infrastructure Requirements for Future-Proof Deployments, 3002006738
- Advanced Metering Systems Online Database (AMI Status DB), Version 1.1, 3002005472
- Guidebook for Advanced Metering Infrastructure Prognostics and Health Management, Second Edition, 3002005471
- Reference Implementation of Open AMI Endpoints Based on IEEE 802.15.4g and Wi-SUN, 3002005587

### Telecommunications 161G

**2018**
- Black Sky Communications Evaluation, 3002013919
- Evaluation and Development of Narrowband Internet of Things for Private Utility Networks: Scoping Study, 3002016415
- Evaluation of SDN in Utility Operational Networks, 3002013403
- FAN Technology Performance Evaluation, 3002013393
Managing Timing and Latency in Packet Wide Area Networks: Time-Sensitive Networking Technology Briefing and Standards Update, 3002013385
Optimizing Wireless Spectrum: Operation and Coexistence in Sub-1GHz Unlicensed Spectrum, 3002013392
Strategic Fiber in the WAN Exploration of Synergistic Fiber Network Deployment for Utility Smart Grid/DA and 5G Mobile Network Operators, 3002013389
Optimizing Wireless Spectrum: Operation and Coexistence in Sub-1GHz Unlicensed Spectrum, 3002013392
The Role of Geospatial Information Systems in Utility Telecommunication Infrastructure Management, 3002013394
Zero Touch Provisioning White Paper, 3002013395

Telecommunications Initiative
2017
A Case Study of the Quality of Service Feature from Commercial Cellular Carriers: The Impact of Quality of Service on Bandwidth, Connectivity, and Reliability Improvements at Ameren, 3002009790
Creating Telecommunication Metrics for the Electric Sector, 3002009803
Communications & Connectivity Technology Newsletter, July, 3002011575
Communications & Connectivity Technology Newsletter, December 2017, 3002011576
Framework for Migrating Telecom Services to Software Defined Networking, and Network FunctionVirtualization, 3002009802
IEEE 802.16S Overview, 3002011195
Leased Circuit Requirements Summary for Protective Relaying, 3002009785
Low Power WAN Technologies, 3002009791
Persistent Secure Wi-Fi Connectivity at Grid Edge: Overview and Operation, 3002009798
Private LTE – Option and Opportunities, 3002009788
Public Networking and Shared Networks: Architecture and Operation, 3002009792
Roadmap and Framework for Telecom Planning, 3002009805
Strategic Fiber Handbook – Phase 1, 3002009793
Strategic Fiber Handbook – Phase 2: Innovative Models Case Study, 3002009797

Serial/Time Division Multiplexing (TDM) Replacement: Technology Options for Packet-Based Replacement of TDM Circuits, 3002009784
Serial to Packet Protection Workshop: Test Results, 3002009783
Unlicensed Noise Floor Study, 3002009787
Utility Telecom Taxonomy and Architecture for Field Area Networks, 3002009786
Wi-Fi Connectivity: Testing Results, Next Phase Continuation and Collaboration Plan, 3002009799

TO JOIN, CONTACT ANY OF THE FOLLOWING TECHNICAL ADVISORS:
West: Christine Hertzog, Senior Technical Advisor, 650.314.8111; chertzog@epri.com
East: Chris Kotting, Technical Advisor, 980.219.0146; ckotting@epri.com
Annette Mosley, Technical Advisor PDU, 972.556.6507; AMosley@epri.com
International: Kevin East, International Director, +44 (1925) 450.207; keast@epri.com
For more information, contact the EPRI Customer Assistance Center at 800.313.3374 or askepri@epri.com

3002015252
January 2019

©2019 Electric Power Research Institute [EPRI], Inc. All rights reserved. Electric Power Research Institute, EPRI, and TOGETHER...SHAPING THE FUTURE OF ELECTRICITY are registered service marks of the Electric Power Research Institute.
Advanced Technologies

Artificial Intelligence: Concepts for Electric Power, 3002010236 (2017/161C)
Line Impedance Evaluation and Calculation for Underground Mesh Networks, 3002010510 (2017/161C)
A Quantitative Evaluation of Camera Resolution on Automatic Power Pole Location Algorithms, 3002011696 (2017/161C)
Detection and GeoLocation of Power Distribution Infrastructure Using Public Domain Photographic Imagery, 3002011490 (2017/161C)
Basics of the Internet of Things: What is it, Who’s Involved, and EPRI’s Research?, 3002010235 (2017/161E)

AMI Applications

Use of Smart Meter and SCADA Data to Predict Phase Connections and More, 3002013761 (2018/161C)
Computer Modeling of AMI System Fast Data Use Cases, 3002011489 (2017/161F)
Home Area Network Issues and Architectural Alternatives, 3002011488 (2017/161F)
Preparing Smart Meter and AMI Systems for Solar Integration, 3002009731 (2017/161F)
Advanced Metering Infrastructure Resource Center (AMI Status DB), Version 3.0, 3002010503 (2017/161F)
Advanced Metering Infrastructure Resource Center (AMI Status DB), Version 2.0, 3002008944 (2016/161F)
Advanced Metering Systems Online Database (AMI Status DB), Version 1.1, 3002005472 (2015/161F)

AMI Data Management


AMI Interoperability

Wi-SUN Meter Test Tool, 3002010501 (2017/161F)
AMI Meter Reference Design and Evaluation Tool, 3002008942 (2016/161F)
Reference Implementation of Open AMI Endpoints Based on an IEEE 802.15.4g and Wi-SUN, 3002005587 (2015/161F)
Advanced Metering Infrastructure Requirements for Future-Proof Deployments, 3002006738 (2015/161F)

AMI Operations & Maintenance

Guidebook for Revenue Protection with AMI, 3002008943 (2016/161D)

Augmented Reality

Storm Damage Assessment: Using Augmented and Mixed Reality, 3002011041 (2017/161C)

CTA-2045 Modular Interface

Performance Test Results: CTA-2045 Water Heater: Testing Conducted at the National Renewable Energy Laboratory, 3002011760 (2017/161F)
Performance Test Results: CTA-2045 Electric Vehicle Supply Equipment—Testing Conducted at the National Renewable Energy Laboratory, 3002011757 (2017/161F)
Performance Test Results: CTA-2045 Variable Speed Pool Pumps: Testing Conducted at the National Renewable Energy Laboratory, 3002011749 (2017/161F)
Performance Test Results: CTA-2045 HVAC Thermostat: Testing Conducted at the National Renewable Energy Laboratory, 3002011747 (2017/161F)
Performance Test Results: CTA-2045 Solar Inverter: Testing Conducted at the National Renewable Energy Laboratory, 3002011748 (2017/161F)
CTA-2045 UCM C++ Library (LIBCEA2045 — OPEN), Version 1.0, 3002009782 (2017/161D)

Common Information Model

Common Information Model (CIM) Compliance Testing: November 2018 Summary of Results, 3002014800 (2018/161D)
CIM Identities Web Services, Version 1.0, 3002011464 (2017/161D)
Common Information Model Compliance Testing for Distributed Energy Resource Group Management: October 2017 Summary of Results, 3002012331 (2017/161D)
CIM Identities Data Entry, Version 1.0, 3002009989 (2017/161E)
Redesign of Common Information Model (CIM) Unified Modeling Language (UML) and Normative Message Profiles (XSDs) for IEC 61968 Part 3 Outage Management System (OMS) Messages, 3002010513 (2017/161C)
2016 European CIMug Meeting Summary, 3002009491 (2016/161C)
A Call to Action: Certification Testing for the Common Information Model, 3002007412 (2016/161E)
Common Information Model (CIM) 2014 Update, 3002006002 (2015/161C)

Connected Workforce

Connected Workforce Technology and Sensor Survey, 3002007925 (2016/161C)

Device Management

Remote Device Management Assessment, 3002012588 (2018/1618)

Distributed Energy Resources (DER) Integration

Overview of EPRI’s DER Simulation Tool for Emulating Smart Solar Inverters and Energy Storage Systems on Communication Networks: An Overview of EPRI’s Distributed, 3002013622 (2018/161D)
Information and Communication Technology (ICT) Program (161) Deliverables

- Mounting Importance of Communications to Monitor and Control Distributed Energy Resources, 3002013480 (2018/161A)
- Applying Standards-Based Demand Response to Support Solar Integration: A Summary of EPRI Testing at the National Renewable Energy Laboratory (NREL), 3002009849 (2017/161D)
- Simulation Tool for Emulating Smart Inverters on Communication Networks, 3002009851 (2017/161D)
- Overview of EPRI’s Simulation Tool for Emulating Smart Water Heaters on Communication Networks: An Introduction to EPRI’s Smart Water Heater Simulator, 3002009852 (2017/161D)
- Summary of Interoperability and Functionality Testing of SunSpec Inverters, 3002009854 (2017/161D)
- DER Grouping Dependencies and the Concept of Operations, 3002009857 (2017/161D)
- Program on Technology Innovation: Test Script for International Electrotechnical Commission 61968-5 Messages, 3002009863 (2017/161E)
- Grid Integration with High PV Penetration: Smart Inverter and DERMS Suit, 3002012155 (2017/Wakefield)
- Grid Integration with High PV Penetration: Approaches for the Japanese Situation, 3002010000 (2017/Wakefield)
- Smart Inverter Testing Summary 2016, 3002009462 (2016/161D)
- Matching DER Application Requirements with Communications Performance, 3002007923 (2016/161D)
- Communications Challenges and Opportunities Associated With the Integration of DER, 3002005756 (2015/161D)

Distributed Energy Resources (DER) Standards

- Program on Technology Innovation: Test Script for International Electrotechnical Commission 61968-5 Messages, 3002009863 (2017/161E)
- OpenADR 2.0b Open Source Virtual Top Node (OADR2.0b VTN) Version 0.9.7.0, 3002007431 (2017/161D)
- OpenADR 2.0b Virtual End Node C++ Library (OADRUB), v0.7.0, 3002007432 (2016/161D)

Distributed Intelligence

- A Guidebook to Centralized, Distributed, and Decentralized Intelligence, 30020010511 (2017/161C)

Enterprise Architecture / Systems Integration

- Enterprise Architecture (EA) and Information Technology Infrastructure Library (ITIL): Aligning Governance, 3002009976 (2018/161E)

- Point-to-Point Standards Integration Cost Framework, 3002009981 (2017/161E)
- Enterprise Architecture Extension – Use Case Impactor, 3002007875 (2016/161E)
- Application Portfolio Assessment for Business Efficiency, 3002007877 (2016/161E)
- Service Oriented Architecture – Versioning and Maintenance, 3002007876 (2016/161E)
- Top Ten Indicators of Enterprise Architecture (EA) Maturity, 3002007400 (2016/161E)

Geospatial Information System (GIS) Data

- GIS Leading Practices Guidebook – Data Cleanup Methods with Cost-benefit Analysis Guidance, 3002010509 (2017/161C)
- Geospatial Information System Data Cleanup: Building Out of Distribution Secondary Models, 3002007922 (2016/161C)
- Electric Utility Guidebook for GIS Data Quality: Conflation, 3002006006 (2015/161C)

IEC 61850

- IEC 61850: More Than Meets the Eye, 3002012556 (2017/161E)
- IEC 61850 Working Group Activity 2016 Summary, 3002007477 (2016/161D)
- 2016 Interoperability Assessment of IEC 61850 Transformer Monitors, 3002007476 (2016/161B)
- Information Technology/Operational Technology Convergence, 3002005772 (2015/161E)

Internal/External Data Integration

- Integration of Internal and External Data for Informed Decisions: 2017 Update, 3002009971 (2017/161B)
Information and Communication Technology (ICT) Program (161) Deliverables

Integration of Internal and External Data Sources for Informed Decisions: Data Simulation, 3002007475 (2016/161B)
Electric Utility Guidebook on Integration of Internal and External Data Sources: Industry Risks, Technical Challenges, and Data Integration Methodologies, 3002005118 (2015/161B)

Interoperability
Summary of Interoperability Tracking and Reporting by the Information and Communication Technology Program in 2018, 3002013481 (2018/161A)
From Innovation to Standards: Technology Evolution, 3002014840 (2018/161E)
Summary of Interoperability Tracking and Reporting by the Information and Communication Technology Program in 2017, 3002010327 (2017/161A)
Program on Technology Innovation: Redesign of CIM UML and XSDs for IEC 61968 Part 3 OMS Messages, 3002007926 (2016/161C)
Program on Technology Innovation: Redesign of CIM UML and XSDs for IEC 61968 Part 3 FIDSR Messages, 3002007927 (2016/161C)
Interoperability Tracking & Analysis Summary, 3002007841 (2016/161A)
The Value of Direct Access to Connected Devices, 3002007825 (2016/161A)

Network Model Management
Leading Practices for Transmission Network Management, 3002014082 (2016/161A)

Outage Data Standard
Development of Outage Management Status Messages and Test Plan for Phase 1: Red Button, 3002006384 (2015/161C)

Precision Time
Precision Time Technology Overview, 3002007843 (2016/161A)
Utility Precision Time Methods: Current State, 3002007474 (2016/161B)

Standards-Based Data Integration
Assessment of Asset Monitors to IEC 61850-90-3: Circuit Breakers, 3002009872 (2017/161B)
IEC 61850 Working Group Activity: 2017 Summary, 3002009873 (2017/161B)
Visualization Techniques for Distribution System Data, 3002007920 (2016/161C)
Electric Utility Guidebook on Using IEC Standards for Asset Health Data Management: Harmonizing Common Information Model (CIM) and IEC 61850 Asset Health Data Models, 3002005119 (2015/161B)
Standard Based Integration Specification: Common Information Model

Substation Data Standard
Substation Data Mapping: Initial Assessment, 3002012587 (2018/161B)
Substation Data Management: An Initial Assessment, 3002012586 (2018/161B)

Synchronized Communications
Synchronized Communication Assessment: Advanced Synchronized Protocol, 3002009870 (2017/161B)
Guidebook on Synchronized Communications, 3002005116 (2015/161B)

Synchronized Data Management
Synchronized Data Management Assessment: Status Report, 3002007473 (2016/161B)
Guidebook on Synchronized Data Management: Current State Update, 3002005117 (2015/161B)

Telecommunications
Black Sky Communications Evaluation, 3002013919 (2018/161G)
FAN Technology Performance Evaluation, 3002013393 (2018/161G)
Smart Grid Communications Intelligence - Issue 20, Winter/Spring 2018, 3002012471 (2018/161A)
Smart Grid Communications Intelligence, Summer 2018, 3002012472 (2018/161A)
Smart Grid Communications Intelligence, Fall 2018, 3002012473 (2018/161A)

Telecommunications Initiative
Private LTE – Option and Opportunities, 3002009788 (2017)
EEE 802.16S Overview, 3002011195 (2017)
Creating Telecommunication Metrics for the Electric Sector, 3002009803 (2017)
Wi-Fi Connectivity: Testing Results, Next Phase Continuation and Collaboration Plan, 3002009799 (2017)
Persistent Secure Wi-Fi Connectivity at Grid Edge: Overview and Operation, 3002009798 (2017)
Low Power WAN Technologies, 3002009791 (2017)
A Case Study of the Quality of Service Feature from Commercial Cellular Carriers: The Impact of Quality of Service on Bandwidth, Connectivity, and Reliability Improvements at Ameren, 3002009790 (2017)
Unlicensed Noise Floor Study, 3002009787 (2017)
Leased Circuit Requirements Summary for Protective Relaying, 3002009785 (2017)
Serial/Time Division Multiplexing (TDM) Replacement: Technology Options for Packet-Based Replacement of TDM Circuits, 3002009784 (2017)
Serial to Packet Protection Workshop: Test Results, 3002009783 (2017)
Evaluation of TV White Space for Utility Communications Networks, 3002007255 (2016/161A)
Information and Communication Technology (ICT) Program (161) Deliverables


Telecommunications Solutions for a Distribution Network: A Hydro-Québec Case Study, 3002006577 (2015/161C)

2017

Smart Grid Communications Intelligencer: Fall 2017, 3002010452 (2017/161A)

Smart Grid Communications Intelligencer: Issue 18, Spring-Summer 2017, 3002010451 (2017/161A)

Smart Grid Communications Intelligencer: Winter 2017, 3002009755 (2017/161A)

2016

Smart Grid Communications Intelligencer: Issue 14, Winter 2016, 3002007445

Smart Grid Communications Intelligencer: Issue 15, Spring/Summer 2016, 3002007446

Smart Grid Communications Intelligencer: Issue 16, Fall 2016, 3002007447

2015

Smart Grid Communications Intelligencer: Issue 11, Winter 2015, 3002005094

Smart Grid Communications Intelligencer: Spring 2015, 3002005095

Smart Grid Communications Intelligencer: Fall 2015, 3002005096

TO JOIN, CONTACT ANY OF THE FOLLOWING TECHNICAL ADVISORS:

West: Christine Hertzog, Senior Technical Advisor, 650.314.8111; chertzog@epri.com

East: Chris Kotting, Technical Advisor, 980.219.0146; ckotting@epri.com

International: Kevin East, International Director, +44 (1925) 450.207; keast@epri.com

For more information, contact the EPRI Customer Assistance Center at 800.313.3374 or askepri@epri.com
**BIOGRAPHIES**

**Information Communication Technologies (161) Team Members**

**Matt Wakefield** is Director of Information and Communication Technology (ICT) and Cyber Security (183) at the Electric Power Research Institute (EPRI). With over 25 years of energy industry experience, his research area responsibilities include furthering the development of a modernized grid with a strong focus on leveraging emerging information and communication technologies that can be applied to the electric grid infrastructure. He received his BS in Technology Management from the University of Maryland. mwakefield@epri.com

**Don Von Dollen** is the Senior Program Manager of the ICT (161) program. With over 23 years at EPRI, Don has spent the past 15 years focused on Smart Grid R&D. He is Chairman of the Implementation Methods Committee within the Smart Grid Interoperability Panel and is past Chairman of the IEEE Intelligent Grid Coordinating Committee. Don led a team of industry experts to develop a roadmap for Smart Grid interoperability standards for NIST. He received his BS in Physics from California State University, Sacramento. dvandoll@epri.com

**Paul Myrda**, P.E., Sr. Technical Executive, manages the ICT for Transmission project set (161B) and leads the Advanced Grid Innovation Lab for Energy at NYPA focused on future grid elements related to advanced applications, cybersecurity, controls, sensors and protection. He represents EPRI on the Advisory Board for the Cyber Resilient Energy Delivery Consortium and North American Synchrophasor Initiative. He has an MBA from Kellogg; MSEE and BSEE from Illinois Institute of Technology; is a member of CIGRE and senior member of IEEE. ppmyrd@epri.com

**Gerald Gray**, Ph.D. is a Sr. Program Manager and leads the enterprise architecture and integration (161E) research. Dr. Gray participates in the development of industry standards such as IEC CIM, MultiSpeak, and IEEE and is a member of the GridWise Architecture Council. He has a BS in Management/CIS from Park University, a Master’s degree in MIS from the University of Montana and a PhD in Organization and Management with IT Specialization from Capella University. ggray@epri.com

**Jared Green** is a Senior Technical Leader and co-leads the ICT for Distribution project set (161C). Jared also serves as the Project Manager for the Southern Company and SMUD Distribution Modernization Demonstration Projects. His experience includes 16 years of utility experience (Distribution, Substations, Resource Planning, and Demand Response) with 4 years of managing EPRI Smart Grid Demonstration projects. He has a BSEE from the University of Alabama and is a registered Professional Engineer and Certified Energy Manager. jjgreen@epri.com

**Ed Beroset** is a Principal Technical Leader in the Advanced Metering Infrastructure (161F) project set. In this position in ICT he is responsible to technically lead and manage research and demonstrations associated with the challenges faced by utilities that are implementing AMI and other communication systems. He received a BS — Computer Engineering, from North Carolina State University. eberoset@epri.com

**Tim Godfrey** is a Technical Executive and is leading the Telecommunications project set (161G). He is directly responsible for research projects involving telecommunications for Smart Grid Transmission and Distribution, Energy Efficiency, and Electric Transportation. These include standards development and communications system architecture, design, simulation, and evaluation. He received a BS in Electrical Engineering from the University of Kansas. tgodfrey@epri.com

**John Simmins**, Ph.D. is a Technical Executive with EPRI and co-leads the ICT for Distribution project set (161C). His current research focuses on integrating back-office applications with devices and personnel in the field. He also leads the EPRI research efforts in the use of augmented reality, social media, data analytics, and visualization to improve grid resilience. He received his BS and a Ph.D. in Ceramic Science from Alfred University. jsimmins@epri.com

**Ben Ealey** is a Sr. Project Manager in ICT for DER/DR (161D) with a focus on standard protocols enabling the communication and control of distributed energy resources (DER) to help utilities and their customers maximize the benefit of these systems. He works closely with industry experts and focuses on various DER technologies, standards, specification groups, and utilities. Ben holds a MS degree in Electrical Engineering — Communication Theory and a BS Electrical Engineering from the University of Tennessee. bealey@epri.com

**Patricia Brown** is a Technical Executive. Her current focus is industry standards primarily the Common Information Model (CIM), in the deployment of data sharing solutions. Her primary work in recent years has been leveraging the CIM to improve asset health and network model data management inside the utility. She holds a BS in Architecture from the University of Michigan. pbrown@epri.com
## BIOGRAPHIES

### Information Communication Technologies (161) Team Members

<table>
<thead>
<tr>
<th>Name</th>
<th>Title/Role</th>
<th>Email</th>
<th>Background/Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girish (Rish) Ghatikar</td>
<td>Senior Program Manager and leads the ICT for DER and integration research. He is a smart grid, demand response, and clean transportation technology innovator who has successfully led technology development for electric grid integration of distributed energy resources, thus enabling California to adopt mandatory dynamic pricing programs and open standards in grid codes. He holds a MS Telecommunication Systems/Computer Technologies, Cal. State, and a MS in Infrastructure Planning/Management, New Jersey Institute of Technology.</td>
<td><a href="mailto:gghatikar@epri.com">gghatikar@epri.com</a></td>
<td></td>
</tr>
<tr>
<td>Sean Crimmins</td>
<td>Principal Technical Leader in the Enterprise Architecture and Systems Integration project set and an enterprise architecture and Common Information Model (CIM) expert. Sean assists with the enterprise architecture and integration research in pset 161E and participates in the IEC standards development. He holds a BE in Integrated Engineering from Manchester Metropolitan University and is TOGAF 9 certified.</td>
<td><a href="mailto:scrimmins@epri.com">scrimmins@epri.com</a></td>
<td>Has over 25 years of engineering and consulting experience in utility telecommunications. He is an active member of the Institute of Electrical and Electronics Engineers (IEEE) and holds a MS from the University of Colorado and a BSEE from the University of Nevada, Las Vegas and is a registered professional engineer.</td>
</tr>
<tr>
<td>Jay Herman</td>
<td>Principal Technical Leader and serves as a lead resource on the Telecommunications project set 161G. He has over 25 years of engineering and consulting experience in utility telecommunications. He is an active member of the Institute of Electrical and Electronics Engineers (IEEE) and holds a MS from the University of Colorado and a BSEE from the University of Nevada, Las Vegas and is a registered professional engineer.</td>
<td><a href="mailto:jherman@epri.com">jherman@epri.com</a></td>
<td></td>
</tr>
<tr>
<td>Walt Johnson</td>
<td>Technical Executive specializing in smart grid strategies, technologies, standards, applications, and IT Enterprise Architecture. He managed EPRI’s OpenADR Demonstration Project and currently runs the Transactive Load Management Signaling Project. Dr. Johnson holds a Ph.D. in Inorganic Chemistry from Indiana University (Bloomington,) and BA in Chemistry from Claremont McKenna College and is a member of Sigma Xi, the Scientific Research Society.</td>
<td><a href="mailto:hwjohnson@epri.com">hwjohnson@epri.com</a></td>
<td>Has over 20 years of utility and industry consulting experience, and over 7 years as a Gartner analyst. Received a BS–Electrical Engineering from Kansas State University and a MA–Linguistics from the University of Illinois, Chicago. He is a registered PE and served as utility co-chair for the CIM Users Group.</td>
</tr>
<tr>
<td>Randy Rhodes</td>
<td>Technical Executive within pset 161E. His focus is on distribution grid model management, enterprise architecture methodologies, IT/OT Integration, and extending the IEC CIM to support DERMS implementation. He has over 20 years of utility and industry consulting experience, and over 7 years as a Gartner analyst. Received a BS–Electrical Engineering from Kansas State University and a MA–Linguistics from the University of Illinois, Chicago. He is a registered PE and served as utility co-chair for the CIM Users Group.</td>
<td><a href="mailto:rrhodes@epri.com">rrhodes@epri.com</a></td>
<td></td>
</tr>
<tr>
<td>Norm McCollough</td>
<td>Sr. Technical Leader within the ICT for Distribution (161C) project set focusing on Augmented Reality. He is also a cross-cutting technologist in several EPRI sectors and is focused on AR and VR technologies and external sensors, persistent WiFi connectivity and standards [P161G], vehicle-to-grid technologies and zero net energy projects in the Electric Utilization sector, including AR/VR technologies for worker wellness in the Environmental sector. An avid inventor, he holds 9 Letters of Patent in related areas. He attended the University of Tennessee.</td>
<td><a href="mailto:nmccollough@epri.com">nmccollough@epri.com</a></td>
<td></td>
</tr>
<tr>
<td>Stephan Amsbary</td>
<td>Sr. Technical Leader focusing on Enterprise Architecture, and integrations standards in pset 161E. His current projects include distribution grid model management, enterprise architecture methodologies, extending the IEC CIM for Customer Support of DERMS interactions, CIM WG14, and WG 19 development, use case development, and other architecture related activities. He is the author for the NIST Smart Grid Framework architecture chapters, part of the development team for NISTIR 7628. He attended the University of Illinois, is a certified TOGAF Architect, and ArchiMate Practitioner.</td>
<td><a href="mailto:samsbary@epri.com">samsbary@epri.com</a></td>
<td></td>
</tr>
<tr>
<td>Chuck Thomas</td>
<td>Senior Technical Leader in PDU, and is leading a $2M collaboration, comprising 12 utilities, to evaluate and test the ANSI/CTA-2045 standard in both laboratories and field installations. He is EPRI’s technical leader for OpenADR research and development. He holds a BS in Electrical Engineering from the University of Tennessee.</td>
<td><a href="mailto:cthomas@epri.com">cthomas@epri.com</a></td>
<td></td>
</tr>
<tr>
<td>Doni Nastasi</td>
<td>Technical Leader and works in conjunction with pset 161D. He has more than 20 years of experience in the field of power quality involving destructive and nondestructive testing, automating test fixtures, developing test protocols, and diagnosing power quality issues. As a hardware and software designer, he holds two patents for designs involving voltage sag testing and energy storage. He received a BS in electrical and computer engineering from the University of Tennessee, Knoxville.</td>
<td><a href="mailto:dhnastasi@epri.com">dhnastasi@epri.com</a></td>
<td></td>
</tr>
<tr>
<td>Karen George</td>
<td>Technical Leader in Enterprise Architecture project set within the ICT program. Her focus is technology transfer, project management, and research in enterprise architecture, grid model data management, and integration of distributed energy resources. She has more than 30 years experience in the renewable energy field, having served as an analyst and project manager with the Colorado Energy Office, the National Renewable Energy Laboratory and the University of Colorado at Boulder Civil, Environmental and Architectural Engineering Department.</td>
<td><a href="mailto:KGeorge@epri.com">KGeorge@epri.com</a></td>
<td></td>
</tr>
</tbody>
</table>
**Christina Huff**

is a Project Engineer/Scientist II supporting the ICT program with Geographic Information Systems (GIS) and data management research. She received a BA degree in International Politics and Economics and a MS in Environmental Planning from the University of Tennessee. She also holds a Graduate certification in Geographic Information Science from the University of North Dakota. chuff@epri.com

**Jithendar Anandan**

is an Engineer/Scientist II in the ICT for DER/DR (161D) project set. His current research focus is on communication architectures that integrate DER and to develop reference implementation for standard protocols. Jithendar has experience in developing device simulation software that interfaces to Advanced Distribution Management System (ADMS) and grid simulators. He holds a MS in Computer Science from Texas A&M University–Commerce. janandan@epri.com

**Michael O’Connor**

is an Engineer/Scientist II and Data Scientist. His current projects are focused on the Data Mining Initiative and the Technology Innovations (TI)–Smart Data Lakes Project. He has experience in computer science, including a wide range of programming languages, parallel programming, algorithm development, web development, and database design. He received a BS in Applied Mathematics and Statistics with a specialization in probability and statistics as well as a BS in Physics from Johns Hopkins University. moconnor@epri.com

**Joseph Estrada III**

is an Engineer/Scientist II within the telecom set 161G. After completing 5 years of military service as a Super High Frequency, multichannel equipment repairer, he began researching NILM and exploits of the C37.118 protocol at the Center for Ultra-wide-area Resilient Electric Energy Transmission Networks. In 2017, he received a BS in Computer Engineering from the Uni. of TN and is researching field-area network technologies, applications for these technologies, and network management tools. jestrado@epri.com

**Peyton Sizemore**

is an Engineer/Scientist I in the ICT for DER/DR (161D) Project. His focus is on communication systems to facilitate demand response and control of DER. Prior to joining the ICT team, Peyton was a principal investigator for the EPRI Knoxville Lab and the lead metrologist for all of EPRI’s test and measurement equipment. He has over ten years of experience in designing and executing tests to evaluate power protection equipment and energy efficient devices. He holds a BAS degree in Electronics and Communications Engineering from the ITT Technical Institute. psizemore@epri.com

**Simon Boka**

is an Engineer/Scientist I in the ICT for DER/DR (161D) project set. His current research focuses on evaluating and testing the ANSI/CTA-2045 standard in both laboratory evaluations and field demonstrations. Simon graduated with a BS in Computer Engineering from The University of Tennessee and has experience with development and support of building control systems. sboka@epri.com

**Christine Hertzog**

is a Senior Technical Advisor for ICT and Cyber Security at EPRI. She was previously the founder of a consulting firm focused on Smart Grid ecosystems and has an extensive telecommunications background. She authored the Smart Grid Dictionary, and co-authored Data Privacy for the Smart Grid. She has also served in an advisory capacity to innovators, industry associations, and publications. She has a MS in Telecommunications from the University of Colorado–Boulder. chertzog@epri.com

**Chris Kotting**

is a Technical Advisor II for ICT and Cyber Security at the Electric Power Research Institute. He was previously engaged as a consultant and author on the development of communication standards for the electric industry, working with SGIP, NAESE, and other industry alliances. Earlier in his career he was on staff at the Public Utilities Commission of Ohio, working in numerous policy and regulatory roles, in both the energy and telecommunications industries, including work in critical infrastructure protection. He has a BA in Communications from the Ohio State University. ckotting@epri.com

**Joseph Estrada III**

is an Engineer/Scientist I in the enterprise architecture and integration (161E) research area. His main work involves software development in the CIM and DER space, contributing to the CIM Test Harness, OpenDERMS, and Power Systems Model Transport projects. Daniel has a BA in English and a BS in Computer Science from the University of Tennessee. dlowe@epri.com

**Annette Mosley**

is a Technical Advisor in the Power Delivery and Utilization Sector and supports the Information, Communication and Cyber Security (ICCS) programs. AMosley@epri.com
**BIographies**

**Information Communication Technologies (161) Team Members**

Ilka Wiland
is the Leader, Product Development and Administration for programs 161 and 183 in PDU. Her responsibilities include technical assistance in the administration of the Annual Research Portfolio, including Operations and Marketing task management. Her experience includes large trade show execution in the high-tech business and the planning, preparation, and organization of technical conferences. Ilka has an educational background in project management, graphic production, and hotel business administration.

iwiland@epri.com

Laura McLemore
is the Project Operations Coordinator for the Information, Communications Technology and Cyber Security Programs within the PDU sector. She has 20+ years of experience in executive administrative support and meeting planning in a variety industries including engineering, consulting, medical, television, and radio.

lmclemore@epri.com

Linda Dabbs
is the Senior Administrative Assistant for the Information, Communications and Cyber Security Programs within the PDU sector. Linda has 25+ years of experience providing executive administrative support. Linda is responsible for member communications, webcast support, tracking advisor engagement, managing program cockpits and event planning.

ldabbs@epri.com

**To Join, Contact Any of the Following Technical Advisors:**

**West:** Christine Hertzog, Senior Technical Advisor, 650.314.8111; chertzog@epri.com

**East:** Chris Kotting, Technical Advisor, 980.219.0146; ckotting@epri.com

Annette Masley, Technical Advisor PDU, 972.556.6507; AMasley@epri.com

**International:** Kevin East, International Director, +44 (1925) 450.207; keast@epri.com

For more information, contact the EPRI Customer Assistance Center at 800.313.3374 or askepri@epri.com

©2019 Electric Power Research Institute [EPRI], Inc. All rights reserved. Electric Power Research Institute, EPRI, and TOGETHER...SHAPING THE FUTURE OF ELECTRICITY are registered service marks of the Electric Power Research Institute.