Information and Communication Technology (ICT)

Applied ICT for Transmission (161B)	Applied ICT for Distribution (161C)	Applied Information and Communication Technology for DER and Demand Response (161D)	Enterprise Architecture and Integration (161E)	Advanced Metering Infrastructure (AMI) (161F)	Tele-communications (161G)
FUTURE STATES	**FUTURE STATES**	**FUTURE STATES**	**FUTURE STATES**	**FUTURE STATES**	**FUTURE STATES**
Standardized Data Structures High-Speed Precision Time-Stamped Data Capitalize on Available High-Speed Precision Time-Stamped Data	Precise System and Data Models Connected Workforce and Devices Increasing Intelligence Through Standards and Integration	Interoperable DER/DR Validated Communications and Control Architectures for DER/DR Optimized Practices for Connecting DER/DR	Enterprise Architecture Maturity Integration Maturity Business Efficiency: IT/OT Convergence Standards and Certification Agile Enterprise	Open, Interoperable AMI Systems Established and Proven Best Practices for AMI System O&M Optimized AMI System Utilization and Value	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 System Interoperability of Telecommunications Systems Through Standards

Program Manager—Donald Von Dollen, 650.855.2210, dvondoll@epri.com

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

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Emerging Technologies and Technology Transfer (161A)

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.

ICT for The Emerging Technologies and Technology Transfer (161A)

- **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.
- **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

- **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.
- **Light(er)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.
- **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.

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Applied Information Communication Technologies for Transmission (161B)

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.

Applied ICT for Transmission (161B)

FUTURE STATES
(2018 Roadmap Update)

Standardized Data Structures

High-Speed Precision Time-Stamped Data

Capitalize on Available High-Speed Precision Time-Stamped Data

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.
  - **Synchrophasor 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
  - **Synchrophasor Communication Assessment – Advanced Synchrophasor Protocol (3002009870):** Developed an Advanced Synchrophasor Protocol to address the limitations of IEEE C37.118 for large-scale synchrophasor data system deployments. Called the Streaming Telemetry Transport Protocol, it includes strong access control and encryption.

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SUCCESS STORY

Applied Information Communication Technologies for Transmission (161B)

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.

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

"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.

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Applied Information, Communication Technology for Distribution (161C)

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.
  - Data Integrity Techniques for GIS
  - Platform Agnostic Asset Identification and Geolocation
- Key Past Accomplishments
  - **Electric Utility Guidebook for GIS Data Quality: (3002010509)** (2017) - This guidebook provides foundational guidelines for improving and maintaining the quality of GIS data. Previous reports listed by year: 2016-**3002007921;** 2015-**3002006006;** 2014-**3002003036**.
  - **Visualization Techniques for Distribution System Data (3002007920) (2016) and Detection and Geolocation of Power Distribution Infrastructure Using Public Domain Photographic Imagery (3002011490)** (2017)**.**
  - **Geospatial Information System Data Cleanup: Building Out of Distribution Secondary Models (3002007922)** (2016) and **Line Impedance Evaluation and Calculation for Underground Mesh Networks (3002010510)** (2017)**.**
- 2018 Deliverables
  - **Evaluation and Demonstration Machine Learning for Asset Recognition: Utility Feature Extraction Using Terrestrial Photogrammetry (3002013113).**

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.
  - IT/OT Guidebook to Augmented/Virtual Reality Applications

Applied ICT for Distribution (161C)

FUTURE STATES (2018 Roadmap Update)

Precise System and Data Models

Connected Workforce and Devices

Increasing Intelligence Through Standards and Integration

- o Data Integrity Techniques for Workforce Management
- Key Past Accomplishments
  - o **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).**
  - o **Connected Workforce Technology and Sensor Survey (3002007925)** (2016)**.**
  - o **Case Study: Using Augmented Reality to Improve Storm Damage Assessment (3002011041)** (2017)**.**
  - o **A Quantitative Evaluation of Camera Resolution on Automatic Power Pole Location Algorithms (3002011696)** (2017)**.**
- 2018 Deliverables
  - o **Reality Computing: A Guide to Augmented Reality, Mixed Reality, Virtual Reality, and Extended Reality (3002013117).**
  - o **EPRI Virtual Reality Web Application and Source Code (EPRI VR) v1.0 (3002014698).**

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.
  - o Document and Create Distributed Intelligence Algorithms
  - o Guidebook to Centralized, Hierarchical, and Local Autonomous Intelligence – Year 2
- Key Past Accomplishments
  - o **A Guidebook to Centralized, Distributed, and Decentralized Intelligence (3002010511)** (2017)**.**
  - o **Common Information Model Primer (3002006001)** (2015)**.**
  - o **Development of Outage Management Status Messages and Test Plan for Phase 1: Red Button (3002006384)** (2015)**.**
  - o **Redesign of CIM UML and XSDs for IEC 61968 Part 3 FLISR Messages (3002010512) & OMS Messages (3002010513).**
- 2018 Deliverables
  - o **A Guidebook to Centralized, Hierarchical, and Local Autonomous Intelligence for Distribution Systems (3002013416).**

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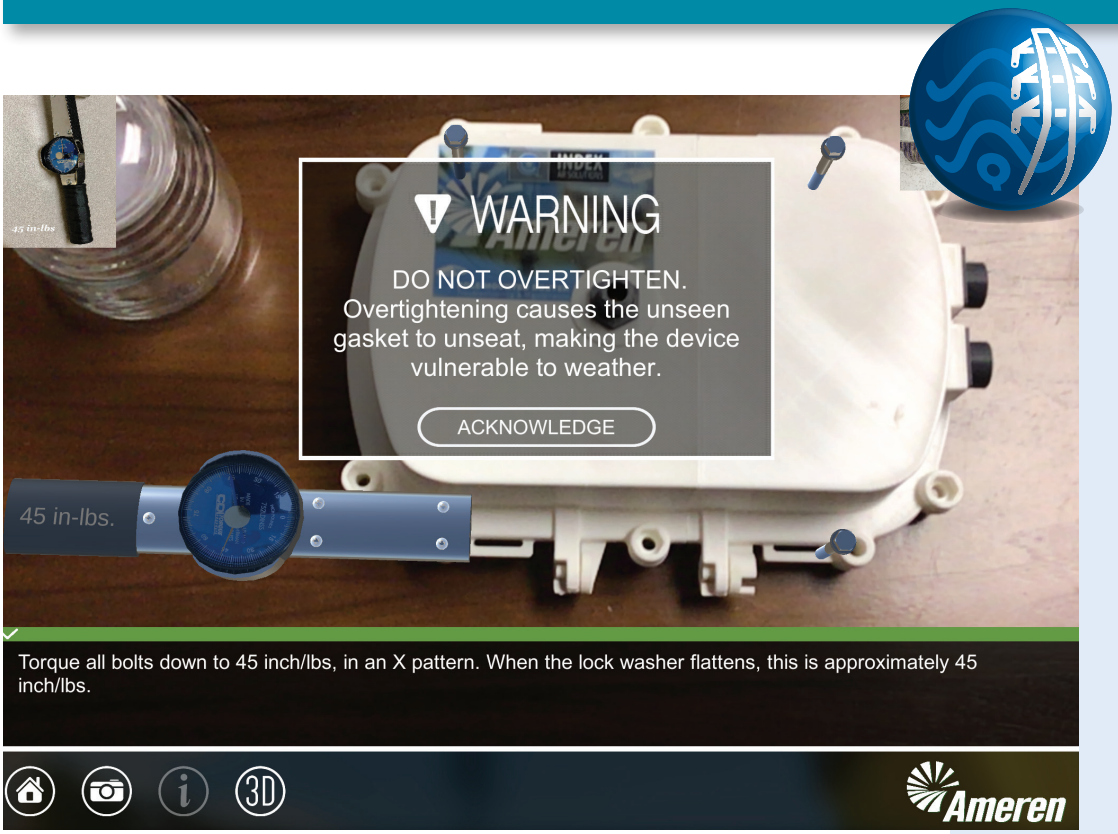
SUCCESS STORY

Applied Information Communication Technologies for Distribution (161C)



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.

"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*

"The project-to-date research results have shown that worker's awareness of surroundings inside a substation can be enhanced with AR/VR technology thus leading to increased worker safety."

Jason Autrey, Principal Engineer at Southern Company

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.

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

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:
  - **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:
  - **EPRI Protocol Reference Guide – 2nd Edition (3002013621)** is a concise digest of communication protocols that allows readers to make 1:1 comparisons of specific aspects of protocols including where protocols fit into the greater communication architecture and the types of DER supported. The 2018 version contains briefs on IEEE 2030.5 for management of smart inverters, IEEE 1815/ DNP3 for smart inverters, SunSpec Modbus for smart inverters, ANSI-CTA-2045-A, OpenADR for demand response, and IEC-61850 for smart inverters.

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:
  - **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

ICT for Distributed Energy Resources (DER) (161D)

FUTURE STATES
(2018 Roadmap Update)

Interoperable DER/DR

Validated Communications and Control Architectures for DER/DR

Optimized Practices for Connecting DER/DR

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:
  - **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:
  - **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:
  - **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.

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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

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"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.

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Enterprise Architecture and Systems Integration (161E)

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).** This guidebook synthesizes information, such as The Open Group Architecture Framework (TOGAF), the Common Information Model (CIM), and the enterprise architecture diagramming standard ArchiMate, for practitioners of enterprise architecture and applies that information using an example project.
- 2018 Deliverables
  - **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
  - **Cloud Integration Guidebook, 3rd Edition (3002012478).** Adds discussion on cloud usage detection, associated International Electrotechnical Commission (IEC) cloud security standards, and the pace of utility adoption.

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

Enterprise Architecture and Integration (161E)

FUTURE STATES (2018 Roadmap Update)

Enterprise Architecture Maturity

Integration Maturity

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

Standards and Certification

opposed to normal life-cycle sustaining innovations) can wreck 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
  - AWS-based Test Harness to support client/server testing
  - soapUI test case library
  - 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.

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SUCCESS STORY

Enterprise Architecture and Integration (161 E)

Enterprise Architecture Collaboration Group Addresses Standards-based Integration

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 datatypes, 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

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"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.

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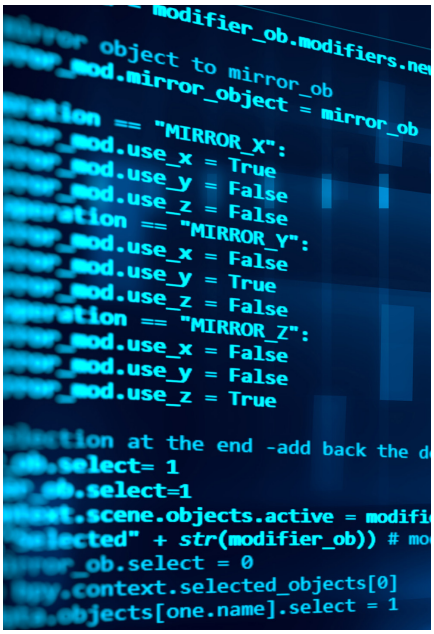
Advanced Metering Infrastructure (161F)



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
  - Guidebook for Revenue Protection, 2nd Edition updates the first edition Revenue Protection Guidebook: Utilizing Advanced Metering Infrastructure **(3002008943).**
  - 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
  - **Next Generation AMI System Design and Utilization – Case Studies in Utility Innovation (3002013400/TBC 3/2019)**

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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?

EPRI Wi-SUN Meter Test Tool

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*

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

"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

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.

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3002015105

January 2019

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Telecommunications (161G)

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: Telecommunications resources – Telecom Director, IT Architect, Network Planning, Telecom Planning, Director IT Network Engineering, Telecom Architect, and System Architect.

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.
- **Optimizing Wireless Spectrum: Operation and Coexistence in Sub 1GHz Unlicensed Spectrum (3002013392).** Analysis of wireless systems and standards operating in Sub-1GHz spectrum. Review of spectrum occupants and protocol behaviors and techniques for coexistence. Updates ongoing development of the unlicensed spectrum surveyor, and the licensed spectrum sharing evaluation for 406 MHz.
- **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.

Tele-communications (161G)

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 Tele-communications Systems Through Standards

Research Results From the Telecom Initiative

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

Next Steps:

- In 2019, Project Set 161G will continue working in strategic telecommunications in four tracks: WAN, FAN, and Management and Systems.
  - 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.
  - 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.
  - 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.
  - 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*

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SUCCESS STORY

Telecommunications (161G)

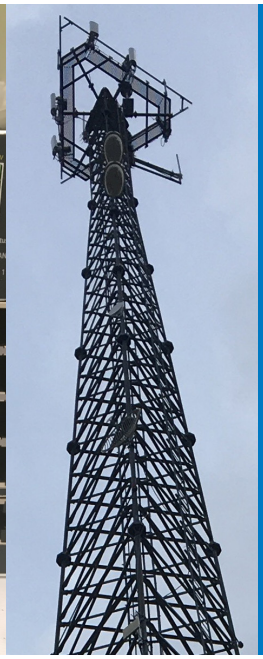
(Left to right) Tim Godfrey, Cole Crews, and Brian Hartman standing in front of Ameren's private LTE Core.

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'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."

C. Cole Crews, Career Engineer, NEO Strategy and Planning, Ameren Services.

Modems and towers in Peoria, IL.

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 the 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.

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ICT for Distribution 161C

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Advanced Metering Systems 161F

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Telecommunications 161G

2018

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