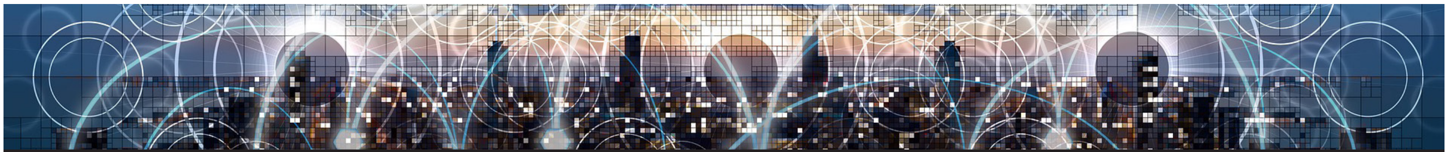
PREPARING FOR THE 2030 ENERGY SYSTEM

A Vision for Electric Utility Information and Communication Technologies (ICT) and the Role that EPRI's ICT Program Plays in Helping Members Realize This Vision

An EPRI White Paper, February 2022



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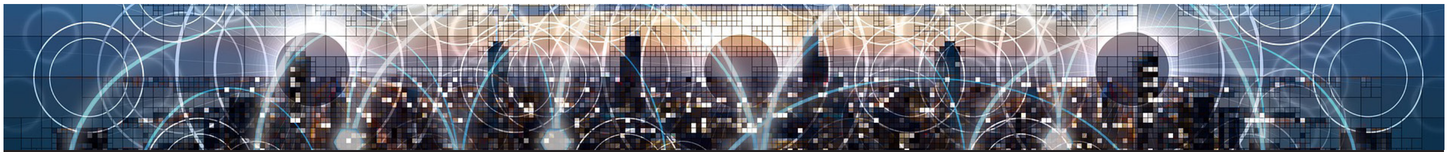


INTRODUCTION

The electricity sector is nearing an inflection point in the way it operates as we transition to a new energy paradigm. State, national and international policies and corporate strategies addressing climate change are driving the change point that will result in a significant evolution in how electricity will be generated and consumed, how the grid will be managed, what energy services will be offered and by which stakeholders. Additionally, the economic value of grid reliability and resilience will grow significantly as additional sectors such as transportation become more reliant on electricity and the number of extreme weather events resulting from climate change increases.

An underlying attribute of all four of these key industry drivers is information and communication technology (ICT). ICT in the electric utility industry encompasses the acquisition of data from the field, the movement of data from its source to its final destination, and the conversion of data into actionable information. ICT is foundational to enabling decarbonization, providing grid flexibility and resiliency and is a key aspect of digital transformation.

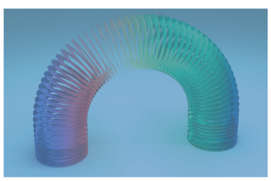
Drivers to Reimagining the Future Energy System

Decarbonization & Electrification

initiatives and regulations are accelerating widescale deployment of low-carbon renewable generation, efficient electrification, and net-zero clean energy systems.

Grid Resilience

against natural and man-made threats continues to be a priority as society depends upon this critical infrastructure to sustain life, health, safety, and economic livelihoods.



Grid Flexibility

is needed due to increased deployment of intermittent renewable generation that need to interact with other generation and controllable Distributed Energy Resources (DER) to continuously balance electricity supply and demand.

Digital Transformation

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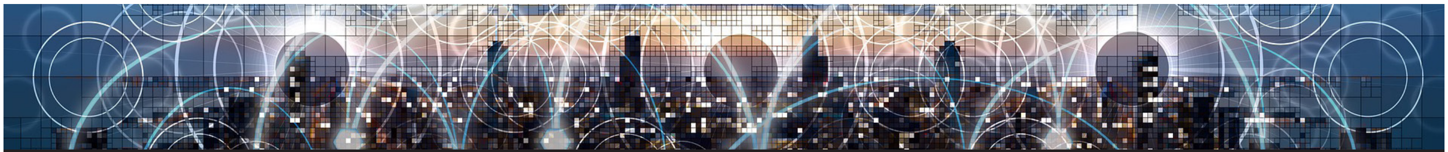
The Role of Information and Communications Technology in the Electric Utility of the Future

As electric utilities develop strategies to address these drivers, some key trends are beginning to emerge:

- Data analytics will permeate every aspect of a utility's operation to enhance decision making in areas including asset management, grid operations, customer service, and event anticipation and response
- Electric utility operations will increasingly rely on interacting with customers and third parties over a variety of time frames including real-time to provide grid flexibility and resilience
- Electric utilities will create a digital workforce that leverages monitoring, telecommunications, access to information and user interface technologies to improve worker productivity and safety
- Grid edge computing will inform real-time decision making
- Electric utility customers will have the electricity service information that they want given to them the way that they want to receive it
- Electric utilities will have greater visibility into all aspects of their operation

"The combination of universal technology trends and industry trends such as cloud computing and decarbonization are changing the way we monitor, control and manage this evolving two-way grid where the customer is at the center of everything we do. As we prepare for the future, three key areas that are important for Exelon and should be transferrable to the industry are: 1) Having an analytics strategy recognizing data is at the center of the future grid; 2) Enabling telecommunications to support the digital grid of the future and 3) Innovation — establishing a foundation and culture to move faster and move together."

Mark Browning, VP of IT & CIO,
Exelon Utilities



In order to effectively address these trends, electric utilities will need to achieve three ICT future states:

Data-Centricity

To better enable data analytics and the exchange of data between all stakeholders, electric utilities will need to transition from being application-centric to adopting a more data-centric philosophy. Meaning that:

- Data will be treated as an asset rather than a costly afterthought
- Data will be widely available, easily shared and easily accessed
- Effective data management, data governance and data quality practices will be adopted
- Standardized data models will be adopted
- Data-centric architectures will be adopted
- Data centric organization structures will be created
- Compute resources and tools for analyzing data will be readily available
- Methods for the valuation of data will be adopted

Interoperability

The grid of the future will be highly complex, with constant interactions between devices and actors. To facilitate this engagement, standardized interfaces that define the physical, electrical, and logical parameters as well as the data exchange between stakeholder environments must be developed and adopted. For example, such interfaces could be located at a customer owned device such as a smart thermostat or the inverter connected to a photovoltaic system. Another example of an interface could be between an electric utility and a third-party service provider. Experience has shown that standardized interfaces can greatly reduce integration costs which can be substantial.

Pervasive Telecommunications

To enhance grid visibility and control, create a digital workforce, enable interactions between utilities and third parties, move data from its source to its final destination and to provide customers with accurate and timely information will require electric utilities to develop ubiquitous, reliable and resilient telecommunications networks. Planning, designing, operating, and maintaining these networks will require utilities to acquire many of the same capabilities that commercial carriers have.

"When I look at the data quality issue, this is one aspect that frequently causes failures in my organization. Figuring out a way to improve data quality and a sustained process to maintain that quality considering a variety of factors is important. What data is on premise, sourced by a third party, who owns the data and who is the beneficiary? As we think about data-centricity, a data management model that is compatible with an agile framework will be important to keep up with the variety of data sets and data structures we have."

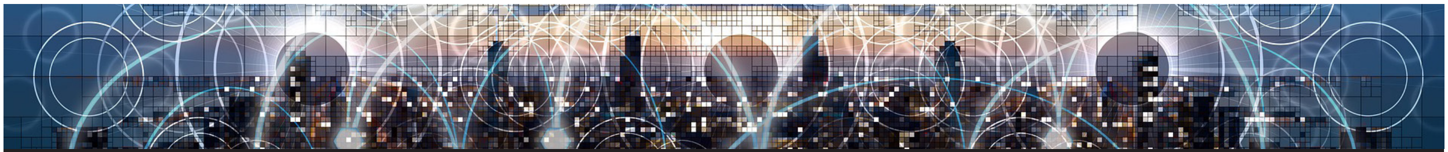
Spencer Wilcox, Chief Security Officer and Executive Director of Technology, PNM Resources

"I do think Interoperability is a noteworthy future state. The industry is very good about talking about the grid as pointed out in the EPRI ICT Vision for 2030, but the grid isn't just substations and lines it includes the entire set of energy sources and the entire set of energy users. To achieve grid flexibility needs for 'just-in-time delivery systems' the amount of data interactions will increase significantly and driving towards interoperability is key to achieve the future vision."

Jim Jones, Vice President and Chief Information Officer, Great River Energy

"As we deploy more and more devices, we have to deal with the need of pervasive communications. How much data will be used at the edge vs. bring back to central platforms? This is an important challenge to understand when grid edge computing will benefit real-time decision making and also when we can benefit from bring data back to the 'cloud' or other central platforms."

Vijoy Matthew, Executive Director IT, Consumers Energy



The Role of EPRI's ICT Program in Helping Members Realize the 2030 Vision for Electric Utility ICT

ICT has played a vital role within electric utilities for decades. As the world rapidly transitions to a decarbonized economy and braces itself for the impacts of climate change, electric utilities will rely on ICT as never before. As this reliance increases, traditional paradigms around data and telecommunications will change and electric utilities will need to be agile to adapt.

EPRI's ICT Program (161) conducts research that provides immediate value to members and society while leading the industry towards the 2030 ICT vision. The following section describe how the ICT Program will help members advance towards a data-centric, interoperable and telecommunications pervasive future.

Data-Centricity

Background

Historically, utilities have taken an "application centric" approach for information systems. This approach aims to produce modular applications that are entirely self-contained. Data is tightly coupled to the application's architecture, resulting in an approach to software solutions that focuses on local problem solving. A widely recognized cost of application centric development is the emergence of data silos, which slow down systems integration and make it difficult to share data across the enterprise. Evidence of application centric development in the utility industry manifests in the many duplicate representations of the same "thing" across different business units.

Data centrism is a philosophy that puts data, not applications, at the core of the enterprise. This approach not only frees data from silos, making it easier to share and allowing its value to be unlocked, but will enable the nearly seamless addition of new consuming applications. Integration changes can be more accurately assessed and implemented because the role of data can be more easily traced throughout databases, systems, and processes. An important benefit of data centrism is that it provides a flexible foundation that does not inhibit business processes change, software application development, or organizational transformation. Much of this flexibility is derived from the fact that data is defined and managed at an enterprise level.

The journey to data centrism requires a paradigm shift within utilities, which runs the risk of being blocked by organizational culture and the inertia of the status quo.

Program Strategy

EPRI's ICT program helps utilities with their journey towards data centrism in three ways:

<u>Advancing the industry's data modeling standards</u> - A key component of data centrism is an enterprise-wide extensible data model. The idea is to center an enterprise's information systems around this data model with the understanding that specific applications will come and go, while the data model remains a constant. This enterprise semantic model is used to make integration of applications more efficient, develop clear standards for exchanging shared data within and outside of the utility, facilitate informed decisions around data quality and data access, and design high-quality data architectures.

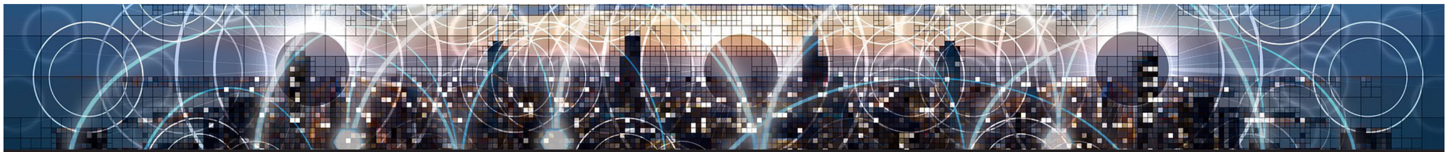
The Common Information Model (CIM) is a semantic model that represents all the major objects unique to the electric utility industry. It was originally developed by EPRI but is now a series of standards under the International Electrotechnical Commission (IEC). Understanding that every utility is unique, a recommended approach is to use the CIM as the basis for a utility's enterprise semantic model, extending the model as appropriate to make it an accurate description of the shared data of the utility. The CIM Primer includes guidance on how to extend the model and build API specifications with the extensions.

The ICT program continues to advance the CIM by determining data requirements for advanced applications and incorporating this information into the standards. It also assists utilities and vendors with the implementation of the CIM through the development of training material, applications guides and test tools.

<u>Capturing leading practices for data management</u> - While vendor applications manage data within an application (OMS, DMS, etc.), utilities are responsible for the data that is shared between applications and, increasingly, between applications and people. To start the data centric journey, a utility needs to take active responsibility for data management. The objective is to treat data as a valuable business asset and to resource data management activities accordingly. Effective data management addresses topics such as data governance, data quality, organization and culture change, and application integration among others.

The ICT program has been capturing leading practices for data management for over ten years and has incorporated this insight into a series of reports and guidebooks to make it easily accessible for members.

<u>Data architecture development</u> - A data architecture documents how the data is organized across different domains and how the data within each domain is managed, throughout its lifecycle, by applications across the enterprise. The architecture is a powerful tool that allow a utility to think about data first, before embarking on the development or purchase of new applications—precisely the approach suggested by data centrism.



The ICT program has developed tools and methodologies that will help utilities develop their data architectures. The program has developed a business capability model that helps utilities determine the people, processes, technologies, and data that will be needed to meet business objectives and the maturity required for these capabilities. The program has also developed reference architectures for specific functions such as DER integration and AMI.

Past Accomplishment

Architecture

- 3002021832, Utility Enterprise Architecture Guidebook, 6th Edition, which overviews enterprise architecture concepts and their application at utilities, including data-related topics like capability modeling, business architecture, data architectures, and data governance (2021) (161E)
- 3002022006, Public Utility Business Capability Model, which supplies a utility industry capability model (in ArchiMate) that supports "big thinking" and can act as a reference in data architecture design for data domains (2021) (161E)
- 3002020883, Architectural Impacts of Disruptive Technology, which illustrates the practical use of business capability models in utility solution design (2021) (161E)
- 3002019424, Federated Architecture for Distributed Energy Resources Integration, which explores the complex world of DER coordination from an enterprise perspective (2020) (161D)
- 3002021854, Advanced Metering Infrastructure (AMI) Reference Architecture, which models the applications or technology functions required and the data exchanged to implement the functions. (2021) (161E/F)

Data Model

- 3002002587, Using the Common Information Model for Network Analysis Data Management: A CIM Primer Series Guide, which describes how CIM information model constructs can be leveraged to manage grid model data inside the utility enterprise (2021) (161E)
- 3002002586, Standard Based Integration Specification: Common Information Model Framework for Asset Health Data Exchange, which outlines CIM-based data architecture for the integration and management of asset data (2021) (161E)
- 3002021521, Enhanced Grid Modeling: A Collaborative Framework for Model Verification, Validation and Quality Tracking, which determines the data requirements for enhanced grid modeling and provides direction for improving the collaboration between GIS professionals and distribution engineers and planners. (2021) (161H)

Data Management

- 3002021856, Cloud Integration Guidebook, 6th Edition: A Guide for Enterprise Architects, which explores an increasingly popular IT technology foundation with implications on utility data management approaches (2021) (161E)
- 3002021850, Digital Transformation: Information Technology – Operational Technology Convergence Guidebook: Fourth Edition, which examines the convergence of the historically distinct utility IT and operations technology (OT) worlds and the organizational changes that will contribute to utility success (2021) (161E)
- 3002021413, Guidebook for Integrating AMI into Outage Management, which describes the essential characteristics of a successful Advanced Metering Infrastructure (AMI) to Outage Management System (OMS) integration. It synthesizes some of the currently known leading practices to assure the success of such a project and gives practical examples. (2021) (161F)

"The grid of the future needs to be more flexible which means utilities need more granular control capabilities. Optimization will require automation and massive levels of interoperability and integration. It's not all about applying technology, but an 'all eyes wide open' approach to build business capability that drives process maturity to the point they can be automated with whatever technology the utility chooses. EPRI can help define that approach for the industry."

Jim Jones, Vice President and
Chief Information Officer, Great River Energy

Advancing Interoperability

Background

Interoperability is the capability of two or more networks, systems, devices, applications, or components to exchange and use information. When many people think about interoperability, they think about "plug and play" where you connect two devices, and they immediately work. This is considered "full" interoperability, but there are many levels that exist between no interoperability and full interoperability. One way of thinking about interoperability is to look at the amount of effort that goes into integrating two system devices or systems. The effort required when there is full interoperability between the systems is near zero. Experience within the industry has shown that the cost of integrating systems when no standards exist can be extremely high. Even small advances in interoperability can result in significant savings for utilities.

Achieving interoperability within the electric utility industry is challenging. It requires multiple stakeholders (utilities, suppliers, end-users, etc.) each with different motivations and objectives to work together. Interoperability begins with standards, but standards alone are not sufficient. Every stakeholder plays a role in advancing interoperability.

Program Strategy

Advancing interoperability has been core objective of the ICT program since its inception. The program's approach to advancing interoperability is strategic, opportunistic, and pragmatic. The program does not attempt to advance interoperability for every issue, but rather looks for issues where the benefits of advancing interoperability would be the most significant for the industry and society. The issues that the program is currently addressing includes integration of distributed generation and flexible load, advanced metering, network model management, telecommunications and extended reality within the utility sector. Once an issue has been identified, the ICT technical team determines what the barriers are for advancing interoperability. Barriers are different for each issue and can include:

- Standards have not been fully developed
- Multiple standards exist and there is a need for harmonization
- Suppliers are reluctant to incorporate standards into products
- Utilities are reluctant to adopt standards
- Testing and certification of standards does not exist

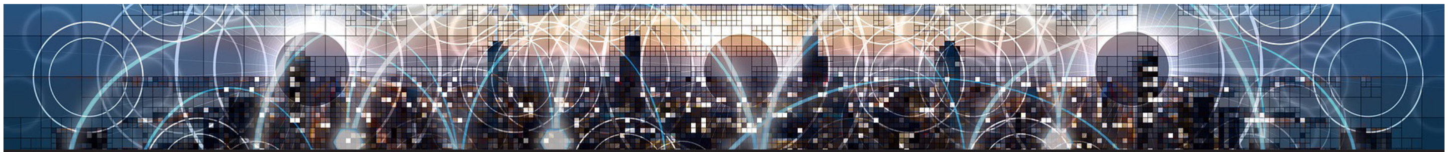
The program's work to advance interoperability for an issue can be multifaceted. As an example of the work that the program does to advance interoperability, the following is a description of the program's activities around the issue of DER integration:

- **Standards Contributions:** The ICT program, in coordination with other EPRI programs, has played an important role in the development of many of today's DER standards including IEEE 1547, OpenADR, CTA-2045, IEEE 2030.5, DNP3 AN2018-01, IEC 61968-5, and others. EPRI has led some of these development efforts while for other it has played a supporting role.
- **Lab Testing:** The ICT program conduct lab tests of commercially available DER equipment and management systems to understand how vendors have implemented standards and whether additional barriers to interoperability exist.
- **Simplifying Standards:** The DER standards landscape is broad and rapidly evolving. The ICT program tracks key inflection points in the landscape to help utilities understand when the time is right to engage (e.g., new regulations driving adoption), identifies gaps or barriers for implementation (e.g., the lack of certification programs means that systems may not be plug and play), and develops approaches to overcome these barriers. This is critical information when developing new DERs, management systems, or customer programs.
- **Guidance on Achieving Interoperability:** Choosing a standard is the first step; however, interoperability is achieved as part of a series of business and technical decisions. To support member utilities, the ICT program develops guidebooks that provide lessons learned from its extensive experience with DER demonstrations and lab tests. This includes information on the key attributes that need to be specified to achieve DER interoperability, repositories of example interactions and interfaces for different utility business applications, templates that utilities can leverage for information and protocol requirements, example interoperability issues and associated solutions, and other guidance not captured in today's standards. EPRI also provides digital twin technologies to help utilities and their vendor-partners demonstrate interoperability and effectiveness of a solution.

Though this example focuses on DER integration, the program is performing similar work for advanced metering infrastructure, controllable loads, network model management, telecom, and extended reality.

Past Accomplishments

- 3002021352, The EPRI Protocol Reference Guidebook (PRG) 5th Edition is a reference document for stakeholders working with DER and DR technologies who want to learn more about the different options for application-layer protocols. (2021) (161D)industry-leading work to identify and mitigate interference to 6 GHz
- 3002022065, EPRI's DER Interoperability Guidebook, compiles knowledge, lessons learned, and guidance on achieving interoperability from DERMS to grid-edge DER. (2021) (161D)
- 3002021410, ANSI C12 Communications Compliance Software, provides a simple and low cost means by which utility personnel, manufacturers or others can evaluate the implementation of the ANSI C12.18 and C12.19 standards in meters. (2021) (161F)
- 3002020378, Telecommunications Standards Guidebook Volume 3, provides an overview of standards relevant to telecommunications in the electric power industry. The focus is on the purpose and relevance of the standards, as well as the development status and roadmap of the standards development organizations. (2021) (161H)



"EPRI was instrumental in the success of Duke Energy's CTA-2045 demonstration project. EPRI worked with the participating utility members of the CTA-2045 collaborative to develop functional specifications, which map the CTA-2045 commands to the functionality of individual appliances to achieve customer-focused demand response. EPRI also assisted in the collaboration between the utilities, communication module manufacturers and appliance manufacturers, including developing tools for testing the communications between the devices. The contributions by EPRI helped Duke Energy identify and solve many issues during the lab testing phase of our demonstration. This enabled our successful field testing of CTA- 2045 technology in load switches, thermostats, water heaters, mini-split HVACs, pool pumps and Electric Vehicle Chargers (EVSE)."

Mike Rowand
Director, Technology Development Duke Energy

Pervasive Telecommunications

Background

Telecommunication has long been essential to utilities and has an increasingly critical role in the operation of a modern integrated grid. Historically, many utilities have implemented stand-alone communications systems that support a single application. Over time, these company's find that they have dozens of these single purpose networks that cannot be scaled and are difficult to manage. Utilities need to break from this mindset and apply the same level of rigor for telecommunications planning and design as they do for planning the distribution or transmission system. They should design the networks to have the necessary levels of reliability and resilience and should leverage technologies and best practices from commercial telecommunications operators whenever possible.

Program Strategy

The ICT program assists utilities in addressing these challenges in three ways:

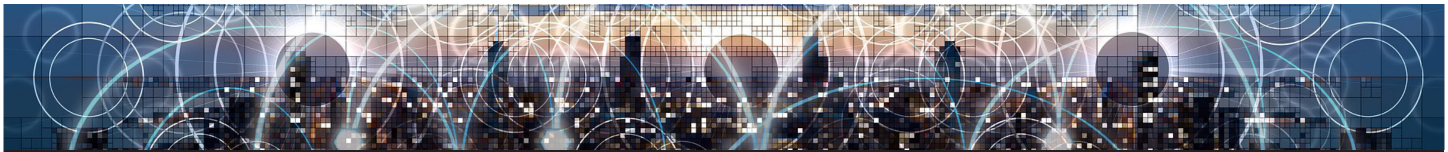
<u>Wide Area Networks</u> - The wide area network (WAN) is the backbone of the utility telecom infrastructure. As new requirements and applications are deployed, the WAN must expand in capacity and geographic presence. The WAN physical plant is increasingly built on fiber, while microwave links and leased services continue to play an important role in many networks. With the opening of the 6 GHz band to unlicensed devices, maintaining the reliability of licensed utility microwave systems represents a new challenge. For many utilities, the long-term goal is to migrate the WAN to incorporate more fiber, but the economics are challenging.

The ICT program is addressing these challenges by continuing its industry-leading work to identify and mitigate interference to 6 GHz microwave systems. It is investigating innovations that will improve the business case for fiber such as new materials and construction techniques and leveraging opportunities with other entities. It is developing case studies on leading practices for WAN operations and maintenance, and it is investigating new WAN technologies such as high-capacity microwave and new satellite technologies.

<u>Field Area Networks</u> - Utilities are faced with demands to provide communication to an increasing number of field devices, and the average amount of data from each device is increasing. At the same time, there is a critical shortage of suitable spectrum to operate a field area network (FAN) using wireless technologies. Unlicensed spectrum is crowded and unpredictable, and there are ongoing concerns about the cost and availability of commercial cellular services. Utility FANs must continue to perform at a high level, especially during manmade or natural disasters. Private LTE and 5G are emerging as a leading solution for the integrated FAN; however, because of the wide range of cost, reliability, and performance requirements, no single FAN technology can be considered universal.

The ICT program is addressing these challenges by developing telecommunications requirements for advanced applications that make use of the FAN. It assists companies that are considering implementing a FAN by evaluating the trade-offs associated with key decisions such as private vs. public networks, licensed vs. unlicensed spectrum and single technology vs. multiple technology architectures. The program captures lessons learned and leading practices for implementing, operating, and maintaining a FAN based on the experiences from leading utilities. It also evaluates emerging technologies such as LPWAN, IoT, and 5G networks for their effectiveness and fitness for utility use.

<u>Planning and management systems</u> - Modern utility telecommunication networks are heterogeneous and complex. Various types of network technologies are used to implement different network tiers and to optimize for application- or location-specific requirements. Long-term success requires best-in-class processes, systems and tools for management and planning, which are continually evolving.



Past Accomplishments

Wide Area Networks

- 3002018508, Unlicensed Use in the 6 GHz Band: Field Test Results from Newton, IL in June 2020, Peoria, IL in January 2021 (3002020360) and Columbus, Georgia in April 2021 (3002022241). All tests showed the potential for interference with incumbent microwave links.
- 3002022243, Analysis of Wi-Fi 6E interactions with 6 GHz FS Radios – Lab Test Results, contains the findings of lab testing, as well as broader learnings regarding the operation of Wi-Fi 6E and its technical aspects that may impact the likelihood and impact of interference. (2021)
- 3002020359, Strategic Fiber Guidebook 2021 Edition provides information on the best practices for the installation, operation, and maintenance of utility fiber optic networks. (2021)
- 3002020361, Integrating and Orchestrating WAN Services contains an introduction to WAN modernization, what has changed from the past and what are the modern WAN technologies and services that involve software-defined networking followed by some implications for utility IT/telecom organizations responsible for providing WAN services to internal customers. (2021)

Field Area Networks

- 3002020373, Private LTE Guidebook 2021 Third Edition is a comprehensive overview of the technology and architecture and identifies spectrum options, use cases, business-case analysis for private LTE network deployment. The report contains four case studies on utility private LTE projects. (2021)
- 3002020362, Frequency Planning and Interference Management for Licensed Spectrum FANs, Case studies were conducted with utilities building and operating networks in the 700 MHz Upper A Block, to better understand how frequency planning was managed and interference was addressed to optimize FAN performance in this band (2021)
- 3002020364, LTE LTE Inter-Network Operation and Roaming highlights LTE and 5G device capabilities to operate on multiple frequency bands and between networks to improve reliability and availability (2021)
- 3002021723, Evaluation of Cellular Based DER Direct Transfer Trip (DTT) Technologies: 4G LTE Technology provides test results and analysis of approaches for using commercial cellular networks to support Direct Transfer Trip protection for DER. (2021)

Planning and Management Systems

- 3002020376, Integration of the Telecom NMS with GIS, evaluation of tools, systems, and processes to integrate the Telecom NMS with GIS data (logical and physical circuits, wavelengths, and related equipment). Also planning and management (non-real- time) that can capture telecom circuit assets for life-cycle management. (2021)
- 3002018513, Telecom Network Management and Manager of Manager Systems: Metrics and Opportunities for Interconnections, Examines (NMS) tools used by utilities, future NMS system requirements identified through future research and proposed development of electric power industry telecom metrics to measure the “health” of the network, including specific case studies. (2020)

“EPRI's in-depth technical knowledge and expertise allowed Ameren to conduct multiple real-world test scenarios to document the impacts of potential interference to our licensed 6GHz microwave links, which are used for critical communications, caused by the FCC proposed 6GHz Wi-Fi solutions which are heading to market. Additionally, EPRI's flexibility to conduct this testing during a worldwide pandemic while maintaining the safety of both Ameren and EPRI personnel was extraordinary.”

Tim M. Spyers, P.E.
Senior Technical Architect Ameren Services

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