Enabling the Distribution System of the Future

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Meet the Author:

An IEEE Fellow, electricity industry visionary, and leader, Dr. Mani Vadari delivers strategic services to a global set of utilities, vendors, and service providers seeking deep subject matter expertise in setting the business and technical direction to develop the next-generation electric/energy system. As a Business Architect, Dr. Vadari has been delivering solutions focusing on Transmission/ Distribution/ generation operations, Energy markets, and Smart Grid for over 35 years. In addition, he is an Adjunct Professor at Washington State University and an Affiliate Professor at the University of Washington. He has published two popular books, "Smart Grid Redefined: Transformation of the Electric Utility" and "Electric System Operations – Evolving to the Modern Grid, 2nd Edition", in addition to over a hundred industry papers, articles, and blogs. His books are serving as textbooks at several universities in the US and around the world

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Agility to innovate and create new value from data will be critical to success:

The following article is the first in a series of advanced energy papers that examine key aspects of the evolving distribution operations landscape and the transformations that will define the successful utility of the future. Authors from the national laboratories and the energy delivery industry will draw on their experience in implementing solutions while enabling us to see the emerging technology and architectural concepts that will define grid operations of the future.

Future papers by the authors will cover topics such as data strategy, integration, and management; the role of distributed intelligence and applications at the edge of the grid; advanced modeling requirements and tools; and new approaches to driving innovation and building ecosystems.

A few years back, a group of experienced distribution system operators and engineers from leading utilities across the United States gathered in a conference room at CenterPoint Energy in Houston for a Department of Energy-sponsored 'Voices of Experience' discussion on how they could apply new technologies to improve distribution operations.

Energized by their recent experience implementing and evaluating new grid technologies funded by the American Recovery and Reinvestment Act (ARRA) Smart Grid Investment Grants, they shared perspectives on how they could better integrate their systems and data to transform their distribution operations. Specifically, several of the utilities that had begun to procure and deploy Advanced Distribution Management Systems (ADMS) shared their experiences and lessons learned.

ADMS is an umbrella term that encompasses an integrated software platform to support a wide range of distribution management and optimization applications. ADMS includes many functions that manage and respond to outages while also optimizing the performance of the distribution grid. The common theme that emerged in this discussion was that implementing advanced distribution functionality is a complex, time-consuming and expensive endeavor, especially the integration of disparate systems and data sources.

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Fast forward five years to today and the drivers for advanced distribution functionality are accelerating. At a time when customer expectations of quality service are higher than ever, electric utilities are facing an array of challenges to delivering a safe, reliable and affordable power supply. Increasing penetration of distributed energy resources — such as rooftop solar and electric vehicles — is creating new operational and planning headaches for distribution system operators. Grid operators must maintain a continual balance between electricity supply and demand, ensure power quality and protect expensive equipment amid two-way power flows, increased load volatility and a rapidly changing ecosystem at the edge of the grid. Adding to this complexity, grid operators are managing more and more intelligent, connected devices on the grid and the data they generate

Succeeding amid this new normal requires ubiquitous sensing and communications to monitor grid conditions across the domains of transmission and distribution systems all the way to the customer premise (a.k.a. Behind the Meter – BTM). Operators also need to manage those domains through a combined architecture of systems, analytics and algorithms based on where intelligence and control are needed to best support the use case requirements. Much of this cannot be done using conventional approaches and mechanisms used today. As an industry, we need to exploit newer techniques such as Internet of Things (IoT), cloud and Artificial Intelligence/Machine Learning (AI/ML) while still maintaining the security and integrity of the systems and protecting the privacy of the customer. In short, it requires intelligent and coordinated control at scale.

A shift of the magnitude defined above also requires rethinking the distribution planning and operations paradigm. This new paradigm should include a constantly maintained and accurate physical power system network model (as-built and as-operated), standardized Application Programming Interfaces (APIs) to exchange data and a set of advanced applications that can capitalize on the richness of data and the fidelity of today's models. It also calls for new control paradigms based on the best architectures (centralized, decentralized or distributed) to solve specific problems through an integrated architecture. Examples of such value-added applications include demand forecasting, Volt-VAR Optimization (VVO), threat/intrusion detection, damage assessment and improved situational awareness at the grid-edge.

Each utility much approach this journey in its own way but there are common challenges and considerations that shape strategy:

- *Type of utility: IOUs, municipals and co-ops all have different levels of resources as well as capabilities of their personnel (IT and power system). Many are also working to solve different problems. For example, an IOU with multiple geographic footprints and large customer base may seek to solve broad challenges first. Munis and co-ops (especially the smaller ones), on the other hand, may have more specific problems that require point-solutions.*
- *Microgrids: Still an uncommon asset, some microgrids are owned by the utility and some are owned by third parties. However, in the continental United States, most of them are still connected to the grid most of the time. Therefore, they must be managed for two different operational scenarios — one for grid connected and one for disconnected.*
- *Multi-dimensional problems: Taking the example of VVO, the solution will depend both on the grid conditions that are causing the Volt-VAR issues and require fixing, but also on the set of controls available to alleviate the root problem when it has been identified. As a result, one algorithmic solution may not solve every VVO problem or capitalize on every opportunity.*
- *Networked or radial configuration: Solutions will need to consider the type of grid they are managing because the networked configuration has multiple paths and hence multiple options to solve the same problem. However, the radial configuration has limited options available because of fewer (or none) cross-connects between the feeders.*
- *DER penetration: In some utility territories, a significant percentage of the load volatility and resulting variability is driven by increasing inverter-based resources. Thus, drivers for a utility with high DER penetration can be significantly different from those at a utility with low DER penetration.*

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While every utility will have a unique combination of ADMS drivers, the idea that each utility will deploy a customized solution to integrate hundreds of thousands or even millions of grid edge devices is not sustainable from a time, cost, and resources standpoint. As an industry, we need to leverage standardization, where it makes sense, to enable cost-effective integration of the growing diversity of DER, edge devices, and data streams. For example, standardizing the APIs that enable applications to talk to each other and exchange data is one significant step that would streamline deployment and integration without eroding flexibility for utilities to tailor their ADMS solutions to their most pressing needs. Such approaches are very common in other industries. A good example is the USB connect protocol that allows virtually all devices to connect to a computer and pass information back and forth.

References for additional reading:

1. *Voices of Experience: Insights into Advanced Distribution Management Systems, whitepaper by the National Renewable Energy Laboratory for the US Department of Energy, February 2015.*
2. *Electric System Operations – Evolving to the Modern Grid (2nd edition), author Dr. Mani Vadari, published by Artech House, used as a textbook by several universities.*