21, rue d'Artois, F-75008 PARIS
http : //www.cigre.org

CIGRE US National Committee
2022 Grid of the Future Symposium

Advanced Metering Infrastructure as a Key Program in LUMA Energy's Grid Modernization

David G. HART, Julio Romero AGÜERO
Quanta Technology, LLC
USA

Aleksi PAASO, Louis SANTILLI
LUMA Energy
USA

SUMMARY

LUMA Energy is responsible for operating, maintaining, rebuilding, and modernizing the transmission and distribution (T&D) systems in the Commonwealth of Puerto Rico. Several factors—including past severe weather events and aging infrastructure—have singifiacntly compromised Puerto Rico's power grid. As a result, the grid's reliability and resiliency have decreased, such that the grid's reliability is at the bottom of the fourth quartile in the United States. The outage frequency in Puerto Rico for the 2023 fiscal year was 6.90 per customer, multiple times worse than any other similarly sized utility in the United States.While this number represents a significant improvement from the previous T&D operators's baseline of 10.6 outagee; t hese reliability gaps are especially impactful to an area facing increasingly frequent extreme weather, especially hurricanes. LUMA Energy planned and implemented various programs and goals to address these issues through thorough redesing and rebuild of the T&D grid. The programs and goals will improve reliability and resiliency, support decarbonization efforts, and yiled to various customer service/societal benefits.

When deploying system replacements thought its rebuild program, LUMA Energy will implement technologies to modernize the T&D grid. The distribution grid of the future must meet traditional requirements but must also be capable of meeting new requirements. These new requirements are driving the need for new solutions at the feeder, substation, and application levels.

This paper outlines the concept of grid modernization, discusses creating supporting programs, and provides an overview of how AMI will play a more prominent role in the grid modernization of future distribution systems.

KEYWORDS

AGI: Advanced Grid Infrastructure
AMI: Advanced Metering Infrastructure
FoF: Feeder of the Future
Grid Modernization

julio@quanta-technology.com

INTRODUCTION

LUMA Energy is responsible for operating, maintaining, rebuilding, and modernizing the transmission and distribution (T&D) systems in Puerto Rico. Several factors—including severe weather events and aging infrastructure—have compromised Puerto Rico's power grid. As a result, the grid’s reliability and resiliency have decreased, such that the grid’s reliability is at the bottom of the fourth quartile in the United States. The outage frequency in Puerto Rico for the fiscal year was 6.90 per customer, multiple times worse than any other similarly sized portion of the United States. While this number represents a significant improvement from the previous T&D operators’s baseline of 10.6 outagee , These reliability gaps are especially impactful to an area facing increasingly frequent weather, especially hurricanes. LUMA Energy planned and implemented various programs and goals to address these issues through thorough redesing and rebuild of the T&D grid. The programs and goals will improve reliability and resiliency, support decarbonization efforts, and yiled to various customer service/societal benefits.

GRID MODERNIZATION

The distribution grid of the future will need to meet traditional requirements but must also be capable of meeting new requirements. These new requirements are driving the need for new solutions at the feeder, substation, and application levels.

The grid modernization plan is to upgrade the distribution system to address the following:

- Aging infrastructure
- Evolving changes to climate and weather patterns (e.g., more frequent and more severe storms and catastrophic events, such as hurricanes)
- Stresses and requirements imposed on the existing grid by the adoption of new technologies, such as DER and electrification

Evolving expectations of customers regarding reliability, resilience, and power quality”

Figure 1 illustrates an envisioned evolution of the distribution grid.

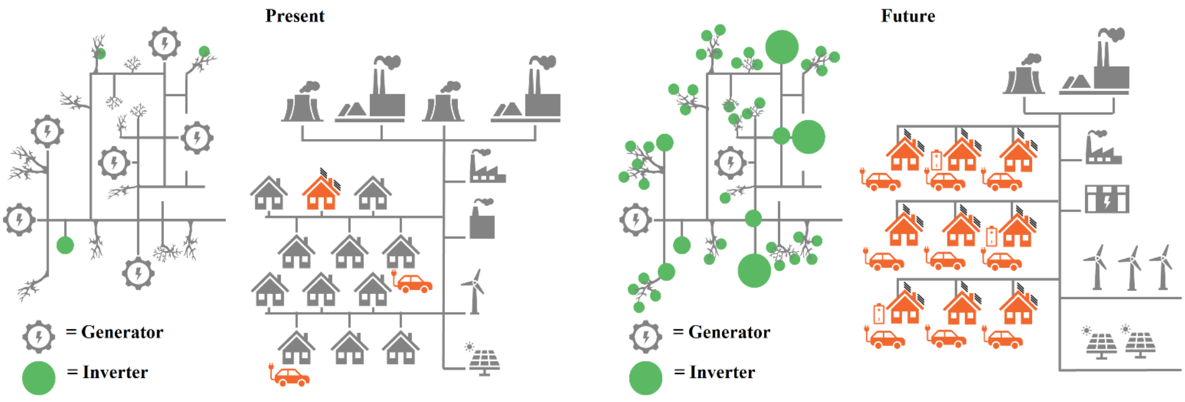

Figure 1. Envisioned Grid Evolution

Grid modernization enables key capabilities and features for a modern and future grid, including the following [1]:

- Improved reliability for everyday operations
- Greater resilience to hazards of all types [2]
- Increased sustainability through the adoption of renewable resources

- Flexibility to respond to the variability and uncertainty of conditions at one or more timescales, including a range of energy futures

Grid modernization typically includes improving reliability via reclosers, vegetation management, as well as efficiency through Volt/VAR control and optimizaiton. In addition to these programs, the grid modernization plan should “include modernizing the power delivery infrastructure to 1) prepare or ‘future proof’ the distribution grid for the adoption of DER (e.g., distributed generation, distributed energy storage, etc.), electrification and emerging technologies, and 2) enable the required capabilities to meet the utility’s strategic objectives and regulatory requirements, such as reliability and resilience improvement (e.g., harden the grid against major weather events), decarbonization (e.g., adoption of DER and electric vehicles), and climate change preparedness.” [5] In the future, the distribution grid will become more complex, involve more system demands, and interface to more devices on the feeder and at the grid edge. Figure 2 shows some of the components and interface points for the feeder of the future (FoF). In the figure, blue denotes more traditional components, and green indicates changing or emerging components. The combination of traditional and changing/emerging components illustrates the distribution grid’s evolving nature. Intelligent sensors in the figure include numerous devices, such as smart meters, phasor measuremewnt units [3,4], power quality meters, and current and voltage sensors.

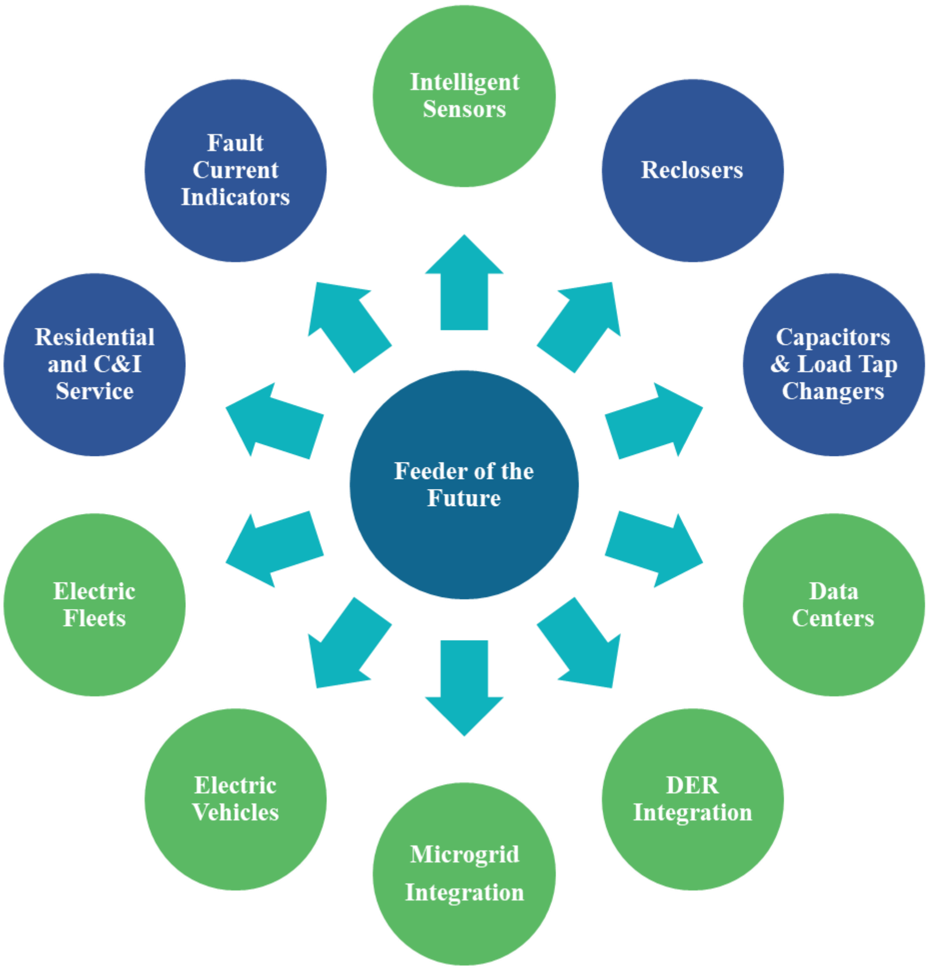

Figure 2. FoF Components

GRID MODERNIZATION PROGRAMS

Grid modernization plan is a prioritized sequence of capital deployments. A grid modernization roadmap consists of a properly sequenced portfolio of programs. Programs are projects or initiatives that can be implemented to realize the desired functionality, capability, or other specific utility goals. For example, since one of LUMA Energy's key drivers is reliability improvement, programs that reduce the frequency and duration of service interruptions are amongst the highest prioirities (e.g., implementing feeder automation, enhancing the outage management system (OMS), or perfoming singifianct vegetation clearing of the heavily ofrested righ of ways). To provide enhanced usage and outage information to customers, program options could include customer portals to enhance customer interaction [5].Once a program is identified, it is prioritized based on information such as the following:

- Relevance to ongoing programs (e.g. ADMS)
- Impact on improving grid reliability and resiliency
- Quantitative and qualitative benefits from implementing the program
- Ability to support future goals of the grid [6]

Additional factors, such as program complexity, technology maturity, implementation risks, and organizational readinessare considered in the program prioritization [6].

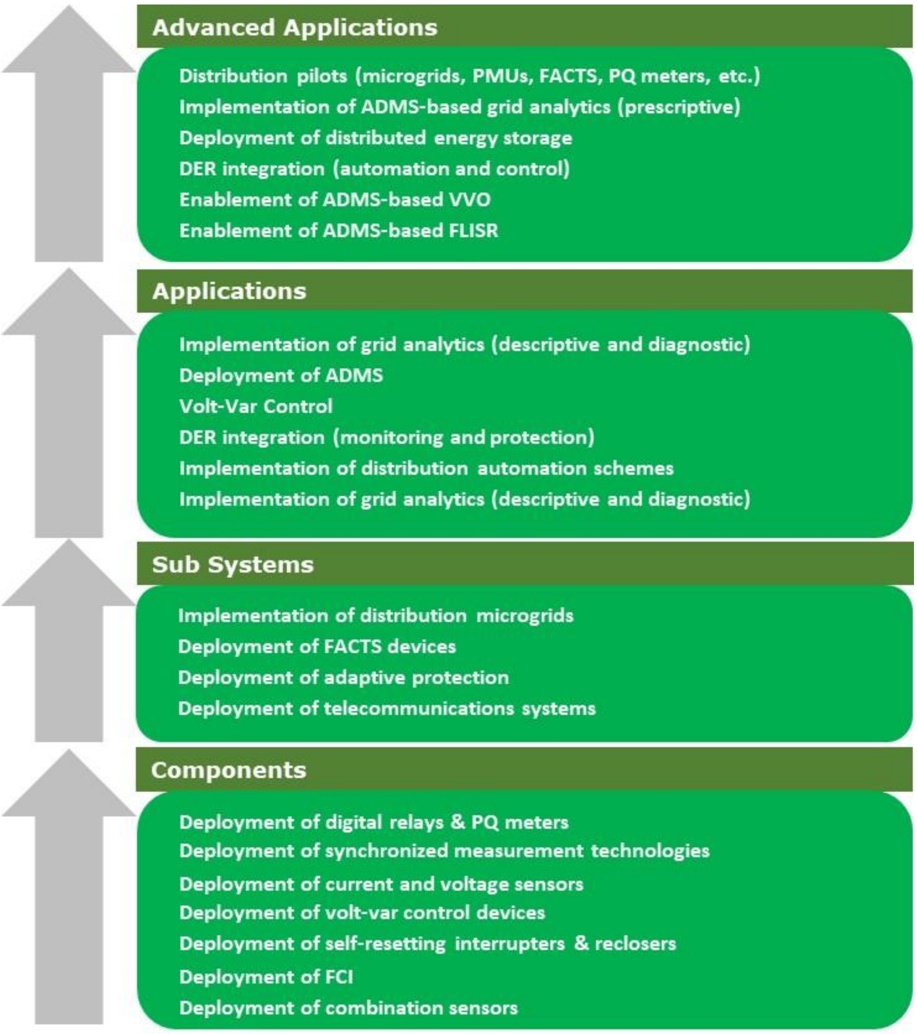

Figure 3. Grid Modernization Programs

Examples of some grid modernization programs under consideration are outlined in Figure 3. In prioritizing these programs, it is important to consider the interdependencies with other components, and a component's potential to help achieve strategic goals. Here it is worth noting that all components are important, particularly in the long term, while some are more important in the short term [5].

The grid modernization plan isdivided in timelines such as short term, mid-term , and long term. The proposed implementation timeline is intended to balance 1) the urgency to address critical short-term distribution system needs, such as reliability improvement, 2) availability of funds, 3the level of effort involved in the implementation of the selected components [5].

As the programs are implemented, deploying sub-system telecommunications is required to enable the applications. Communication is always a key issue for distribution networks and often involves several different solutions such as microwave, fiber to substation, dedicated radios or cellular modems, or other technologies. If an AMI network is deployed, however, it has the potential to address many of the overall communication requirements.

GRID MODERNIZATION AND ADVANCED METERING INFRASTRUCTURE
Historically, residential electromechanical meters were manually read and te consuer usage recorded by the meter reader. Large commercial and Industrial (C&I) customers had more sophisticated metering capabilities such as time of use, demand. As metering systems have evolved from these manual read systems to drive-by systems for improved efficiency and accuracy, and most recently to fully integrated two-way systems which has driven substantial changes in metering system capabilities. As part of an Advanced Metering Infrastructure (AMI) system, smart meters have functionality such as load, demand, and voltage profiling previously only available for large C&I customers available at every metering point. With two-way communications, an AMI system can provide additional information on outages, outage duraction, service voltage, power quality, etc., which can be of tremendous benefit to the utility and the end customer. Such programs enable a broad range of capabilities that result in utility cost savings and customer satisfaction improvements by providing the ability to offer more information to the utility and customers, AMI is a key modernization program and enabler of advanced functionality in other systems such as customer information systems (CIS), outage management systems (OMS), and advanced distribution management systems (ADMS). As such, AMI programs are seen as top-priority foundational programs due to a large number of related and dependent programs, as well as the savings and customer benefits they make immediately available [7]. Figure 4 shows the evolution of meters to smart meters in an AMI system.

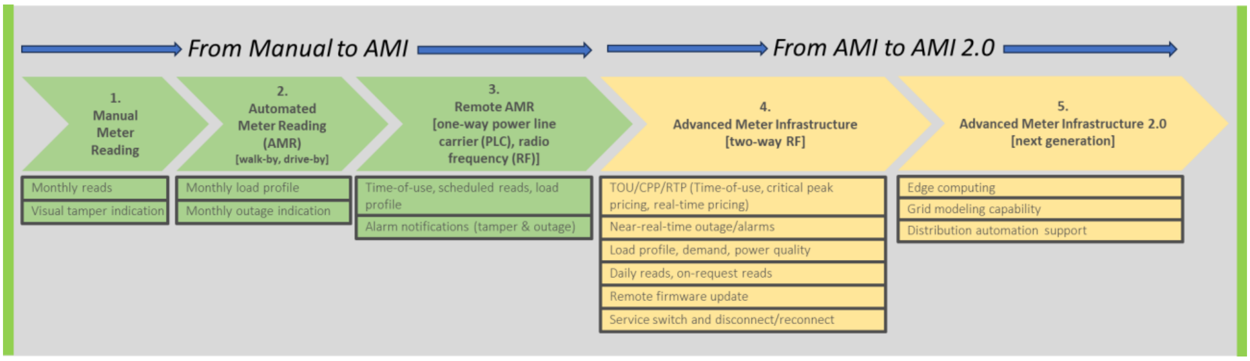

Figure 4. Evolution of Meters to Smart Meters/AMI Systems

The AMI system implements a two-way remote meter reading capability that includes the smart meters,a digital communications network (DCN) to the meters and other grid edge devices, a wide area network (WAN) to the system access points, and the system head-end applications that interface to systems such as billing, outage management, etc. While new technologies are in progress, AMI systems typically utilize the ‘star’ (a.k.a. point-to-multipoint) and ‘mesh’ (a.k.a. peer-to-peer) architectures [5].

Since AMI systems have been deployed in the field for many years, the initially deployed systems are reaching the end of life and will need to be replaced. During the deployment of the AMI systems, the technology has continued to evolve. Commonly referred to as AMI 2.0, the next generation of AMI technology enables new functionality that can support utilities in better understanding and managing the distribution grid. While the new functionality varies by the AMI supplier, it is worthwhile to point out some of the key AMI 2.0 features available on the market:

1. **Grid Modeling Capability**: Grid modeling involves functionality in the smart meter that allows it to determine which phase the meter is installed on. It may also include the capability of the meters on the transformer's secondary voltage to self-identify and form a virtual meter for the transformer. The grid modeling capability is important following a major storm. During restoration, the focus is on restoring power to the customers, and the grid can be modified at the feeder level. Alternatively, the distribution transformer can be connected to a different phase. By knowing which phase and transformer the meter is on, the distribution grid model can be updated. Grid modeling is also useful for improved load flow analysis, phase balancing, and other applications on a routine basis.
2. **Edge Computing**: Edge computing is the meter’s ability to include applications in the meter developed by third parties or the meter vendor. Edge computing allows for developing specialized applications in the meter. This can potentially be used to interface to DER devices, perform advanced power quality functionality, or develop a specialized application. These applications can be deployed at meters across the grid and allow for using a customized application that addresses utilities’ future, unforeseen needs.
3. **Improved Distribution Automation Support**: While most AMI systems have been used to support feeder automation and other applications using the AMI communications network, there are some improvements in the overall implementation to allow for performance closer to a SCADA pipeline. The tradeoff in using an AMI digital communications network versus a dedicated SCADA network involves many factors. These include SCADA communications availability, the criticality of the function to perform during a storm (e.g., feeder reconfiguration vs capacitor bank control), and the cost for communications in a program (e.g., fault current indicators or Volt/VAR control and optimization) in relation to overall benefits. In reality, the implementation is often a combination of many factors based on the individual case. New technologies may also impact the overall approach to AMI communications in the future.
4. **Advanced Analytics**: Analytics can leverage grid modeling capabilities, edge computing, and other smart meter functionality to improve insights on the system operation and impacts due to storms, electrification, DER deployments, and other factors.

As mentioned earlier, it is important to understand that each AMI supplier will offer different functionality at various price points. Engineers must understand the AMI system’s capabilities and how to cost-effectively leverage the capabilities to support the various programs. In order to do this, utilities should define use cases and applications beforehand (e.g., system model support, feeder restoration schemes, or electric-vehicle monitoring) and the AMI system pricing model.

Rather than discussing and viewing the meter as a metering device, utilities (and AMI suppliers) are shifting toward viewing the meter and its DCN as a component of a grid modernization plan [5]. If fully leveraged, the grid modernization plan will leverage the grid modeling capability, edge computing, and DCN to support the grid modernization applications. Figure 5 illustrates this idea. With the new utility drivers, utilities have the opportunity to fully leverage AMI 2.0 as part of their overall grid modernization program. This expanded focus from AMI's traditional role to a much wider role in grid modernization is referred to as advanced grid infrastructure (AGI).

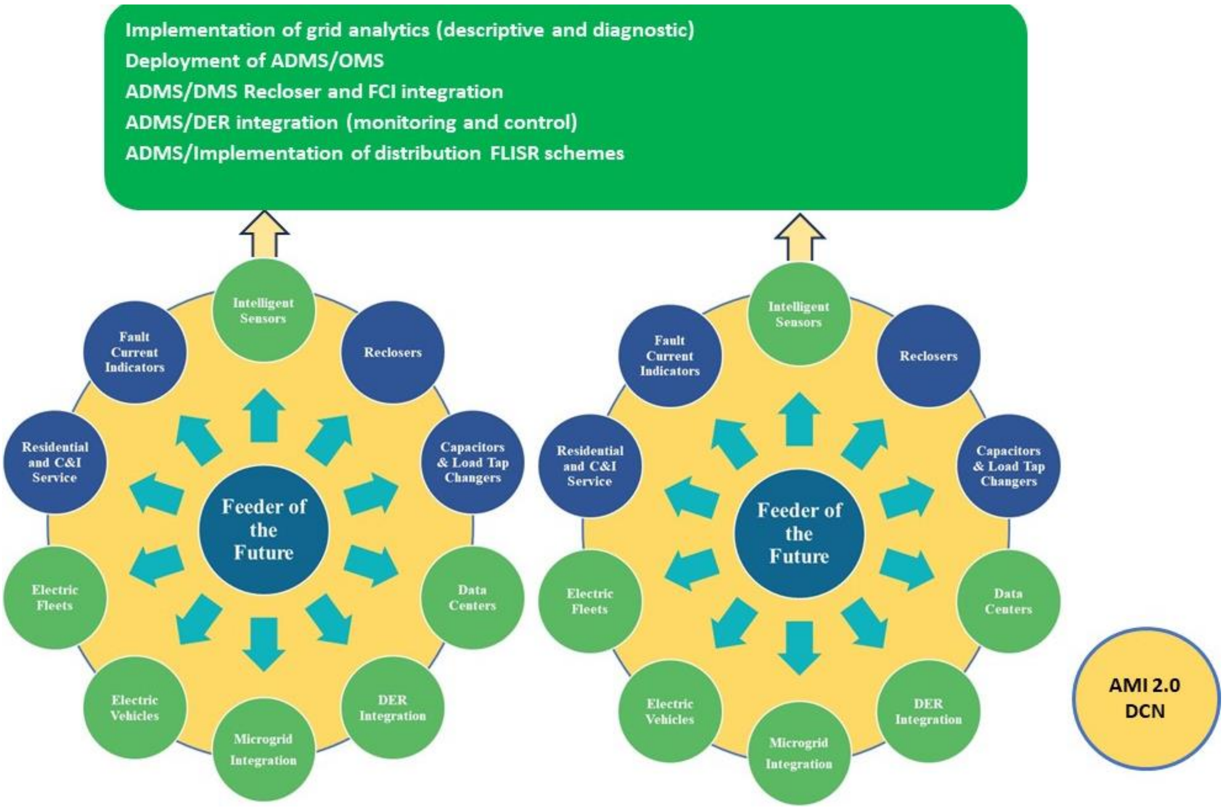

Figure 5. Grid Modernization Programs Leveraging AMI 2.0

NEXT STEPS AND SUMMARY

As LUMA Energy and other utilities continue grid modernization initiatives, integration of renewables and DERs, adoption of electric transportation, and climate change readiness AMI 2.0 can support programs to proactively manage distribution system assets to optimize operations, improve performance, and minimize (or prevent, to the extent possible) system disruptions [5].

Like other utilities, the Puerto Rico grid is transforming with the addition of DERs, including solar, EV, batteries, and microgrids. However, the aged infrastructure and limited information on the grid will impede the system's performance. To support this transition, LUMA Energy is implementing grid modernization programs such as recloser deployments, Fault Current

Indicators (FCI), Substiaons with IEC 61850, phasor measurement units (PMU), and new EMS, ADMS, and DERMS capability. The next major step is to deploy AMI 2.0 as part of an overall AGI concept as part of the grid modernization plan.

Key components of the AGI grid modernization program are as follows:

1. Advanced Meter Infrastructure (AMI) – Enhance customer service, improve meter-to-cash processes, and add sensors to provide real-time system voltage/current.
2. Digital Communication Network (DCN) – communication network for AMI as the core tenant with available capacity and capabilities for incorporating intelligent electronic devices (IED) distribution assets. The DCN will integrate devices such as reclosers, fault indicators, capacitor banks, voltage regulators, and other sensors.
3. Advanced Analytics – Advanced analytics will process this large volume of data and use machine learning algorithms to provide proactive actionable tasks for grid resiliency, reliability, and sustainability. Potential applications include SAIDI/SAIFI calculations, grid modeling, power quality monitoring, transformer loading, and EV and DER detection.
4. Customer Engagement – Customer engagement will include advanced energy efficiency, demand response, electric vehicle, and distributed-generation-promoting programs. It will include a customer portal, providing customers with detailed information on their energy usage, promoting energy efficiency, and supporting affordability.

BIBLIOGRAPHY

[1] J. Romero Agüero, A. Khodaei, R. Masiello, "The Utility and Grid of the Future: Challenges, Needs, and Trends," *IEEE Power and Energy Magazine*, Vol. 14, No. 5, Sep-Oct. 2016, pp. 29-37 https://ieeexplore.ieee.org/document/7549242

[2] National Academies, *Enhancing the Resilience of the Nation's Electricity System* (2017), https://www.naspi.org/sites/default/files/2021-08/quanta_distt_synchronized_.

[3] "Distribution System Synchronized Measurement Technology Deployment – Industry Roadmap Development," Oak Ridge National Lab, 2021.

[4] E. Udren, J. Romero, L. Hintos, D. Hart, K. Jones, "Advance the Distribution Grid with Synchronized Measurements," *T&D World*, September 2022.

[5] D. Hart, J. Romero Agüero, A. Paaso, "Utilizing Advanced Metering Infrastructure (AMI) as a Foundational Component of a Grid's Modernization," PACWorld Conference 2022.

[6] David G. Hart, Julio Romero Agüero, Bob Dumas, Donald Hall, and Mike Longrie, *Grid Modernization for Public Power Cooperatives: Creating a Roadmap for Investments*, whitepaper for Quanta Technology.

[7] Bob Dumas, David G. Hart, Mike Longrie, and Jeff Richardson, *Smart Meters and Grid Modernization: Guide to a Successful AMI Implementation*, whitepaper for Quanta Technology.