Thought leadership
White paper

3 lessons hydropower generation can learn from transmission and distribution

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Abstract

Hydropower facilities share many similar challenges with transmission and distribution (T&D) utilities: pressure to improve reliability, efficiency and profitability, protect against new security threats and address the impacts of an aging infrastructure and workforce.

This paper outlines best practices gleaned from T&D utilities to help hydropower facilities optimize generation assets against the challenging demands of a modern, digitized electrical grid.

The following themes will be explored:

Grid modernization

It's the same story for many plants: big pressure to produce more energy with a large loss in headcount through retirements and downsizing. On top of that, much of the plant's equipment could be up to 65 years old and past its useful service life. Utilities responsible for transmission and distribution perform due diligence when implementing innovative technologies through extensive pilot testing. The best practices and lessons learned from these pilot programs can help the hydropower operators reduce risk when modernizing systems with newer technology.

Powering Business Worldwide

Harnessing big data, realizing the value of Internet of Things (IoT)

As hydropower facilities move from supporting an aging grid to an effective and completely modernized grid, management teams need to proactively focus on rapidly changing technology. This section will describe why data and analytics hold the power to lay the groundwork for the smart grid of tomorrow. Areas explored will include the results of smart monitoring and control solutions applied in various utility environments.

Addressing the critical nature of cybersecurity

Connected devices and the vast amounts of data they generate create opportunities as well as risks: from manufacturing and testing to installation and service. In this section, the author will explain why cybersecurity threats must be taken seriously before presenting a system-wide defensive approach specific to organizational needs. Attendees will learn best practices to keep control system networks ever alert to changes in cybersecurity and work to prevent any potential vulnerabilities.

Market drivers in the electric industry

The invention of the electrical grid was named by the National Academy of Engineering as the single greatest achievement of the 20th century. Per the Hydropower Vision report[1], published by the National Hydropower Association and completed by the Department of Energy, the greatest challenge of the 21st century is "ensuring the availability of low-carbon, affordable and secure energy."

The electrical grid has been undergoing a transformation to tackle these challenges. This transformation has been driven by customer demand and new legislative and regulatory requirements. Demand response technology has provided utilities greater end-user consumption insight and centralized control to optimize power usage within consumers' homes and smart commercial or industrial buildings. The inclusion of distributed energy resources into the electrical grid has provided a means for the utility industry and consumers to offset peak demand with local, green energy sources such as hydro, wind and solar generation.

Investment in distribution and transmission systems — in storm-hardening programs, driven by large storms such as Super Storm Sandy in 2012, and Smart Grid and demand response programs, driven The American Recovery and Reinvestment Act of 2009 — have had a positive impact on the efficiency, reliability and affordability of energy. The hydropower market is now well positioned to incorporate proven, known technology into existing hydropower generation operational programs and realize the benefits, learning from the pilots of the T&D Smart Grid technology implementation.

Overall, grid transformation is likely to drive investment in hydropower generation. With the generation mix changing away from fossil (particularly coal) and nuclear sources toward green sources such as wind, solar and hydro. Meeting energy demand with these renewable sources requires greater grid flexibility and reliability. In 2015, hydropower accounted for over 48 percent of renewable power generation[1]. Many hydropower generation facilities were built prior to 1950 and must update their facilities to incorporate today's technology and design, pursuing increases in efficiency, reliability and operating life of existing units[2]. Over $800M was invested in hydropower generation modernization in 2017 and this trend is expected to continue.

Two worlds meeting — a comparison between T&D and generation

Generation and operation of the electrical grid have been largely separated since the 1995 passing of Order 888, mandating utilities separate generation and transmission assets[3]. This inherently separated the sharing of innovation regarding equipment and operational strategy. At the same time, consumers, particularly large users, have become more knowledgeable in the utilization of electricity — but this has largely occurred separate from the generation sources.

Per the National Conference of State Legislatures (NSCL)[4], 29 states, Washington DC and three territories have adopted renewable energy targets through Renewable Portfolio Standards (RPS). These standards have increased the focus on incorporating renewable generation and resources as a part of the utility supply portfolio, resulting in increased focus on improving hydropower plant efficiency and flexibility to meet peak demand — improvements that increase overall grid reliability while meeting legislative and regulatory requirements. Each RPS also defines what type of power generation is classified as renewable and counts towards these mandates. Per the Hydropower Reform Coalition[5], in 2014 only 37 states, including the District of Columbia had provisions for including hydropower though they might be limited by size, operational efficiency requirements or environmental regulations. Consequently, the value of hydropower as a renewable generation source has not been fully captured across the United States.

In 2012, the U.S. Department of Energy[6] stated that utilities saw as much as a 49% improvement in SAIFI (System Average Interruption Frequency Index), i.e., outages, through the implementation of feeder automation. New technologies and equipment monitoring have increased safety of personnel. Standards driving interchangeability and cybersecurity have been developed to ease implementation. Best practices have been developed through DOE funding grants on how to implement new technology, ensure the assets are protected, and communicate the value of these programs and increase consumer engagement. The availability of data has eased the road for project justification to continue the electrical grid transformation.

These are all concepts that are applicable to the upcoming modernization of hydropower generation.

Key issues hydro generation needs to address

Three key areas should be addressed as leaders develop the strategy for hydro generation: grid modernization, leveraging IoT technology and concepts, and cybersecurity.

Grid modernization

Grid modernization between transmission and distribution and generation facilities is not that different at its core — driving efficiencies in power generation and the workforce as well as improving system reliability. In addition, FERC requires equipment reviews and completion of necessary upgrades as part of the license renewal process. Three categories for lessons learned from utility grid modernization projects have emerged: equipment upgrade and associated technical standards, consumer education and support, and safety improvements.

New equipment technology has emerged that integrates digital control, remote control and communication — and can operate equipment with higher levels of sensitivity and accuracy. When modernizing equipment at a generation facility, it is important to ensure it all operates with standard interchangeability, meaning subsystems will communicate with each other and operate on the same basis of measurement. Over the past 15 years of distribution smart grid implementation, new standards have emerged to ensure manufacturers are incorporating both this interchangeability and cybersecurity into their designs. Vacuum breakers are an example of equipment that has been developed with grid modernization needs in mind and can also be applied within the walls of a generation facility. Industry standards such as IEEE Std C37.59-2007 — IEEE Standard Requirements for Conversion of Power Switchgear Equipment — are requirements for utility distribution and generation facilities. Generation facilities referencing these standards for testing will benefit from meeting these standard requirements.

Customer support and engagement were unexpected hurdles for utilities on the road to the Smart Grid. Smart Grid programs, such as smart meters, microgrids and demand response programs, were originally designed largely without customer input. They were designed by utilities and submitted for review and approval to the PUC, which theoretically acted in the end users' best interest. However, end users were rarely engaged to determine if they would support and "opt in" to energy-efficiency programs and pay for the equipment to run them — though over time it would have a positive impact[7] on their monthly bills. As a result of poor feedback for participation programs implemented in 2009 and 2010, utilities began outreach programs[8]: websites educating customers, community summits with local leader support, local educational institution partnerships, investments in community projects such as solar farms, and post-implementation success stories and environmental impact statements. The hydro generation industry should undertake a similar effort to support grid modernization and educate its customer base about choosing this form of renewable energy to power their homes. Power customers now want to be part of the process and educated energy users.

Safety is always a top priority for all employers — and risks increase when operating equipment that is over 60 years old. In 2018, NFPAs 70E Standard for Electrical Safety in the Workplace was updated to reflect new requirements for arc flash safety, including new testing and classification of equipment. The standard improvements have driven greater awareness of the hazards and risks associated with working on energized equipment. As a result, equipment studies, arc flash training, improved PPE and equipment innovation have emerged to improve safety.

Transmission and distribution yards typically have the real estate to separate equipment, allow more working space, and give operators equipment such as hot sticks to allow for safe operation. When metal-clad switchgear houses are used, space becomes more limited. With less working space, arc flash hazards become much higher. To provide a higher degree of protection, new technologies have been incorporated into the switchgear; it can now be built to arc-resistant standards to allow users to operate equipment without the threat of an arc flash. Relays have been equipped with light-sensing sensors that can detect an arc and help limit the amount of arc energy by tripping out the breaker quicker. Technology also has changed the way breakers, PTs and CPTs are drawn out. The cells can now be integrated with motor operators that allow the devices to be drawn out from a remote location. An operator can open and close the breaker, and put it in the connected, test, or withdrawn position without even being in the same building. Figure 1

Hydropower generation can use some of these technologies for its medium voltage switchgear as well. Space in very limited in a hydro facility. Much of the utilization equipment in a dam is operated at 600V and less. Technologies exist that now allow UL1558 switchgear to be front mounted and put up against the wall. Devices such as arc quenchers can be installed in the switchgear to limit arc energy below 1.2 cal/cm^2. This not only limits the need to use arc gear with some type of exhaust, but provides some of the highest degree of protection against an arc fault. Equipment damage is so minimal that after a fault, the equipment can be up and running with minimal repair. During most arc faults, switchgear must be deenergized and structures typically need to be replaced. The power breakers and molded case breakers can have an arc reduction maintenance system with the trip unit. Some arc reduction maintenance systems have analog circuits that recognize an arc and bypass the normal electronics in the trip unit, allowing the breaker to open in under 40 Msec. This can lower the arc energy in a downstream panel with a 40 kA fault to less than 1.8 cal/ cm^2. Figure 2

There are many solutions to improve operator safety and limit equipment damage in even the tightest spaces. The key is to understand what is available.

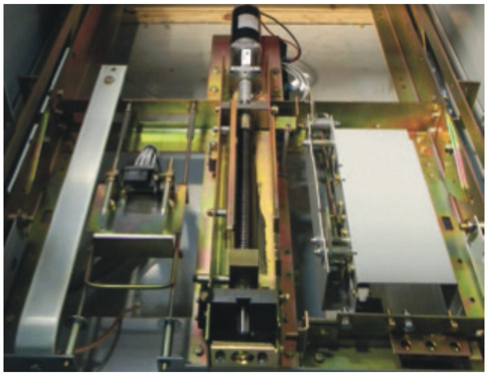

Figure 1: Picture of racking mechanism built into the MV cell

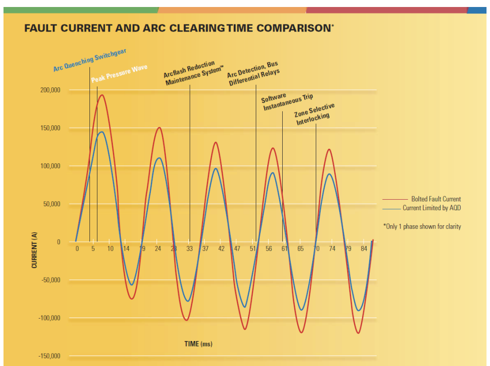

Figure 2: Comparison of arc clearing times

Harnessing big data, realizing the value of IoT

While the IoT is defined by the capability to send and receive information from objects and devices using the internet, its true value is making the data actionable. The utility world has been using IoT for one-direction communication and control for many years. This can be seen in thermostats that can be controlled to turn off during peak demand hours or distribution circuits that automatically reconfigure their reclosers to provide power to a set of customers during an outage. The grid is now undergoing a second transformation to further leverage IoT, allowing communication to go two ways. Customers' systems suggesting times for equipment to be turned off in an effort to reduce peak demand is a prime example. In addition to this user benefit, the utilities also have easy accessibility to system data on performance and benefits of the grid modernization initiatives. Benefits to data availability include system modeling for proposed improvements, justification data for proposals to the local PUC and results from approved programs, and quicker response to customers during restoration efforts.

These same principles can be applied to a generation facility. Equipment with data sensors provides real-time notification of outages and optimization of maintenance plans, contains memory of system events used for troubleshooting and future improvements, and allows remote control of assets for those plants with minimal staffing requirements. The data could also be used for modernization project justifications or prioritizations among a fleet of assets or providing necessary documentation to FERC during the lengthy relicensing processes.

IoT is also currently leveraged in the incorporation of digital twinning in hydro generation facilities. This is the digital or virtual representation of a physical asset using real-time data for optimization of output, predictive analysis and equipment modeling. Digital twins are used in multiple industries, including manufacturing, aviation and now, utility. Within the utility industry, it is most prevalent in distributed energy resources and renewables optimization, but it can be seen in coal, nuclear, and now hydro generation to optimize equipment and power generation.

There is also a benefit to human resources to leverage IoT and data communications technology — talent in Generation Z will be attracted by the use of the latest control technologies. They are more comfortable and excited to use the "latest and greatest," which will help address the void created by the increased retirements of baby boomers, estimated to be approximately 17% of the workforce in 2018[9].

Addressing the critical nature of cybersecurity

Cybersecurity is required to protect critical infrastructure within the utility grid, the reliability and functionality of the grid, and consumer data for energy consumption. With the growing use of smart devices and the IoT in the electric grid, there are an increasing number of avenues for outside users to penetrate the grid's industrial control system (ICS). This is a known concern for all areas of the grid. In 2018, the Congressional Research Service[10] published a report focused on electric grid cybersecurity. Examples of real and simulated cyberattacks were outlined, highlighting the need for action in updating requirements for grid security and response to such attacks. As outlined in the report, the simulated "Aurora" attack in 2007 for power generation demonstrated when a circuit breaker or breakers are opened and closed, an out-of-phase condition damages alternating current (AC) equipment connected to the grid. This highlights just one example of known risk for generation power facilities.

Recent changes in the NERC-CIP standards have focused on supply chain requirements, assessment of critical infrastructure, multi-level authentication, monitoring of access within the network and risk management programs[11]. However, with each system so diverse across the country, the standards outline just the required result, allowing users to establish the how. Equipment manufacturers are an ideal partner for determining system needs and developing the roadmap for full compliance with current standards as well as completion of risk management assessments. They can advise on best practices throughout the industry and incorporate the latest standards into security patches to ensure future compliance. Equipment such as Intelligent Electronic Devices (IEDs) — which have been typically used for substation applications and comply with all current product and cybersecurity standards — could be applied for hydro generation applications to facilitate secure communication.

The first focus after a grid cybersecurity event is to turn the lights back on. Smart Grid technology enables the distribution system to respond to a substation event by rerouting the grid or increasing generation from another source to compensate. This is effective in local or regional outages, but it would not be effective in large-scale outages. The next step is to repair the affected device or system. However, if the equipment is damaged, how is it replaced? Congress and the DOE are evaluating a strategy of building a strategic reserve of critical components[10], initially focused on large power transformers, which typically have significant lead-times from overseas manufacturers. A similar program could be developed for critical assets within a hydro generation fleet.

IT departments within utilities are becoming increasingly important to modernization efforts. FERC and DOE are requiring utilities in the Bulk Electric System (BES) to comply with all cybersecurity standards, and develop risk management programs and response action plans to address large-scale power outages. Inclusion of an IT professional is recommended for all grid modernization efforts. Benefits include addressing threats upfront and identifying scoping requirements early in project budgeting, determining equipment specifications to address cybersecurity, and completing testing when communication devices or remotely controlled devices are online to ensure proper security is in place.

Final considerations and conclusion

It is an exciting time to be part of the electrical industry, with average $800M annual investment[2] in hydro generation. This investment will make the grid more reliable and efficient with new technology and communications available. By not creating knowledge silos in the implementation of emerging technology, we can enjoy the benefit of realizing a more reliable and efficient grid in a shorter window.

Summary of key issues and lessons learned

Key issue	Category	Lesson learned
Grid modernization	Equipment upgrade and technical standards	• Implement new technology to update equipment – including digital controls, remote control and communication • Incorporate interchangeability and cybersecurity in product standards & specifications • Reference and require compliance to latest product and application standards
	Consumer education	• Plan for outreach programs to improve community and customer perception of modernization plans • Education websites, community summits, local influencer, institutional partnership, local investment, post-implementation success storie These should all highlight benefits to target customers
	Safety improvements	• Ensure equipment and project plans meet current standards – NFPAS 70E Standard for Electrical Safety in the Workplace • Incorporate equipment technology, such as arc reducing maintenance systems, to improve operator safety and limit equipment damage
Leveraging IoT technology and concepts	Data availability benefits	• Predictive equipment failure & maintenance needs • System modeling • Data for project evaluation and proposal • Digital twinning for scenario planning
	Talent	• Attracts Generation Z workforce with latest technology trends • Addresses Baby Boomer generation retirements
Cybersecurity	Changing standards	• Leverage equipment manufacturing partner to ensure compliance to latest standards • Leverage technology proven in T&D, such as IEDs • Incorporation of IT personnel in project planning phase
	Supply chain	• Review of critical asset inventory

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