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Electric Energy T&D MAGAZINE

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Electric Energy T&D MAGAZINE

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Cover photo: AEP's award winning energized 345 kV ACCC conductor upgrade in Texas

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CIO TOP 10 Vendors to Watch in Smart Grid

ACS™
Advanced Control Systems

POWERPOINTS

Off the Grid

As the technology of renewable energy marches on, the appeal to live off the electric grid is growing exponentially.

The burning question is which technology does one embrace.

Running on Waste

There are two brothers that own a dairy farm in Eastern Ontario. One of the brothers is an engineer and put his talents to work building a small scale anaerobic digester (AD) to transform the waste from all of their beasts to methane. Now they are supplying the entire farm using generators.

Dairy manure is well-suited for anaerobic digestion, having a relatively high dry matter content of about 12 percent. A dry matter content of 6 to 14 percent is considered the best range for digestion.

Anaerobic digestion is used in agricultural, municipal and industrial systems to treat organic materials. The process typically holds the material in an oxygen free environment for a 2 to 20 day period at a temperature of 30 degrees Celsius to 60 degrees Celsius. At this temperature and in the absence of oxygen, microorganisms break down the organic materials to produce biogas, consisting primarily of methane and carbon dioxide. Depending on the system design, the biogas can be combusted to run a generator producing electricity and heat, or it can be burned as a fuel in a boiler or other burner. In addition, the following advantages are usually found with AD systems:

- reduced odour and pathogen levels in the manure
- production of energy usually in the form of heat and electricity
- reduced greenhouse gas production from the farmstead, and
- improved fertilizer value of the manure through homogenization and mineralization.

The beauty of this operation is that they no longer have their $2500 monthly hydro bill.

A Cautionary Tale

My big brother has a farm north east of Toronto, Ontario. Not long ago, he asked me to look into the possibility of setting up three wind turbines with a view to supplying the farm and selling excess power into the grid.

I contacted a friend who is a high-ranking official at our provincial power system to feel him out on the prospects and challenges to be found in the exercise. He was very straightforward in his explanation. Assuming the energy company builds the turbines then my brother's three acres or so then fall under the jurisdiction of the utility and therefore it becomes private property. Access roads must be built and maintained, vegetation management becomes a priority, fencing and security must be in place. In other words he could say goodbye to that property. The other thing my friend said was that having structures like this on the land could kill his resale value if he ever decided to sell. Cables must be sunk deep and there must be proper connections at the farm.

The expense would be extortionate. But the reward of supplying yourself with electricity is definitely a bonus. There's no real guarantee the output of the wind mills would be profitable to the utility.

The Sunny Side of Life

My son is an electrician and has been installing more and more solar panels on residential and industrial units.

He is finding out how simple it is to generate solar power to offset use from the grid. Excess electricity produced can be exported to the grid where you receive a minimum of your retail rate.

Why lease power when you can own and produce it for less? By installing a solar PV system, one will be able to save on operating costs by producing your own power and hedging against volatile electricity prices. Protect the bottom line while protecting the environment.

Getting started

A detailed and comprehensive solar site assessment is a necessary component for any solar electric installation. A typical site assessment includes the following:

- Accurate measurements of roof or ground space including locations of plumbing stacks, chimneys, skylights, attic vents, etc
- Shading analysis from proposed location for solar (sometimes several points need to be analysed to determine the best location) – this data is used to provide accurate energy production estimates
- Discussion with home or business owner to determine route of cable from site of solar electric array to location of inverter/mains panel
- Determine location of inverter(s) and integration in to the building's electrical system.

The installer can then provide a preliminary ballpark cost, energy production, and an economic analysis specific to your home/building through email as a first step. For new construction residential and commercial projects, the installation company can provide a design and quote directly from the drawings for the building.

Making the decision to switch to solar is an awesome one. However, getting started and understanding the process can often be fraught with uncertainty for those unfamiliar with the industry. A qualified electrical contractor can usually provide turnkey systems and take care of all of the permitting, grid connection application, etc. Here is a list of the steps for a typical residential installation:

1. **Initial estimate** – If high quality satellite images are available, accurate estimates for system size and energy production for your specific house can be provided.
2. **Site assessment** – The contractor visits the site to obtain detailed site specific information required for a solar installation including detailed roof measurements, electrical capacity of your electrical system and a shading analysis (if required). For a new construction home, a system right from the architectural drawings can be designed.
3. **System design & quote** – The contracting firm will design a system specific to your roof space, budget and electricity needs. This is an iterative process and multiple options can be presented.
4. **Permitting and grid connection application** – ALL the permitting required (Electrical, Building and/or Development permits) and the application to connect the system to the grid will be handled by the electrical company.
5. **Installation and commissioning** – Done by highly trained and experienced installation crews.
6. **Final walk through with the homeowner and delivery of system manuals**

How do grid tied systems work?

Residential Grid Tied Solar Electric Systems
Solar panels are typically installed on the roof of the home and/or garage. These photovoltaic (PV) cells convert sunlight into direct current (DC) power.

The inverter(s) convert DC electricity from the solar array to the AC electricity found in the building. The inverter feeds electricity into the electrical distribution system. The bidirectional meter which is supplied free of charge by the utility, keeps track of both the energy imported from the grid and the energy exported to the grid. Savings and export credits are reflected on your electricity bill.

If you own an electric car, you can charge it up with solar power generated on your own home.
Your home remains connected to the utility grid to supply you with electricity when you need more power than your system is producing, such as at night.

Commercial Grid Tied Solar Electric Systems
Photovoltaic (PV) modules convert sunlight into direct current (DC) power. The inverter(s) convert DC electricity from the solar array to the AC electricity found in the building.

The inverter feeds electricity into the electrical distribution system. The bidirectional meter which is supplied free of charge by the utility, keeps track of both the energy imported from the grid and the energy exported to the grid. Savings and export credits are reflected on your electricity bill.

Some customers require that a solar system be installed to run separate aspects of their building such as opening a large garage door in an apartment complex

It looks like the time is nigh to get on the renewables bandwagon. I'm very pleased that steps are being taken to save our planet and ourselves.

National Renewable Energy Laboratory High Renewable Electricity Growth Continued in 2015

November, 2016

The 2015 Renewable Energy Data Book shows that U.S. renewable electricity grew to 16.7 percent of total installed capacity and 13.8 percent of total electricity generation during the past year. Published annually by the National Renewable Energy Laboratory (NREL) on behalf of the Energy Department's Office of Energy Efficiency and Renewable Energy, the data book illustrates U.S. and global energy statistics, including renewable electricity generation, renewable energy development, clean energy investments, and technology-specific data and trends.

"Since it was first released in 2009, the Renewable Energy Data Book has provided useful insights for policymakers, analysts, and investors," NREL Energy Analyst Philipp Beiter said. "The 2015 version of the data book highlights the ongoing trend of growing renewable energy capacity and generation in the United States and globally."

The 2015 Renewable Energy Data Book compiles recently available statistics for the 2015 calendar year. Key insights include:

- Renewable electricity accounted for 64 percent of U.S. electricity capacity additions in 2015, compared to 52 percent in 2014.
- Renewable electricity generation increased 2.4 percent in 2015. Solar electricity generation increased by 35.8 percent (11.7 terawatt-hours), and wind electricity generation increased by 5.1 percent (9.3 terawatt-hours), while generation from hydropower dropped by 3.2 percent (-8.2 terawatt-hours).
- The combined share of wind and solar as a percentage of renewable generation continued to grow in the U.S. in 2015. Hydropower produced more than 44 percent of total renewable electricity generation, wind produced 34 percent, biomass produced 11 percent, solar (photovoltaic and concentrating solar power) produced 8 percent, and geothermal produced 3 percent.
- Wind electricity installed capacity increased by more than 12 percent (8.1 gigawatts) in a year, accounting for more than 56 percent of U.S. renewable electricity capacity installed in 2015.
- U.S. solar electricity installed capacity increased by 36 percent (5.6 gigawatts), accounting for nearly 40 percent of newly installed U.S. renewable electricity capacity in 2015.
- In 2015, California continued to have the most installed renewable electricity capacity of any U.S. state (nearly 31 gigawatts), followed by Washington (nearly 25 gigawatts) and Texas (more than 19 gigawatts).California has a diverse mix of renewables led by solar PV, hydropower, and wind. In Washington, the main contributor to renewable capacity is hydropower, while wind is the largest contributor in Texas.
- Oklahoma had the highest growth rate (30 percent) in installed renewable electricity capacity additions in 2015, followed by North Carolina (27 percent), Utah (27 percent), and Kansas (27 percent). Additions in wind capacity were the main contributor to growth in Oklahoma and Kansas, whereas additions in solar PV capacity accounted for most of the growth in North Carolina and Utah.
- Installed renewable electricity capacity increased to more than 29 percent of total electricity capacity worldwide in 2015. Renewables accounted for more than 24 percent of all electricity generation worldwide.

The 2015 Renewable Energy Data Book is produced by NREL's Strategic Energy Analysis Center. For more on the data book, see the EERE Blog.

NREL is the U.S. Department of Energy's primary national laboratory for renewable energy and energy efficiency research and development. NREL is operated for the Energy Department by The Alliance for Sustainable Energy, LLC.

Southern California Edison SGIP Awards Southern California Edison the 2016 President's Award

SCE Receives Award for Their Leadership in Collaboration

November, 2016

The SGIP 2016 President's Award was given to Southern California Edison (SCE) for their leadership and collaboration in driving requirements to IT/OT systems as a result of high-penetration distributed energy resources (DER).

One of the biggest challenges is unlocking the tremendous potential that technologies such as rooftop solar, on-site energy storage, electric vehicles and energy management systems can provide to the local power grid while maintaining grid reliability and safety standards. To meet these challenges, SCE originated the idea of the Grid Management group, which was launched in February, 2016 and is facilitated by SGIP. This working group seeks to bring together grid operations technology and business leaders from utilities to discuss key operational concepts/capabilities and architecture principles relating to future Grid Control, as well as operational technologies needed to manage a more complex grid due to the rapid rise of DERs.

The award was presented by David Forfia, SGIP Board Chair, and Sharon Allan, President and CEO, SGIP, at SGIP's 2016 Grid Modernization Summit. The SGIP 2016 President's Award for Leadership and Collaboration was accepted by Andy Paylan, Manager, Advanced Technology, Distribution Analytics & Controls, and John Bubb, Principal Manager - Smart Meter Operations, Development & Quality at SCE.

"I am pleased to present this award to SCE who more than exemplified these qualities for which they were recognized: innovation, leadership, collaboration, excellence and transformation. It has been a pleasure working with their team," said Sharon Allan, President and CEO, SGIP.

THE GRID TRANSFORMATION FORUM

Envisioning the 21st Century Grid

Key Industry Trends

We are in discussion with Dave Bryant, Director Technology with CTC Global.

EET&D: With the 'winds of change' blowing like we've never seen in the history of T&D, what do you feel are the key trends and how do you perceive the industry is adapting?

Bryant: Before we cover your question, I think it would be helpful to take a quick look back at how the landscape has changed over the last several decades. For instance, back in the mid to late 1900's, there was very little connection between the electric power companies and consumers in most parts of the world. For those fortunate enough to have access to electricity, customers simply plugged in their appliances and ran them judiciously as needed. Electricity was a consumer's luxury and, following the great depression, folks recognized that fact and were aware of the costs. People conserved, naturally.

In the 1970's and beyond, consumers in developed countries took electric power delivery much more for granted and only really thought about electricity during power outages when the microwave, TV and ultimately their computers wouldn't operate. Over the last decade or so, our power companies and consumers have become much more connected.

EET&D: It sounds like you are teeing the conversation up to discuss Smart Grid.

Bryant: Well, we can certainly start there. The whole idea behind Smart Grid is to leverage data, smart meters and smart appliances to help squeeze the most out of our existing system. In other words, the Smart Grid concept allows electricity providers to control or incentivize consumers to use more electricity during off-peak hours and less during periods of high demand. This is due to the fact that demand has, in many cases, outgrown supply and development of new generation isn't a necessarily an easy task.

Add to that new environmental goals, policy changes, the closure of conventional generation resources and grid congestion, and you can see why this has become a major movement.

As an aside, it's quite encouraging to see how much more connected the utilities are with their customers. Many electricity providers have very informative websites and actively leverage social media to connect with an increasingly more 'data hungry' and informed consumer base.

EET&D: In terms of environmental goals and changing policy, where do you see us heading?

Bryant: My perception is that the climate change discussion has grown deep roots. It's fair enough that there are still two sides of the argument, but I suspect that in the wake of superstorms Katrina, Sandy and many others, the vast majority of our utilities recognize that the concept of climate change is quite real and that the frequency and severity of extreme weather events is substantially impacting grid reliability and associated repair and maintenance costs.

This awareness, coupled with climate policy changes, very tough regulations, reduced costs associated with renewable generation resources, growing consumer awareness, and many other factors are driving the 'environmental goal' forward at a pace most utilities are not generally accustomed to.

EET&D: How do you believe the utilities are adapting to the non-glacial pace?

Bryant: Frankly, I don't think they have much choice. Regulations such as FERC Order 1000 are opening things up to increased competition. Government policies that put limits on CO_2 and other GHG emissions are creating tremendous pressure. And other policy changes that relate to investment returns are driving the pace. Fortunately many new technologies offer the utilities several options.

EET&D: Such as?

Bryant: On the generation side there is obviously a huge move towards renewables such as solar and wind which are still receiving favorable government incentives to develop. We are also seeing a trend to convert coal fired plants to natural gas.

Additionally, new energy storage devices such as pumped hydro, flywheels and other novel kinetic devices are supplementing new battery storage technologies. Distributed generation and micro grid technologies are also beginning to play important roles.

EET&D: What about the grid itself?

Bryant: This is a good and quite challenging question. Planners have a very tough time aiming at a moving target. Existing sources of generation are being shut down. New sources of generation are being added - often from remote locations - and many new lines, including HVDC lines, have been proposed and are working their way through the approval and funding process.

Other grid challenges relate to the fact that much of our grid is substantially aged. The American Society of Civil Engineers, for instance, gave our grid a D+ rating when they completed their last survey in 2013. In addition to the age of the grid and its vulnerability to storm damage, it can often be highly congested.

EET&D: What is the significance of grid congestion?

Bryant: Grid congestion is essentially a situation that prevents consumer access to the least expensive or cleanest source of energy due to the fact that the wires and operating system don't have the capacity to transfer more power through a given circuit. The economic impact, historically, has been measured in the billions of dollars.

EET&D: What is being done to rectify this?

Bryant: Many congested lines are being upgraded with high-capacity, low-sag conductors such as ACSS (Aluminum Conductor Steel Supported), ACCR (Aluminum Conductor Composite Reinforced) and ACCC (Aluminum Conductor Composite Core). These upgrades - supplemented in some cases by other technologies - are definitely mitigating grid congestion and enabling access to cleaner sources of generation.

EET&D: Can you offer an example?

Bryant: Earlier this year, American Electric Power received the Edison Electric Institute "Edison Award" for reconductoring 240 circuit miles of a 345 kV line using the ACCC type conductor while the line remained energized. In addition to doubling the capacity of the existing corridor, AEP also realized a 30 percent reduction in line losses compared to the conventional ACSR (Aluminum Conductor Steel Reinforced) it replaced.

EET&D: The added capacity is obviously beneficial, but what is the significance of reduced line losses?

Bryant: Another good question. Transmission line losses in developed countries generally range from 2 to 4 or 5 percent. In underdeveloped countries such as India, overall system (technical) losses can exceed 20 percent. Commercial losses (or theft) can be significantly higher. In AEP's case, the project was in Texas. Based on a relatively low load factor of 34 percent and a peak operating load of 3,100 amps, it is estimated that AEP will save over 256,000 MWh per year.

On the cash side, at a reported wholesale cost of electricity of $0.12 per kWh in that region, that equates to a savings of over $30 million per year. On the 'green' side, assuming the U.S. national average CO_2 emissions from all combined sources of generation (1.372#/kWh) the CO_2 savings equates to a reduction of 159,484 Metric Tons of CO_2 per year. This is the equivalent emission reduction of removing over 33,500 cars from the road (1 car = 4.75 MT/year). Conversely, the reduction in line losses also freed-up 29.25 MW of generation capacity at an additional savings of roughly $35 million.

EET&D: These are impressive numbers.

Bryant: I agree. The efficiency aspect of transmission lines has, historically, been given relatively little consideration. With that said, over the last several decades we've spent billions of dollars improving the efficiency of generation equipment to reduce operating costs, and billions more improving the efficiency of demand side appliances to reduce the need build additional generation. Today we have the option of leveraging modern transmission technology not only to improve grid capacity and reliability, but also to improve its efficiency and support climate change mitigation initiatives.

EET&D: Thank you Dave for taking time out of your schedule to speak with us on a most interesting subject.

Bryant: My pleasure. Thank you.

About the author

Dave Bryant is Director of Technology at CTC Global Corporation in Irvine, California. Dave was a co-inventor of the patented ACCC conductor and ancillary hardware components. His 35 year background as a design engineer focused on the use of advanced composite materials in numerous industrial applications which helped expedite the development, testing, and commercialization of the ACCC conductor.

GREEN OVATIONS

Innovations in Green Technologies

Open-Source Smarts: How OpenFMB™ Supports DER Management

By Aaron Smallwood

If there's one kind of system that just about every firm has, it's a database. And, guess what? About 25 percent of relational databases are created with open source software, according to analysts at the research firm Gartner.

There are plenty of reasons open source code is gaining popularity. Among them are cost, as it's often cheaper than proprietary code you can get from only one vendor. Also, it often has enhanced reliability and security because both of these improve due to the rigorous peer review that open source code undergoes by the community.

At SGIP we are encouraging the industry to embrace open source solutions like Open Field Message Bus, or OpenFMB™. The OpenFMB™ framework can help utilities effectively manage a circuit with high penetration of DERs by adding a layer of local data exchange and control to augment a distribution management system (DMS).

Initially the brain child of engineers at Duke Energy, OpenFMB™ has been expanded and developed by SGIP's OpenFMB™ working group. In March 2016, it was ratified as a standard by the North American Energy Standards Board (NAESB). At SGIP's 2016 Grid Modernization Summit held November 7th through 10th in Washington, DC, SGIP made the OpenFMB™ code available to all and welcomes new development efforts from industry players.

Built to evolve with our changing grid

OpenFMB™ isn't a manufactured product, technology or solution. It's a reference architecture, a framework for distributed intelligence designed to drive interoperability and facilitate data exchange between field devices.

By design, OpenFMB™ operates in harmony with existing and commonly used standards, such as the International Electrotechnical Commission's Common Information Model (CIM). Similarly, OpenFMB™ is a common semantic or data model to be shared across various systems. You don't have to use the CIM, but it is commonly used throughout the electric industry in North America.

Other key ingredients of OpenFMB™ are publish/subscribe (Pub/Sub) protocols. These are used widely in the Industrial Internet of Things (IIoT) industry, and the development team leveraged three popular standards:

- DDS: Data Distribution Service
- MQTT: Message Queue Telemetry Transport
- AMQP: Advanced Message Queue Protocol

In addition, several principles guided development of the framework. First, it had to be an agile and evolving architecture. One of the core beliefs held by development team members is that there is no one-size-fits-all technology that enables DERs to integrate with the existing power systems. So, our industry needs a framework that is flexible enough to handle any data model and any pub/sub protocol. At the same time, we don't want to reinvent the wheel or duplicate any efforts in the standards community. It's more efficient to leverage what already exists.

Additionally, our development team focused on trying to solve real problems and delivering business value. Plus, we made sure the system is flexible, scalable and backward compatible. And, naturally, we built security in from the start.

An elegant work-around

So, what does OpenFMB™ do? It eliminates the need to send data back to a head-end system, wait for that system to crunch its numbers and make a decision, then carry out the decision via a control signal sent back to a grid-edge device.

That's what happens in today's utility landscape. A typical Supervisory Control and Data Acquisition (SCADA) system and DMS may come prepackaged with vendor-specific hardware, telecommunications and software. The only way to stitch various systems and technologies together is in the back office through integration. That takes time ... lots of it. If you're trying to coordinate solar and storage, for instance, the round-trip involved in such an effort takes so long, the cloud cover you were trying to correct for may already have moved on.

Today, it can be difficult to get information in the field shared between devices. So, we took the concept of an enterprise service bus and we put it as close to the grid edge as possible. With many of the devices that we would interconnect through this bus, there's already a computer with some type of Linux system installed, so you may not even need additional hardware with things like inverters and controllers.

Instead, you could use OpenFMB™ to put in a virtual node that would allow peer-to-peer communication using a semantic model based on common languages and protocols. And, because of how the OpenFMB™ framework was designed, it can run on top of any network – wired or wireless. You can install multiple buses to direct interaction patterns and isolate data exchanges for multiple use cases.

One of the key benefits of OpenFMB™ is its ability to enable distributed intelligence. This feature is what's needed for the efficient and scalable management of distributed energy resources, particularly on circuits with high penetrations of solar PV.

Another key attribute of the framework is its ability to provide local device coordination that is harmonized with existing centralized system control. Through this feature, grid operators can begin moving to a layered DER-management paradigm. That's important because a lot of the analytics that are needed for DER integration while also avoiding reliability issues will need to be at the grid-edge. And, based on those analytics, we're also going to have to coordinate DER-optimization to support the grid itself.

Putting OpenFMB™ to work

Once you start applying OpenFMB™, interaction patterns for each use case can be utilized to segment and isolate the data exchanges. For example, suppose you're using a bus for microgrid optimization or distributed energy resource management. To achieve optimization, you need a variety of actors that share a common set of parameters.

In the use cases noted above, you may have a common interaction pattern that facilitates near real-time readings of kilowatts, VARs, voltage, current, phase angle, kilowatt hours, time stamp and state of charge. All the unneeded parameters that you can potentially get from the connected devices are not published to the bus.

You'll be able to find code and documentation for the above microgrid use case on the OpenFMB™ Collaboration site, at *www.openfmb.io* a newly launched website available to any industry player that wants to leverage this architecture for grid modernization efforts.

The new site includes:

- An OpenFMB™ overview that helps newcomers learn what OpenFMB™ is, how it works and future activities
- Guidance on how you can get the standard itself from NAESB
- OpenFMB™-related publications and an ever-growing use case library
- Informational wiki's and ways for the community to interact with one another as we move forward

Best yet, you'll have access to OpenFMB™ code itself, hosted on an OpenFMB™ GitHub site. GitHub is an online collaboration site designed for hosting and developing open-sourced software. It allows people to download the code and share additional code that they've developed. We're making the foundational set of OpenFMB™ code available so that developers and vendors in the electric industry can build upon it and create an active open-source community.

Among the types of code now available on the new site *www.openfmb.io*, you'll find the OpenFMB™ Developers Toolkit, which is a downloadable, turnkey, executable file. Once you download it, you will be able to extract and install it, and you'll have an OpenFMB™ implementation largely ready to use. Along with the code comes a full set of instructions and how-to information to help you get the most of this resource.

The site also has a do-it-yourself section for advanced users, and that contains several code snippets that you can manipulate and configure yourself. Once you have a basic familiarity with the OpenFMB™ code set, you can use these code phrases to explore security, experiment with scaling and pursue multiple use cases on your own.

SGIP is excited to share this site and its abundant resources with industry, but we're also equally excited to see what people do with it. There's a whole new grid-operations landscape out there to be addressed with OpenFMB™. SGIP invites you to explore this framework by visiting *www.openfmb.io* and be sure to bring your insights and innovations back to the site so you can share them with the entire grid-modernization community.

Sources:

Gartner – open source soft database software -- *http://www.infoworld.com/article/2916057/open-source-software/open-source-threatens-to-eat-the-database-market.html*
Benefits of open source -- *http://opensourceforamerica.org/*

About the Author

Aaron Smallwood is VP, Technology at SGIP. He is responsible for leading SGIP's Program Management Office and working with member committees and groups in advancing SGIP's technology strategy and agenda.

Aaron has been in Information Technology for 20 years and in the utility industry for the last 15 years. As Director of IT Operations at the Electric Reliability of Council of Texas (ERCOT), Aaron was responsible for the multi-data center IT operations of ERCOT's real-time grid and market systems, deregulated retail market systems, Enterprise Data Warehouse, systems integration, and market settlement systems. In other roles at ERCOT he led business/technology alignment, IT strategy development, program financial management for the Texas Nodal Market Implementation, IT stakeholder relationship management, and the IT divisional project office.

Prior to ERCOT, Aaron was responsible for managing the relationship between IT and utility business units at Aquila, Inc., working with utility and IT leaders to ensure that IT services were aligned with business objectives and that IT was positioned to support their needs.

From Research to Action

Workforce Management Tools for an Integrated Grid

By Dr. John J. Simmins

Over the last decade, there has been a revolution in commercial and personal electronics and the communication systems that tie them together. Technology is making the world smaller, and using technology to leverage data, resources, and other information will enable utilities to enhance their ability to provide safe, reliable, affordable power. This revolution is profoundly impacting many areas of the electric power industry, from transmission to distribution, to customers, and even the utility workforce. In fact, tools for workforce management present utilities with opportunities to improve worker safety and understanding while increasing system resiliency.

Vendors are developing applications to facilitate specific work flows to meet the needs of the utility industry. Typically, this is being done in a piecemeal, non-integrated fashion, resulting in a hodgepodge of technologies. The industry is in a position to get ahead of this development and achieve a standard approach. Integrated, advanced workforce management tools would support the transformation of the power system to become more flexible (through new methods of communication and control), more resilient (through the ability to more quickly predict, respond, and recover), and more connected (through improved monitoring and data analysis/management).

Building on lessons learned from other industries and from thought leaders in our own industry, the power industry is working to identify the actions required to take full advantage of advanced workforce management capabilities. The Electric Power Research Institute (EPRI) is contributing to the development of standards to automate work flows for electric utility workers, and developing the technology (such as augmented reality) to put some of those standards into action.

Simplifying with Standards

The widespread, successful use of advanced workforce management tools will depend on the development of, and adherence to, common standards. Standards enable users to "mix and match" the most appropriate technology to their particular needs, and enable vendors to develop products with the confidence that they will be able to communicate and share data with other applications. Standards provide consumers, regulators, and other stakeholders with a level of assurance that these tools will safely interact with the power system and contribute to the reliable generation, delivery, and use of electricity.

Currently, utilities are independently developing their own workforce management tools. A large number of the technology and process requirements underlying these tools are common from one utility to the next, but a fully integrated, standards-based approach is lacking. For example, during mutual assistance scenarios, utility crews often bring their own technologies to the field, introducing multiple communications platforms to an inherently complex situation. The use of standards and common interfaces would increase value and provide faster restoration times by reducing the amount of training and hardware required to establish secure communications and coordinate work management tasks across service territories.

Modern Technologies to the Rescue

Using the latest in commercial computing, standards, and communication technologies, the remote worker can be integrated into the back office and have access to data and work processes as if they were there. Tablets, smart phones, and wearable computers provide a multipurpose platform through which users can accomplish many tasks. For example, while the smart phone is a functioning phone, it can have any number of additional applications installed to perform various functions.

Compare that with what field or plant workers typically carry. They might have a radio, a ruggedized laptop, and various probes, sensors, and scopes to perform diagnostics. With modern technologies, these can all be combined into one rugged tablet or wearable computer that can interact with multiple back office systems through the use of standard messaging.

Working with utilities around the world to vet requirements, EPRI is developing technology and standards to automate work flows for the plan-design-build-operate cycle, equipment maintenance, and vegetation and outage management. EPRI is working with the Common Information Model (CIM) and Open Geospatial Consortium (OGC) communities to identify gaps between utility work management requirements and the emerging standards these groups are developing. By identifying requirements and working with technology developers, EPRI is accelerating the rate at which these technologies can be deployed.

EPRI is also developing technologies, such as augmented reality, to help increase worker efficiency and safety in the field. EPRI is coordinating an effort across its four research sectors to create a common platform for workforce management and visualization to facilitate cooperation during large weather events. It is also developing open-source software and coordinating with vendors to get these new technologies into the hands of utility work professionals. EPRI's latest report, Assessing Augmented Reality for the Electricity Industry, provides a good example of EPRI's role in this space.

We know that as utilities drive toward power system transformation, delivering safe, reliable, resilient, and high-quality electricity remains top-of-mind. The combination of advanced electronics and communications—with some standards to guide the way—will provide new opportunities to deliver on the utility mandate. For more information about EPRI's augmented reality and workforce management R&D, visit *smartgrid.epri.com* or contact me directly at *jsimmins@epri.com*.

About the author

Dr. John J. Simmins is a Technical Executive at the Electric Power Research Institute (EPRI) where he manages the Information and Communication Technology for Distribution project set. His current research focuses on integrating back-office applications and integrating with devices and personnel in the field. Dr. Simmins also leads EPRI efforts in the use of augmented reality, social media, data analytics, and visualization to improve grid resiliency. Prior to joining EPRI, Dr. Simmins was with Southern Maryland Electric Cooperative where he managed engineering and operations applications. He received his B.S. and a Ph.D. in Ceramic Science from Alfred University.

Protection and Control System Impacts from the Digital World – Part 2 of 2

Part 1 of the article appears in the Sept/Oct issue.

By Stefan Meier and Steven Kunsman

7. The Digital World opens up Cyber Threats

Cyber security creates fear in our industry as mentioning NERC/CIP compliance can lead to the wrong behavior. The information available in our utility systems is essential for advancing system performance, proactive control and improved operations and maintenance. Cyber security standards provide the framework and requirements either towards compliance or technical solutions. The educational benefits to understanding these requirements is paramount in the adoption and embracing cyber security as a key enabler to our modern monitoring and control systems.

The fact exists that substation automation, protection and control systems have changed significantly in the past decade and will continue to change with technology advancements. Systems have become more interconnected and provide end users with much more information to allow for higher reliability and greater levels of control. Interoperability between different vendor products and systems has been achieved by developing products and solutions based on open standards and by leveraging commercial technology like standard Ethernet technology. This change in technology has not only brought huge benefits from an operational point of view as discussed in the previous sections, it also permits substation automation, protection and control systems to address cyber security issues similar to other traditional, enterprise systems which have been facing the same industry challenges for years.

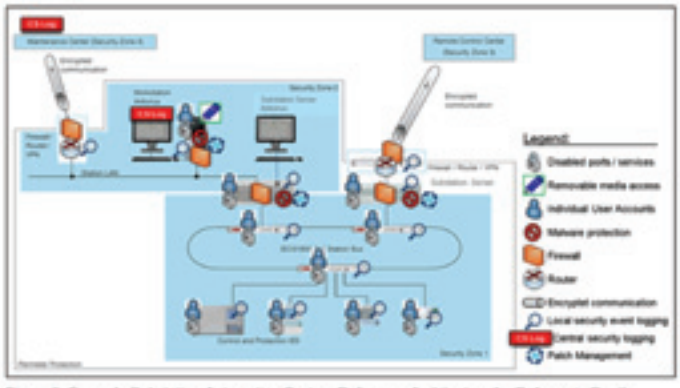

Figure 9: Example Substation Automation System Reference Architecture for Defence in Depth

Tightly integrating the control system components and allowing inter-connected control systems with the external systems not only allows for more and faster information exchange, but, it also provides entry points for hackers and increases the need to protect against cyber-attacks. Using Ethernet and TCP/IP based communications not only make systems more interoperable, but also opened the door for trojans, worms, viruses and Internet based attacks, etc. The need for secure substation automation protection and control systems as well as the entire utility Information Technology infrastructure is being pushed in many markets by regulations to ensure national security due to the potential impact that a coordinated cyber-attack on the electric utility control system could have on wide scale outages. The key to any successful security system is deploying Defense-in-depth strategy as shown in Figure 9. Threat models are constantly changing, the bad guys are getting smarter and the monitoring and management of the overall IT systems is paramount to keep the power system control equipment safe and secure.

In addition to government driven efforts the increased importance of cyber security for power systems has also lead to various standard bodies and working groups taking on the challenging topic. The focus, level of detail and maturity of these efforts are quite broad. At the moment five initiatives seem to be most advanced, which we will discuss in the following paragraphs and should be included in your utility overall cyber security policy and practices.

7.1. NERC CIP

The NERC CIP regulations have had the biggest impact on electric utilities so far and been the focal point of most security programs. The regulation makes a clear statement that the main responsibility for securing the electric grid lies with the utilities and that it is not just about technology but also about processes. There are some shortcomings of the current version, i.e. the exclusion of serial protocols or the focus on a single electronic security perimeter. An additional area for improvement is the definition of critical assets and critical cyber assets. While the definition of what is deemed critical and what is not has been made a bit clearer within the NERC/CIP standard version 4 and 5 [17], protection of critical (cyber) assets is still done in an all or nothing fashion. If a cyber-asset is classified as critical all NERC CIP requirements apply, if it is not classified as critical then it must not be protected at all (unless it is within the electronic security perimeter).

This all or nothing approach does not take into account different levels of criticality and does not allow for different levels of security, which is a common best practice for security of computer based systems. However, the ongoing revisions are constantly looking at different levels of criticality, which will hopefully lead to a more realistic and more granular approach to cyber security. It is important to note that the NERC standards are performance based standards that inform the utility what security measures need to be implemented and monitored. Therefore, no product or technical solution can claim to be NERC CIP compliant but rather the technical solution can support the utilities compliance to these standards. On the other hand, the IEEE and IEC develop technical standards that provide the technical blueprint or the "How" for the utility security solution and the most important standards are listed below.

7.2. IEEE C37.240

Jointly within IEEE PES Substations and PSRC, this standard is based on the applicability and the technical implementation of the NERC CIP and NIST Smart Grid security efforts for substation automation, protection and control systems. The standard on "Cyber Security Requirements for Substation Automation, Protection and Control Systems" provides technical requirements for substation cyber security. It presents sound engineering practices that can be applied to achieve high levels of cyber security of automation, protection and control systems independent of voltage level or criticality of cyber assets. Cyber security includes trust and assurance of data in motion, data at rest and incident response.

7.3. IEC 62351

IEC 62351 is a technical security standard that aims to secure power system specific communication protocols such as IEC 61850 or IEC 60870-5-104. While most parts of the standard have been released in 2009 more work is needed before systems compliant to IEC 62351 can be put on the market. First of all, the affected communication standards must be changed to support IEC 62351. In addition there are some technical challenges with securing real time traffic that must be addressed by the working group of IEC 62351.

7.4. IEEE 1686

Security of intelligent electronic devices is the scope of IEEE 1686. The document defines in technical detail security requirements for IED's, e.g. for user authentication or security event logging. The standard very nicely points out that a) adherence to the standard does not ensure adequate cyber security, i.e. that adherence to the standard is only one piece in the overall puzzle, and that b) adherence to every clause in the standard may not be required for every cyber security program. With this the standard gives vendors clear technical requirements for product features but at the same time leaves room for specific, tailored system solutions at the customer site.

Summary Benefits of the Digital Substation

A fully digital substation is smaller, more reliable, has a reduced life-cycle cost and is simpler to maintain and extend than an analog one. It offers increased safety and is more efficient than its analog equivalent. Not every substation needs to be catapulted into a wholesale digital world – it depends on the substation size and type, and whether it is a new station or a retrofit of the secondary system. Different approaches and solutions are required. Flexible solutions allow utilities to set their own pace on their way toward the digital substation.

- Increased system availability by replacing of electromechanical, static or old fashioned digital secondary equipment with modern numerical devices bundled to a real-time communication network and connected to a higher level system such as a substation automation system or SCADA, allows continuous monitoring of all connected secondary equipment.
- Increased system and personnel safety utilizing remote control combined with authority and rule-based access and remote testing, allows increased system safety and security. Personnel safety is increased since more tests can be done without putting the test personnel close to primary equipment or without the risk of inadvertently opening current transformer (CT) circuits.
- Increased functionality with a fully distributed architecture coupled with un-restricted communication and process capability enables the system to add new functions easily with zero or minimal outage time, giving the user additional benefit with respect to safe and secure system.
- Interoperability through deployment of IEC 61850 compliant solutions, interoperability with regard to communications with other manufacturer's equipment can be achieved. The benefit is IEDs from different suppliers can be mixed on the same bus without concern for communication incompatibilities.

Conclusion

Technology has changed significantly from over the past 30 years and will continue advance enabling more benefits from The Digital World. The early adoption of microprocessor relays started the era into The Digital World. Along with their significant advantages, they also introduced our world to software and communicating devices to the realm of Cyber Threats in our changing environment. The introduction of the IEC 61850 station and process bus standards for substations has provided a platform that all manufactures can develop upon to achieve the overall goal of interoperability.

John Burger's visionary ideas are being realized with the technology available today. In addition to the interoperability benefits, footprint of primary switchgear reduction using sensors (NCIT) replacing conventional measuring transformers and breaker controls allows a much safer work environment and a massive reduction of cabling by going from a lot of copper cables to a few fiber optic communication cables. As for the challenges presented by the cyber threats, the industry must embrace modern device capabilities to deter, delay and detect the bad guys. Let us not forget that the multifunction relay is today the source of information that can enable higher level systems to be proactive in the overall power system stability. Most importantly, the "R" in NERC means reliability so while CIP standards might drive organizations to shutdown communication access to the substation information, it is so crucial that the substation data be accessible to higher level systems.

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Stefan Meier has been working with ABB Switzerland for more than 15 years. He held several positions, from commissioning of substation automation systems, through technical support and project management. Today he is a global product manager for process bus solutions, where he coordinates the introduction IEC 61850 process bus in pilot and commercial projects. Stefan studied electrical science at the University of Applied Sciences Northwestern Switzerland, and holds a master degree in business administration from Edinburgh Business School of Heriot-Watt University, Scotland.

Steve Kunsman is a recognized Substation Automation Specialist with over 32 years in substation automation, protection and control applications, communications technologies (IEC 61850 and DNP), cyber security for substation automation, and the Relion product family of protection and control relays. His ABB career began in 1984 as an Electrical Designer for the protective relay group and has held various engineering, technology and product management positions within the North American and global substation automation organizations. Steve holds a B.S. in Electrical Engineering from the Lafayette College in Easton, Pennsylvania and an MBA in management of technology from Lehigh University in Bethlehem, Pennsylvania.

Animal Outage Mitigation Key to Improving Reliability

The Importance of Collecting Outage Statistics and Causes

By Ellen Smith

Good data provides the ability to make appropriate decisions regarding an animal-caused outage problem.

In order to understand the animal-intrusion issue, including the cause of the issue, utilities need to measure, establish targeted goals and then make informed decisions to meet or exceed those goals.

Utilities must begin by reviewing their asset management processes for collecting data relating to animal-intrusion caused outages and equipment damage. Utilities need to be more rigorous when it comes to collecting outage data. A lack of data or even inaccurate data can lead to inaction or inappropriate action being applied to a problem. There are a number of reasons why utilities may have difficulty obtaining data; however, performing a review of the data collection methods and driving improvements to the areas of weakness will address this threshold issue. Listed below are some of the top reasons why data has been incomplete or inaccurate and should be used to eliminate reasons why poor data collection processes exist:

- A low-risk outage (momentary outage, limited customers affected, occurrence at night, etc.)
- Data collection did not occur (operator/field personnel were busy, etc.)
- Inconsistent or nonexistent reporting standards (operational drift)

Root-cause analysis, a necessary next step

While time consuming, performing root-cause analysis on a regular basis promotes the discipline necessary to completely understand the cause of any animal-contact issue. The analysis also will rapidly expose common themes, allowing for an informed decision on next steps and an optimized investment in equipment protection. Applying the same practices utilities commonly use for their existing safety-based root-cause analysis is an excellent start to ensuring that this methodology is applied correctly and swiftly.

Specific animal-caused outage metrics need to be identified and tracked during monthly asset management meetings similar to other operational reliability measures, such as System Average Interruption Duration Index ("SAIDI"), System Average Interruption Frequency Index ("SAIFI") and Customer Average Interruption Duration Index ("CAIDI"). A more complete review of operational challenges can be performed, and the appropriate actions may be prioritized and acted upon. Suggested measures include:

- Count of animal-caused outages (segmented by voltage):
  - > System-wide
  - > By planning area or region
- Percentage of animal-caused outages compared with total outage numbers:
  - > System-wide
  - > By planning area or region
- Number of substations with an Animal Protection Plan (deployment measure):
  - > Planned vs. actual by voltage level
- Number of substations inspected for animal-intrusion risk (i.e., damaged fences and damage mitigation equipment):
  - > Planned vs. actual
  - > Whether outage mitigation is complete or comprehensive
- Number of lines/circuits inspected for animal-intrusion risk:
  - > Planned vs. actual
- Work plan completion for animal-caused outage mitigation equipment installations:
  - > Planned vs. actual
- Outage root-cause analysis completion rate (percentage)
- Top 10 list of substations with highest animal-caused outages for the fiscal year (i.e., poor performer)

However, before acting on the results of the data, utilities must develop an asset management strategy that acknowledges the problem and their response to it. While animal-contact outage goals currently are not mandated by regulatory bodies, utilities should set aggressive goals at the asset class level to assist with the identification of the riskiest assets. The table below recommends the risk categorization that should be used to help identify and then target the riskiest assets so the prioritization for animal-contact mitigation can be included in the annual planning process. Once these assets are placed on the work plan for the appropriate fiscal year, tracking progress against the plan should be included in the regular monthly review period.

Substation Voltage Level	High Risk	Medium Risk	Low Risk
Transmission	Greater than **1** Outage per Year	**1** Outage Every **1** to **5** Years	Less than **1** Outage Every **5** Years
Subtransmission	More than **1** Outage per **6** Months	**1** Outage Every **6** to **24** Months	Less than **1** Outage Every **24** Months or More
Distribution	More than **1** Outage per **6** Months	**1** Outage Every **6** to **24** Months	Less than **1** Outage Every **24** Months or More

Source: "The Case for Eliminating Animal-Caused Outages in Electric Substations and on Powerlines", FTI Consulting, 2016

Additionally, the dynamic nature of animal movement and migration, along with ever-changing environmental factors (e.g., urban expansion, industrial buildup, oil or shale exploration) requires a periodic (at least annual) review of substation assets that already have animal-contact mitigation equipment installed. The results of this assessment should lead to root-cause analysis and then a plan for further mitigation – be it replacing the damaged animal-protection equipment or completely redesigning a mitigation plan. These considerations for existing assets may then be included in the risk scoring of the greater asset portfolio.

Cost Recovery Strategies

Since the installation of substation animal protection products is in the public's interest, it is important for utilities to install the most appropriate solution that will correct the situation. While the cost and the sheer number of substations make the cost to implement a complete solution seemingly difficult to implement in a cost-constrained environment, utilities should prioritize by the high-risk assets and then capitalize the cost of these installations so they can be included in the rate recovery process.

The capitalization of construction costs for a new substation installation can likely occur if the animal protection method is included early in the project initiation process. There is an additional benefit to installing the right protection at a new substation during the construction phase because the downtime that would otherwise be necessary to retroactively install animal guards, for example, is eliminated. Existing substations also can benefit from the capitalization of the installation if the costs are structured properly. Further, proactively installing animal protection yields additional cost benefits in the form of avoided costs that would otherwise be realized by outages.

A capitalized cost case could be justified by meeting certain conditions. Specifically, if an animal protection device is categorized as a "betterment" or "system/reliability improvement", where it adds to the productive capacity or improves the efficiency of an existing facility, it may be capitalized.

Recommended Approach

The first step:

Following the approaches outlined above can serve the needs of all stakeholders by ensuring an aggressive, cost-effective, customer-centric solution. This starts with the utility reviewing its outage reporting for all substation outages. Knowing where the most vulnerable substations exist supports a risk-based investment approach where high-probability, high-impact areas receive investment priority. Over time, implementation can be applied to all areas in order of priority, and risk containment can be accomplished. Having accurate data facilitates discussions with regulators who can subsequently support cost recovery considerations for these capital programs.

The follow-up action:

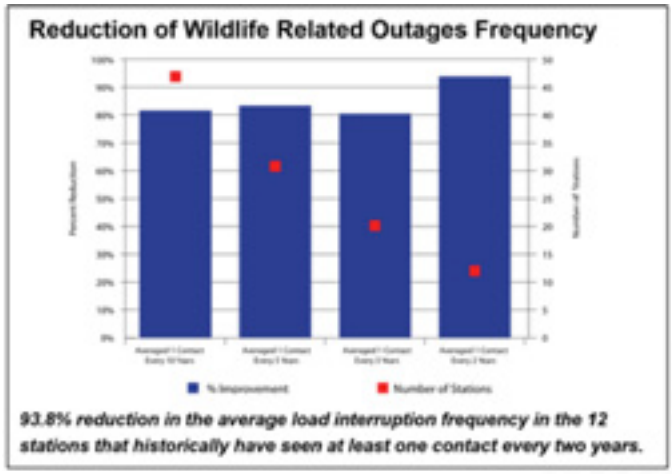
Utilities need to establish Engineering Standards to implement cover-up on at risk assets and facilities. As part of defining the engineering standard, utilities should do a comprehensive analysis on the available industry cover up products including their track record of effectiveness, comprehensive coverage/protection capabilities, quality of protection, and achievement of industry guidelines such as IEEE 1656 - 2010. Utilities may need to use a specific class of cover-up such as precise fit or a blended mix of cover-up or fencing suppliers based on the unique equipment requirements and configurations and in consideration of the species that are potential risks to a utility distribution system.

*A Case Study: AltaLink Statistical Performance of Greenjacket Outage Mitigation Solutions**

AltaLink, a Berkshire Hathaway Energy company, is Alberta's largest regulated electricity transmission company. AltaLink manages more than 13,000 kilometers of lines and 300 substations and regularly tracks and reports on animal-caused outages as part of their data collection process.

As part of the effort to improve reliability, AltaLink adopted the use of cover-up to prevent animal caused outages. The following report on the statistical performance of cover-up, outlines the improved reliability performance effectiveness of reducing the instances of animal and bird caused power outages.

AltaLink has tracked the performance of Greenjacket cover-up at its substations since 2005 and the improved reliability performance is significant. According to Mike Bartel, VP Asset Management at AltaLink, "Greenjacket has improved our load interruption duration performance by 95 percent at AltaLink substations where we had been experiencing frequent wildlife contacts/interruptions. It is rare to find such an investment in reliability that essentially guarantees effectiveness. This type of improvement not only improves our reliability performance, it also improves our customer satisfaction and reduces our impact on the environment."



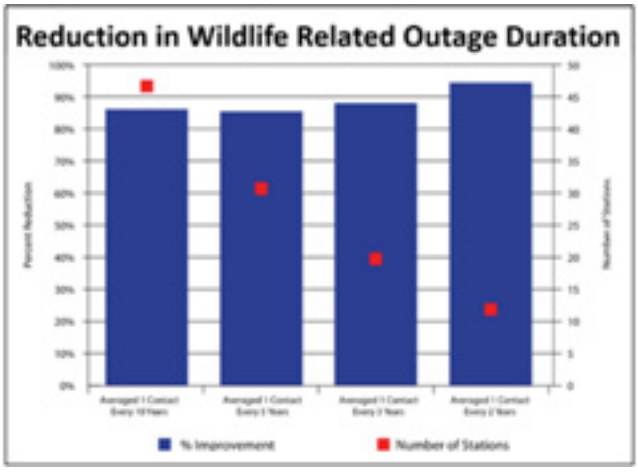
Source: AltaLink Statistical Performance of Greenjacket Outage Mitigation Solutions

In the set of 47 stations that have seen an average of one or more wildlife contacts every ten years:

- On average, the outage rate due to wildlife contact has reduced from *one outage every 3 years to one outage every 16 years*.
- On average, the load interruption rate due to wildlife contact has reduced from *one load interruption every 2 years to one load interruption every 13 years*.
- On average, the load interruption duration due to wildlife contact has reduced from *86 minutes per station per year to 12 minutes per station per year.*

In 12 high frequency contact stations where there has been an average of one or more wildlife contacts every two years:
On average:

- The outage rate due to wildlife contact has reduced from one outage every year to one outage every 10 years.
- The load interruption rate due to wildlife contact has reduced from one load interruption every year to one load interruption every 19 years.
- The load interruption duration due to wildlife contact has reduced from 248 minutes per station per year to 12 minutes per station per year.

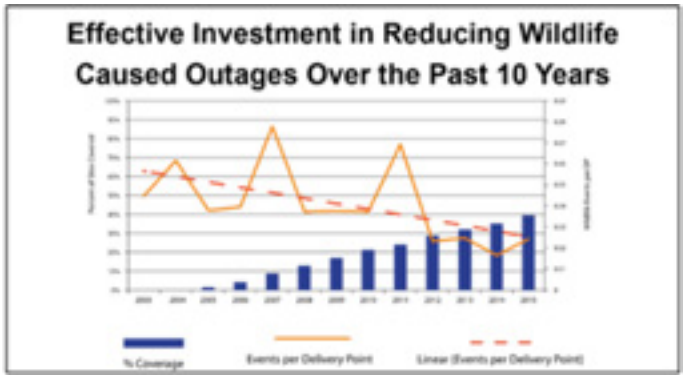


Source: AltaLink Statistical Performance of Greenjacket Outage Mitigation Solutions

Cover-up by Greenjacket Inc. continues to deliver significant results for AltaLink:

1. A 94 percent reduction in frequency of wildlife-caused outages across the substations covered with Greenjacket
2. On average, the outage rate due to wildlife contact has reduced from one outage every year to one outage every 10 years
3. Reductions in load interruption duration has gone from 248 minutes to 12 minutes; an improvement of 95 percent

Greenjacket plays an important role in AltaLink's focus on delivering reliability, exceptional service to their customers, and protecting the environment. AltaLink's 10-year historical performance tracking proves the significant impact that Greenjacket has had on improving AltaLink's reliability measures. AltaLink has written Greenjacket cover-up into its standards. Based on a risk evaluation, AltaLink continues to deploy Greenjacket cover-up within its remaining substations.



Source: AltaLink Statistical Performance of Greenjacket Outage Mitigation Solutions

About the author

Ellen Smith leads the Power & Utility group at FTI Consulting, bringing 30 years of industry experience, specializing in business advisory and litigation support services. Ellen's areas of expertise include matters involved in power and utility operations, power reliability related damages, utility regulatory strategy, emergency response, strategic communications and Cyber Security.

* All data was collected, analyzed and provided by AltaLink to Cantega, Inc.

New Standard Approved for Nuclear Safety Equipment

The Importance of Collecting Outage Statistics and Causes

By John White

A new global standard will contribute to achieving the nuclear power industry's continuing emphasis on the integrity of its safety-related equipment and practices, as global demand for nuclear energy rebounds.

In March, the IEEE and the IEC (International Electrotechnical Commission) announced their approval of IEC/IEEE 60780-323™-2016, which provides consistent principles, methods and procedures for cost-effectively qualifying safety-related electrical equipment deployed in nuclear power plants around the world.

Adoption of the standard consolidates the requirements to which vendors must qualify their equipment, and minimizes the documentation required for compliance with standards. The net result contributes to improved safety for nuclear power. It also eliminates the burden on manufacturers to prove their compliance to the sometimes disparate requirements of individual customers around the world. The new standard and other efforts also make it simpler and easier for customers to ensure vendor compliance to equipment qualification requirements.

Why is this development important? "Important to Safety" electrical equipment is designed and relied upon to shut down a reactor in an orderly manner in case of an accident or design basis event, in what is potentially an extremely harsh environment. IEC/IEEE 60780-323 establishes the process by which equipment manufactures demonstrate that their equipment will perform in those harsh environmental conditions, as well as afterwards for post-accident monitoring.

Conditions inside a nuclear plant during a design basis accident can exceed peak temperatures of 350 degrees Fahrenheit, 50 pounds of pressure, 200 megarads of radiation and contact with a caustic spray that's injected into a plant during these events.

Moving to one standard

The unified global standard, IEC/IEEE 60780-323, is based on the historical fact that the global nuclear industry had two separate standards to choose from. Until now, IEC 60780 existed for the European Union and countries that turned to the EU for guidance in this area. The IEEE 323 family of standards served the United States and stakeholders who adopted its provisions.

The unification of these existing standards eliminates the duplication of equipment testing by manufactures that serve both markets. This is the first step in bringing the entire world into standards-based compliance for the qualification of "Important to Safety" equipment. When the end-user utility buys such equipment, it can rest assured that the product meets a single global standard.

Changing market

This approach is increasingly important as more manufacturers enter the nuclear market to provide components needed in the next generation of nuclear power plant designs. These new reactor designs will be built in many areas of the world that do not have an established history of operating nuclear power plants, nor strong regulatory oversight. Within these emerging markets for nuclear power plants, a single joint standard will provide a stable base for the future of the nuclear power industry.

In other words, countries and companies that did not participate in the first generation of nuclear power plants are now taking leadership positions in the development of the next generation of nuclear power plants. The challenge to the nuclear industry is how to effectively transfer knowledge and lessons learned from past decades to a new generation of nuclear engineers.

Adherence by manufacturers and nuclear power plant owners to a global standard for 'Important to Safety' electrical equipment is a strong step towards a safer, more cost-effective nuclear power industry. Plant designers can better focus their work by designing to the new standard as well.

History of standard, unified effort

IEEE 323 and its daughter standards have been in development since the early 1970s. IEC 60780 was first published in 1981. Most existing nuclear power plants, worldwide, are committed to meet one of these qualification standards. These existing nuclear power plants must meet the standards in which they committed to when they were licensed. New plants would need to meet the new unified standard if and when, as expected, it is adopted by the EU and the U.S.'s Nuclear Regulatory Commission (NRC).

The two standards development organizations decided in 2010 to collaborate on unifying their respective standards and, therefore, advance the safety of nuclear power through the use of a single global standard.

Conformity assessment

A separate but related effort is underway to simplify and reduce the cost to vendors and customers of the process for assessing equipment's conformity to standards, whether that's their legacy obligation to meet a historical version of the qualification standard or a new plant's need to meet the new, unified standard.

The IEEE Nuclear Power Conformity Assessment Program is being developed collaboratively by the IEEE Nuclear Power Engineering Committee (NPEC) and the IEEE Conformity Assessment Program (ICAP).

A conformity assessment program would ascertain that components are genuine (counterfeit parts have been detected in the supply chain) and, as components have become more complex, new failure modes must be evaluated.

In addition, a single, global format for reporting testing information would give oversight authorities an apples-to-apples means of assessing compliance with standards. If the NRC looks at a test report at one location for one power plant and determines it is acceptable, then there's no need to duplicate that effort for another plant because the test report will reflect the same information.

Meeting the requirements of the ICAP should provide vendors with a commercial advantage in the global market. Nuclear power plant owners, the end users, can rely on equipment that meets these requirements, without having to ensure compliance on a case-by-case basis.

Next steps

The goal of all these efforts is to insure that "Important to Safety" equipment meets the highest global standards, wherever it is produced or implemented, and that oversight is simplified and streamlined through a robust and consistent assessment and reporting process. This represents a powerful, relatively inexpensive solution to a major safety concern raised by the nuclear power industry itself.

Work on gaining adoption of the IEC/IEEE 60780-323 standard by relevant authorities continues and development of the conformity assessment program and reporting template is making progress.

The market-driven need for these measures has been recognized and met with thoughtful action to ensure the safety of nuclear power in a changing world.

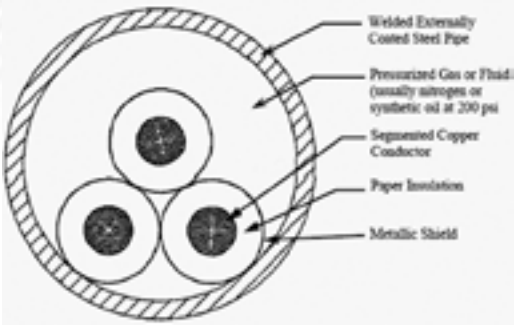
About the author

John White, chair, IEEE Working Group 2.1 on Equipment Qualification, Senior Consultant, True North Consulting.

Mitigating the Effects of Age on Critical Underground Cable Transmission Equipment Through Restoration

By Jillian Leinen

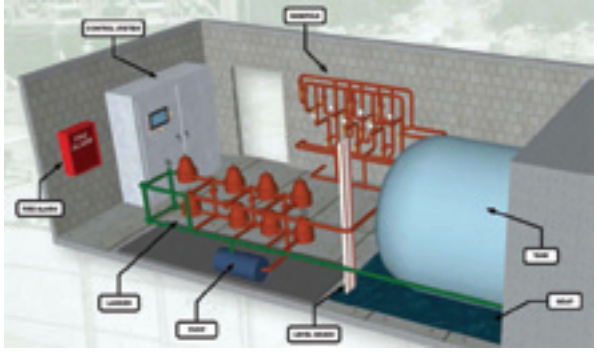
There are approximately 4500 circuit miles of 69kv to 345kv underground transmission cables in service in the United States, most of which are High-Pressure Fluid-Filled (HPFF) cables. HPFF cable systems are complex durable systems, recognized for their reliability, however, as is the case with most complex systems – they are only as good as their weakest link. While the conductors have significant life left, much of the critical infrastructure supporting these cable systems is nearing end of life and decision makers at electric utilities must make a choice in how to address the aging components that support these HPFF cables. Targeted, surgical replacement of major components is cost effective methodology for modernizing and upgrading these HPFF systems.



HPFF Cables and Aging Ancillary Infrastructure

A HPFF pipe-type underground transmission line consists of a steel pipe containing three high-voltage conductors. The conductors are insulated with oil-impregnated kraft paper and covered with skid wires to reduce friction during installation. Within the pipe, the cables are then surrounded by dielectric fluid maintained at 200 psi to further insulate the cables. The dielectric fluid is regulated by external plants that maintain the needed pressure and ensure feeder health. Without the required dielectric fluid pressure, the insulating capabilities are compromised. Despite the increasing demand for solid dielectric cables the installed base of HPFF cables is so large that it remains the primary underground transmission cable in much of the county, in large part because of its reliability, superior ampacity and long service life – consistently exceeding that of its solid cousin. But while the cables themselves have an almost infinite life, much of the ancillary infrastructure supporting these HPFF systems are quickly reaching 'old age.' The most vital and often most neglected components of these intricate systems are **Pressurizing Plants and Circulating/ Cooling Plants**.

Pressurizing Plants: HPFF cables require pressurization with dielectric fluid for everyday operation – this is accomplished using installations known as pressurizing plants. Commonly referred to as pumping plants or pump houses throughout the electric utility industry, pressurizing plants are critical to the performance of the feeder. If pressure is lost, the cable must immediately be de-energized to prevent damage, resulting in the loss of a transmission path. Often located in substations and housed in insulated enclosures, these plants include a reservoir tank that holds reserve fluid, hydraulic ladders and relief valves to maintain proper pressures, pressurizing pumps, alarms, monitors and controls



Circulating/Cooling Plants: In addition to pressurizing the fluid, a feeder can have a circulating or cooling plant to help augment cable ratings. Circulating the fluid that insulates the cables helps remove hot spots which in turn increases capacity. Circulating plants can be upgraded beyond circulation to include forced air cooling and refrigeration. Forced air cooling and refrigeration are popular options to increase ratings of HPFF cables while using existing infrastructure.

Pressurizing plants commissioned in the 60's and 70's, while still operable, are reaching the end of their usable life-cycle and are not scalable to meet the needs of increasing demands. Bob Ryan is the president of Walker US, Inc., a pressurizing plant manufacturer in New Jersey. He recalls the first time he set foot in an aging plant during a substation walkthrough. "Our first inspection of pump houses and circulating plants left some wonderment as to how they were still in operation," Bob Ryan said. "The truth is, equipment made in the 60's and 70's was made to last. The individual components however, were beginning to fail and difficult to repair in kind".

When faced with the issue of component obsolescence, utilities have few options. The reliability requirements of these plants demand the highest quality parts. As these parts fail and no replacement is available, a new plant may seem the only viable option. However, installing a new plant is a costly proposition that often requires long duration transmission outages while also creating significant logistical problems. There is a more effective way to restore 'like new' operation to HPFF pressurizing, circulating and cooling plants: HPFF Equipment Restoration.

The Immediate and Long Term Benefits of Restoration

In most cases, the tanks, structures and much of the piping are still in excellent condition, restoring the plant to like new operational condition only requires that critical individual subsystems such as the controls, pumps and valves to be replaced.

Restoration of a pressuring plant is less expensive and requires a much shorter outage than the replacement. Oftentimes there are no permitting requirements and zero rigging needed to complete the project and is much more economical. A complete restoration is often less than one tenth the cost of a new installation which often exceeds one million dollars. Perhaps of greater importance than the cost savings associated with refurbishing a pressurizing plant is the considerably shorter downtime. Complete plant replacements require long outages which can be difficult to schedule and expensive, costing utilities millions and impacting service reliability. A complete restoration can be achieved in weeks while commissioning a new plant can often take up to six months. 'Like new' restorations can include improvements such as new pressurization ladders, pumps, manifold assemblies, controls, instruments, leak detection capabilities, and hydraulic components. "A sawzall, new instruments and a new control cabinet cures most of what ails these equipment structures." Bob Ryan says. "Some restorations include modern oil level sensors, new pressure relief valves; even a complete ladder replacement. Old valves can also be replaced and repositioned. New heat, vents, lights and fire alarms are the finishing touches. At the end of a Walker restoration, the pump house or cooling plant looks and performs as new."

Above: A typical retrofit ladder. A pump house ladder allows control of feeder pressure through pressure relief valves, check valves and instrumentation.

The Preferred Choice

With the advantages that restoration provide, justifying the installation of a completely new plant is difficult. Restoration provides the functionality, scalability and technical advantages of a prefabricated plant, while reducing feeder downtime, being more ecological, and a providing a more cost effective solution.

1. **Reduced Feeder De-rate.** Restorations provide the unique benefit of reducing de-rate times by allowing work to be done within the confines of the plant. It also prevents the need to de-energize overhead feeders to crane into place a new plant. Red tape is reduced due to the fewer permit requirements. Additionally, de-rate time can be reduced even further using a portable pump house. Leaving the existing infrastructure of the plant allows for external connection to a temporary pressurizing setup which can be used to place the feeder back into full service while the work is being performed. The time table for a complete plant replacement can be up to six months while a "like new" restoration can be realized in a matter of weeks.

2. **Fewer Permits**. The installation of new plants requires a multitude of permits to satisfy city and state requirements. Using the existing structure and leaving in place select components of the plant reduces the need for many of these permits and allow for faster project completion and less delays.

3. **Ecologically Friendly.** Restoration generally involves the re-use of the reservoir tank and piping that carries the dielectric fluid to the feeder. Re-using this equipment prevents unnecessary waste must be treated as hazardous.

4. **Material Cost Savings.** Restoration focusses on the components that require attention and leave in place the ones that do not. The act of restoration not only saves money in terms of time but also replacement of materials.

Ultimately restoration provides a quick and cost effective solution that allows utilities to keep their feeders online longer, reducing cost and reducing waste. It also affords the opportunity to complete multiple restorations in the same timeframe and cost as installing a new plant.

Summary

Despite the advancements in solid dielectric cable technology, the installed base of HPFF cable represents the largest proportion of underground transmission cable in service in the United States. The simple fact is, a High-Pressure Fluid-Filled cable's life is almost infinite, solid cables, on the other hand, often show signs of failure in less than 20 years. It is because of this incredible life cycle that much of the support equipment must be meticulously maintained and when needed, restored to "like new" operation. Given the option to replace or restore, Bob Ryan of Walker US feels it's a simple decision. "It just makes sense. With the time and money saved, not to mention the aggravation, using restoration to improve reliability and modernize your HPFF system is a good solution for the short term and long run".

About the author

Jillian Leinen is the owner and CEO of Walker US, a company that designs and manufactures solutions for electric utilities. She is responsible for running all facets of the business as well as managing high profile projects. Jillian joined Walker after graduating Villanova University with a BSE in chemical engineering. She quickly put her engineering expertise to use and successfully executed projects that have brought the company into the electric utility industry. Jillian succeeded Bob Ryan as CEO and became the majority shareholder of Walker US in 2016.

New Developments in Thermography Enable Automated Conditioned-based Maintenance Strategy

Increasing reliability through continuous and remote substation asset monitoring

By Lenny Shaver

Conditioned-based maintenance (CBM) is essential for electric utilities. In fact, most utilities have initiatives and investments to realize these goals. The use of thermography is a well-proven technique for monitoring conditions and detecting faults in electrical equipment. For many years, portable thermal imaging cameras were a reliable tool in condition-based and preventive maintenance of electrical distribution systems in low-, medium-, and high-voltage installations, where they are often used at periodic time intervals.

However, manual thermography inspections limit the practicality and scalability of applying CBM. There is significant cost in performing the inspections and the data gathered tends to be imprecise. Finally, even if good data is collected, there is a shortage of effective tools and resources to analyze the data. Advancements in thermography allow this proven CBM tool to be automated thus enabling utilities to better realize CBM.

Detecting equipment problems before failure

With much of the equipment at electrical power substations nearing the end of useful life, the potential for faults or the complete failure of these devices due to their age increases. Use of thermal imaging to detect equipment problems is attractive since the non-contact nature of the technique allows assessments to be done safely while equipment is in operation.

However, manual and periodic inspections are limited. They are expensive since workers need to travel and haul equipment which takes them away from other important work. Manual inspections are also prone to error and the results are highly variable depending on load and weather conditions. In addition, due to limited resources, the biggest difficulty may be finding time or people to interpret the results of the manual inspections.

Optimized maintenance concepts in this industry call for automated methods that are data driven. New advancements in data anomaly analysis and continuous monitoring of critical substation connections and assets, such as transformers, bushings, and capacitor banks, provide an automated early-warning detection of developing failures. Electric utilities need an automated, data-driven method to analyze electrical equipment.

Replacing manual inspections that may be erroneous or periodic, with a more rigorous and continuous automated monitoring method allows operators to identify transient thermal events that were not detectable with manual inspections. By deploying thermal imaging systems at critical locations throughout the electrical power distribution system, electric utilities have continuous, online monitoring without the personnel constraints and limited resources. The end result is the decrease in maintenance activity and the procurement of replacement devices becomes a viable strategy. Furthermore, the safety and reliability of the substation equipment is increased and the loss of the distribution of electrical power from a major asset failure can be prevented.

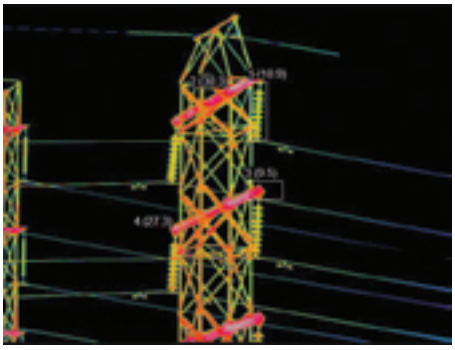
Automated & Remote Thermal Imaging Monitoring

Designed with maintenance-free electronics, automated and remote thermal imaging systems offer a high degree of accuracy for demanding electric power utilities while accurately measuring asset temperature without contact in even the most adverse environments. These systems allow utilities to continuously monitor the temperature profile and long-term thermal trends of assets within an electrical power substation remotely. This allows for incredible condition-based maintenance by allowing operators to automatically detect temperature deviations from normal operating conditions in real-time.

The most comprehensive systems for monitoring electric power substations combine both thermal and visual imagers on a pan-tilt unit, fixed thermal imagers, and fixed single point infrared pyrometers. Camera enclosures and cooling systems may also be included for more reliable, long-term installations.

Data Automation and Informing Users

Automated thermal imaging systems have a communication link from each camera to a controller that allows for quick access to the camera's thermal readings and configuration options. The local controller can be a utility-approved computer or a server which will run the included software. This software allows the user to define automated 'inspection tours' of the substation or industrial setting to monitor multiple areas. Operators can also use the software pan and tilt controls for manual positioning of pan-tilt units. Data from the controller is also published to existing data historians, for example PI from OSIsoft, using Modbus or OPC protocols.



In parallel, data can optionally be published to a Microsoft SQL database using a separate server. This provides a central repository for data and images from substation and plants throughout a user's enterprise. With such a system, centralized engineering and operations staff can easily review data and images from all camera from anywhere on the corporate network. The data collected by the cameras can be put in the hands of experts, wherever they may be. The thermal images and temperature data can also be setup to trigger alarms, automatically publish reports, and perform retrospective analysis. Because of this technology, this software can help identify transient thermal events not detectable with manual inspections.

Since this type of software uses authenticated web browser access, users can capture, access, and analyze data on managed assets remotely. Users can also set up email notifications for reports, alarms, and warnings. Real-time notifications can be sent to experts who then review the data, suggest additional investigative action, and schedule conditioned-based maintenance.

While automated and remote thermal imaging systems are a very accurate and reliable solution especially for substations and electrical switchgear monitoring, they can also be used in industrial settings such as detecting hot spots in fuel storage facilities or monitoring for degradation of refractory in high temperature furnaces and vessels.

About the author

Lenny Shaver has been with LumaSense Technologies in a variety of engineering, product development, and product management roles for more than 15 years. Today Lenny leads LumaSense Technologies' software development team and solutions roadmap taking advantage of his broad industrial experience to guide developments to meet customer needs. In earlier roles at LumaSense, Lenny led multi-disciplinary teams to develop turn-key solutions for power plants, steel plants, and petrochemical refineries that combined infrared technology, sensors, mechanics, networking, computers, and software to improve process and safety. Lenny started his career as a design engineer developing optical sensing solutions for harsh energy and industrial applications. Prior to joining LumaSense, Lenny was a mechanical engineer at Watlow Electric. Lenny has two engineering degrees (BSME and BSEPP) from Washington University in St. Louis, is published in many trade journals, presents at industry events, and has a US patent for a novel temperature sensor. Lenny works out of LumaSense headquarters in Silicon Valley California and lives with his family in San Francisco.

THE BIGGER PICTURE

BY J. SINGER, R. O. MUELLER AND J. KULLMANN

WEATHER FORECASTING AND DATA USAGES

Accurately forecasting weather conditions is a challenge faced by all utilities. Expensive decisions related to storm preparedness and demand/renewable forecasting are made on a daily basis, but how good are the forecasts utilities rely on? Macrosoft's 2016 utility survey delves into these issues to answer valuable questions.

Introduction

Macrosoft's 2016 survey examines utility weather forecasting practices and usages of the data. The online survey was completed during August 2016 by 109 respondents representing primarily investor owned utilities, with a smaller portion from municipals and cooperatives.

Every day, utilities make several important operational and financial decisions based on weather forecasts. **But where do these forecasts come from and how good are they?**

The survey takes a systematic approach to address these questions with the objectives stated as:

- Understand weather forecasting practices employed by utilities
- Identify perceived strengths and weaknesses in existing practices
- Categorize how weather data is being utilized
- Determine best practices

Weather Forecasting Resources and Services

There are a wide variety of weather forecasting resources available to electric utilities. Many are free public-domain options that include, the National Weather Service, internet sites, and even TV weather reports. Next, there are commercial subscription services that deliver custom forecasts based on specific utility related requirments. At the next level, there is an in-house meteorologist working directly for the utility.

Staff Meteorologist

A staff meteorologist is a dedicated resource working directly for the utility. Having a highly trained resource who understands your specific needs and requirements producing daily forecasts sounds like something that is highly desirable. But, it turns out that only 29 percent of the respondents have a staff meteorologist. That leaves 71 percent without a dedicated, professionally trained resource.

- 79% of the companies that employ an in-house meteorologist have at least 500K customers
- 64% of the companies that employ an in-house meteorologist open their Storm Center at least three times a year

Commercial Weather Forecasting Service

There are a number of commercial companies that offer customized weather forecasts specifically designed for electric utilities. It is not atypical for a utility to utilize more than one of these services. The results state that 73 percent of the responding utilities use at least one of these commercial services, with 11 percent using 3 to 4 different services. This leaves 27 percent of the respondents not using any commercial services.

Public Domain Forecasts

While the 'public domain' forecasts are prepared by trained meteorologists, they do not often take into account the weather elements and geographic particulars that are relevant to electric utilities.

With all too important decisions made by utilities based on their weather forecasts, it was interesting to gather statistics on utilities that exclusively rely on public domain forecasts. The results show that 31 percent responded that they solely rely on public domain forecasts. This is statistically similar to the 27 percent that reported on the previous question that they do not use any commercial services. Interestingly, 28 percent of the respondents that said they solely rely on public domain forecasts employ a staff meteorologist. In Macrosoft's attempt to understand what types of utilities solely rely on public domain forecast sources, several data correlations were examined.

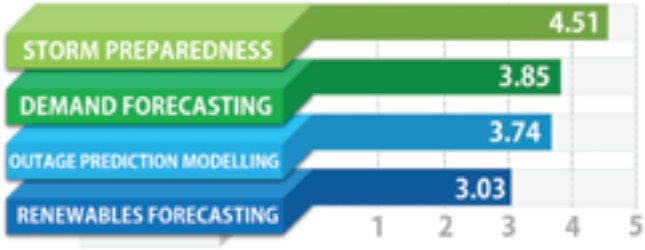
- Smaller companies rely solely on public domain forecasts, with 64% having less than 500K customers.
- The number of Storm Center openings does not affect a utility's reliance on public domain forecasts. 50% opened less than 2 times and 50% more than three times.
- 29% of the companies that solely rely on public domain forecasts are located outside of the US.

Weather Data Usages

The average person looks at daily weather forecasts to determine if they need a sweater, umbrella or boots. Electric utilities are also watching forecasts but the decision they make are much more consequential with potentially huge financial impact.

Importance of Weather Forecast in Business Operations

Participants ranked on a scale of one to five the importance of using the weather forecasts across four separate business operations. Leading across responses was the use of forecasts for Storm Preparedness with it being ranked over 4.5 out of 5. The three other surveyed uses of weather data is being used for Demand Forecasting 3.85; Outage Prediction Modelling 3.74; and Renewables Forecasting 3.03.



Importance Of Using The Weather Forecasts Across Four Separate Business Operations

Each of these four areas has a large financial impact to the company, but preparing for storms appears to be the top reason utilities are collecting or preparing forecasts. It is Macrosoft's opinion that as this valuable forecast data is coming into the company and being utilized for storm preparedness there would be great value with little incremental investment to support other areas of their operations, assuming there is a high degree of confidence in the forecast data.

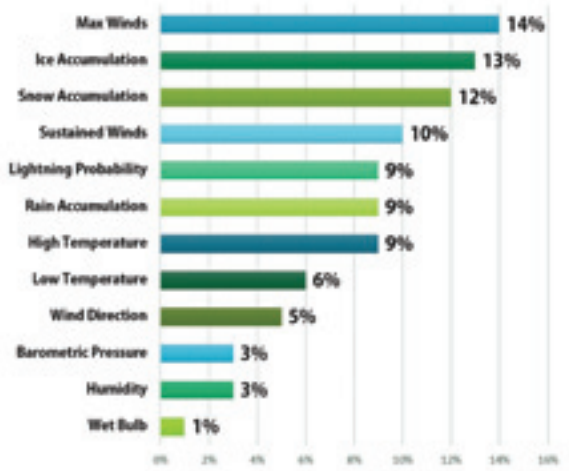
Outage Prediction Models

About 20 percent of the electric utility companies responding to the survey indicate they do not have a formal outage prediction model. The companies with outage prediction models in place are evenly split between feeding the weather data elements into the outage algorithm.

Of the companies that feed the forecast data into outage prediction models, only 33 percent apply statistical verification of the forecasts they receive. An additional 17 percent indicated though they don't currently verify accuracy currently they would like to include verification of forecasts.

Macrosoft safely concludes that as the use of outage prediction models increase, reliable weather forecasting becomes even more important.

Of the companies that feed the forecast data into outage prediction models, the top three elements that go into the model include: Max Winds, Ice Accumulation and Snow Accumulations. Rarely used elements included Wet Bulb, Humidity and Barometric Pressure.



Forecast Data Elements Fed Into Outage Prediction Models

Forecast Outlook

When preparing this survey we suspected that the majority of electric utility companies forecasts looked out 7-10 days. We were surprised to learn 60 percent of participants' forecasts are under one week out. Clarification was not received as to why this length of time was selected, but it is suspected that it is due to accuracy. With companies feeling that decisions should not be made based on forecast data that is greater than one week out as the accuracy is too low to make business impactful conclusions.

Specific Weather Elements

Gaining a clear understanding of which weather elements are forecasted, and electric utilities' satisfaction with the forecasts they receive is very insightful. The 109 participants were asked to rank twelve weather elements for their importance to decision making and the satisfaction they current have with the forecasts provided.

Most surprising was uncovering that across the twelve elements surveyed the three utilities rate as the most important: maximum winds; ice accumulation and sustained winds were amongst the lowest satisfaction.

When looking at the full table of information, it is clear that Ice Accumulation is the biggest area of concern. It ranks as the second most important weather element but dead last in satisfaction of the forecast. As little as a quarter of an inch difference across lines and trees results in a huge variance in the amount of downed equipment. If weather services could simply get this right, utilities would be much happier.

	Importance	Satisfaction
Maximum Winds	1	5
Ice Accumulation	2	12
Sustained Winds	3	8
High Temperature	4	1
Lightning Probability	5	11
Low Temperature	6	2
Snow Accumulation	7	9
Rain Accumulation	8	6
Wind Direction	9	4
Humidity	10	3
Barometric Pressure	11	7
Wet Bulb	12	10

Weather Elements Ranked Most Important But Are The Toughest To Forecast

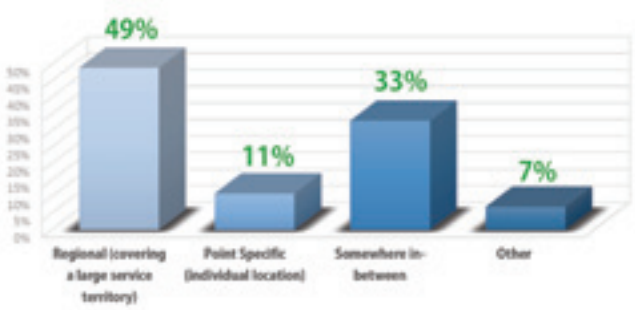
It is imperative to know which forecasts get ice accumulation correct as it is so important to decision making.

Best Practices

One of the key objectives of the survey is to identify best practices being employed at various utilities. It is helpful to know about what colleagues at other utilities are doing and saying in the area of weather forecasting when it comes to formulating your company's strategies. This section looks deeper into several areas where utilities are working towards improving the accuracy of their forecasts. These areas include: the geographic specificity of forecasts, the collecting of observational data, and applying statistical verification to compare actual versus forecast. Additionally, we found a significant amount of evidence by asking the open ended question, "In your opinion, what can be done to improve confidence with your weather forecast?"

Geographic Specificity of Forecast

Almost half of the respondents' report using a Regional (covering a large service territory) forecast.



Geographic Specificity of Forecasts

General purpose regional forecasts that cover a large geographic area might not provide the level of detail to address specific utility related issues. Differences such as elevation, coastal proximity, population density, tree coverage, etc. potentially impact the accuracy of these regional forecasts. At the opposite end of the spectrum are Point Specific (individual location) forecasts, which are reported by 11%. Finer granularity is desirable, especially when feeding forecasts into other systems such as outage prediction models. The remaining third of the respondents report a hybrid approach, 'somewhere in-between' a regional and point forecast.

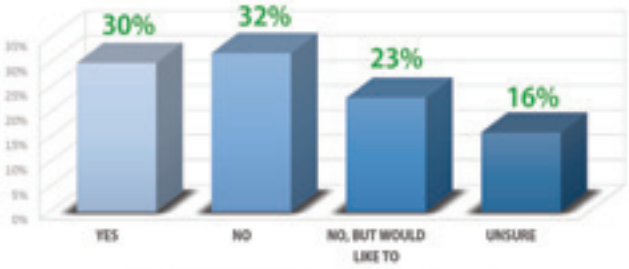
Collection of Observational Weather Data via Field Weather Stations

Another best practice is the collection of observational weather data via field weather stations. This type of service is provided by the National Weather Service, Earth Networks (Weather Bug), and a variety of other providers.

Collection of Observational Data from Weather Stations

Statistical Verification of Weather Forecasts

Statistical verification of weather forecasts is an interesting best practice which involves comparing the weather forecast to the actual observational results using advanced statistical methods.

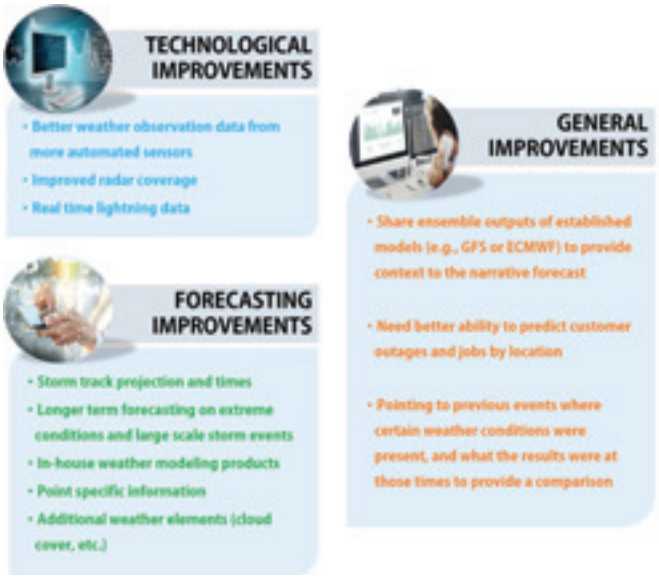


Statistical Verification of Weather Forecasts

Thirty percent of respondents report that they are currently employing statistical verification of their forecasts. Additionally, 23 percent report that they are not currently, but would like to in the future.

Factors Needed to Improve Confidence in Weather Forecasting

The open ended question, "In your opinion, what can be done to improve confidence with your weather forecast?" was asked to all respondents. Since confidence is a critical element in any forecast, this provides a broad collection of evidence that is useful in identifying best practices. The responses to this question are classified in three general categories: technological improvements, forecasting improvements, and general improvements.



Conclusions

Macrosoft elected to focus our annual Utility survey on how weather forecasting is being used by electric utilities. The topic was selected as the weather conditions appear to be more severe with hotter hots, colder colds and windier winds. Utilities are faced with providing continuous power to an unforgiving client base that expects undisrupted delivery no matter what the conditions. Due to the huge financial decisions that are made based on weather forecasts Macrosoft wanted to understand best practice and usage of forecasts to determine how this can be measured and scored.

The survey provided many insightful observations including:

- Over 70% use commercial services but only 29% of the respondents have a staff meteorologist. That leaves 71% without a dedicated, professionally trained resource
- Of the companies that feed the forecast data into outage prediction models, only 33% apply statistical verification of the forecasts they receive.
- The most important weather elements are the toughest to forecast, specifically Ice Accumulation ranks as the second most important weather element but dead last in satisfaction of the forecast.

It is disappointing that only 13 percent of respondents rank the forecasts they receive as a 9 or better on a scale of 1-10. Almost every day somewhere in the United States there is an impactful storm. These storms have a major impact on how electric utilities manage their operations. Waiting until it hits is too late.

Utilities are investing hundreds of millions into hardening their infrastructure to ensure they can withstand the impact of a weather event. It is our conclusion that companies need to be focusing resources on ensuring they received detailed forecasts of weather elements that are impactful to operations and then score these forecasts as to their accuracy so good decisions can be based on good data. Utilities using forecasts must eliminate the garbage in – garbage out paradigm.

Today electric utilities are well past the age when simply "Red Sky at Night… Sailor's Delight" reflected an accurate forecast. In today's digital world with real-time major financial decisions in a connected world, it is important to ensure the forecasts you receive are the best they can be and that the decisions you make are based on focuses that score highly on a accuracy scale.

The full 24 page report can be found at *www.resourceson-demand.com*

ABOUT THE AUTHORS

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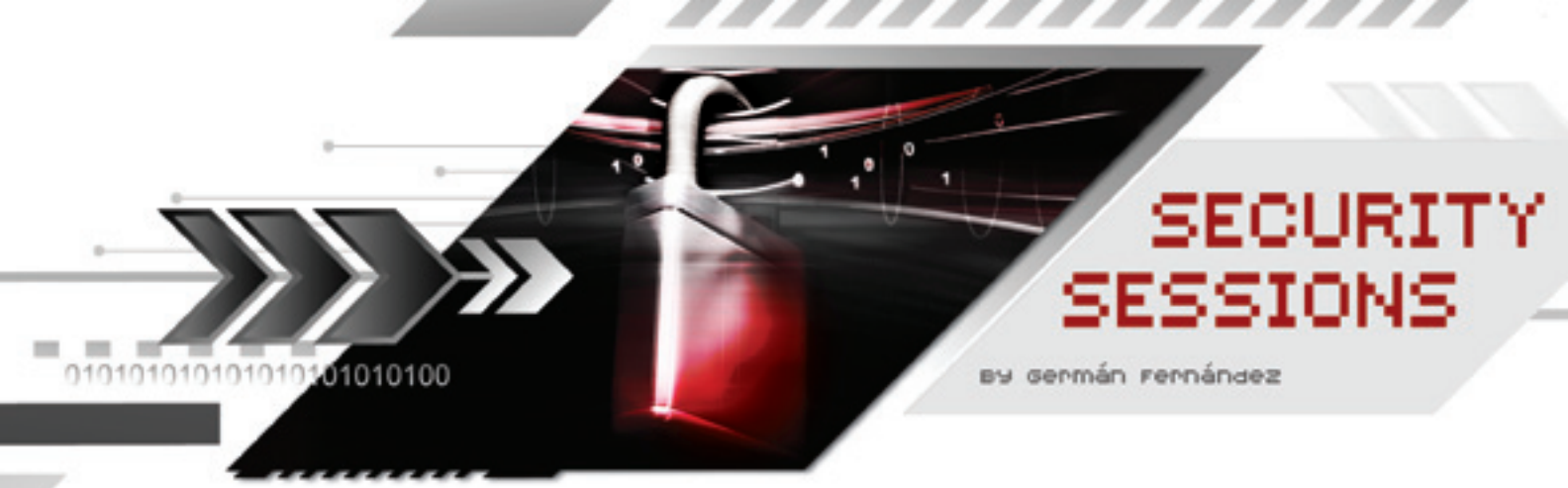
John Kullmann is Vice President at Macrosoft. With more than twenty years' experience, John is a recognized expert in business development efforts for professional services firms. He is responsible for expanding Macrosoft from its traditional roots as a leading software development and system implementation company into an equally accomplished provider of packaged technology products.



Combatting Cyber Threats in the Electrical Grid: A Guide for Engineers

Electrical grid security continues to be top of mind for power and utility companies. A recent sniper attack on a Utah substation highlights that grid vulnerability is a very real problem and that teams must be prepared to handle the variety of security issues that face power engineers today.

Physical threats, such as external attacks, are far too common, but threats can also come from the inside. Cyberattacks in the electric power industry are on the rise, with more than 75 percent of those surveyed by Tripwire saying they experienced a significant cyberattack in the past 12 months.

A sound, holistic cybersecurity policy requires a collection of measures adopted to prevent unauthorized use, malicious use, denial of use, or modification of information, facts, data or resources. A good cybersecurity policy doesn't just protect against intentional attacks from outside the network, but also internal issues and unintentional modifications of information. Cybersecurity is about making a facility more reliable and reducing network downtime. It's not about defeating hackers or terrorists – contrary to popular belief, they only account for 10 percent of known incidents.

New Complexities Require Strong Communications Networks

New technologies – such as transmission control protocol/internet protocol (TCP/IP) based technologies for both substation automation networks and wide area network (WAN) communications between substations – have opened most industrial communication networks up to more cyber threats.

Having an effective cybersecurity policy in place is a simple first step to maintaining the reliability and safety of substation and grid operations. There are a few key criteria that make a strong cybersecurity policy:

- Confidentiality: Preventing unauthorized access to information
- Integrity: Preventing unauthorized modification or theft of information
- Availability: Preventing denial of service (DoS) and ensuring authorized access to information

Power grids have become increasingly complex over the years. More interconnection with systems across countries has made failures and mistakes more likely – and their potential impact greater in scope and cost. Strong communications networks require commercial off-the-shelf technology; Ethernet and TCP/IP-based communications protocols; open standards, such as IEC60870-5-104 and IEC61850; the integration of legacy industrial protocols and Modbus TCP; remote connections with multiple devices; and use of public networks and interconnection with company IT systems.

Five Steps for Superior Security

How do teams build up levels of security and ensure those remain constant? Cybersecurity is an iterative process and as surrounding conditions or threats change, systems and policies must adapt.

When cybersecurity issues are not fully addressed, downtime occurs, which is costly. Since it's not realistic to assume all threats can be prevented 100 percent of the time, recovery strategies after issues occur are also critical to protect network uptime. There are five critical levels for network security that will help teams keep threats minimal and reverse any damage threats have caused the network:

1. **Preventative security**: Intended to prevent an incident from occurring, and reducing the number and types of risk. An example of this kind of layer is password protection and policies.
2. **Network design security**: Minimizes the vulnerabilities and isolates them to prevent an attack from affecting other parts of the network. This is achieved by limiting the number of connections through a zones and conduits method.
3. **Active security**: Implemented before and during an event. These measures block off traffic or operations not allowed or expected in a network. Examples of this layer include encryption, protocol-specific deep packet inspection, Layer 3 firewalls and antivirus use.
4. **Detective security**: Identify and characterize incidents by evaluating activity registers and logs. This can include log-file analysis and intrusion detection system monitoring.
5. **Corrective security**: Aims to limit the extent of any damage caused by an incident. Protocols are built in for retrofitting preventative security and the network design security measures once a vulnerability is detected. Firewall and antivirus updates are the most common mechanisms in this layer.

Only having one point of defense is not the most effective way to enforce cybersecurity throughout a communications network. Rather, a best practice is to deploy multiple layers of defense throughout the network so if one is bypassed, another layer provides defense. No matter how good it is, relying on one security system sets teams up for security failure.

Defense in Depth: Ensuring multiple layers for robust security

Teams need to make sure each of the security layers throughout the network is slightly different so that if an attacker finds its way past the first layer of defense, they don't have the capabilities for getting past all subsequent layers of defense as well. Each of the defenses should be designed so they are context and threat specific – they should essentially be designed for the specific threat at hand.

The electric power grid system can be exposed to multiple threats at once, ranging from computer malware and angry employees to DoS attacks and information threats. Each of these vulnerabilities needs to have an appropriate defense mechanism at the ready. In substation applications, sophisticated supervisory control and data acquisition (SCADA) aware firewalls observe network traffic all the way down to specific types of commands. This defends against the context of the threat to the system.

A few other steps teams should take to ensure multiple layers of defense include:

- Prioritize threat responses and make sure mission-critical systems are secure first.
- Create a culture of security by keeping teams informed and educated on security best practices.
- Update existing risk assessments regularly, including both physical and virtual checks.
- Don't apply a one-size-fits all solution across the entire IT and SCADA system. The threats, risks and goals of these systems are different, and so should be the solutions.
- Install routers and firewalls between the corporate backbone and the substation network for more security support.
- Implement stateful inspection or deep packet inspection to ensure only authorized packets travel between both networks.
- Segment between the operational network and telecom network by creating demilitarized zones for servers and computers in the operational network with external access.

Complete protection against every potential cyber and physical attack is not possible, but most threats can be avoided with a strategic and holistic security strategy. At the core, being able to quickly detect, isolate and control the threats is the key to success so that the impact on the rest of the network is limited. Substation security requires vigilance against both accidental and intentional threats to the network. Following an integrated security approach that has multiple layers of defense is the best way to limit damage, control threats and manage risks more efficiently.

ABOUT THE AUTHOR

Germán Fernández has more than 15 years of experience in the electric power industry, specifically pertaining to industrial Ethernet networking and telecommunications technologies. He is the global vertical marketing manager for the energy market at Belden. Germán has managed power projects worldwide as a system integrator and brings a deep understanding of cybersecurity needs for electric power utilities to his role at Belden. He is also a member of the Cigre Working Group D2.40.

Guest Editorial 1

Oxy-PFBC: Paving the Way to Low-Cost Carbon Capture

By Don Stevenson and William Follett

As renewable energy grows as a serious option for delivering capacity for power generation, fossil fuels continue to serve as the top source for energy production worldwide.

It's a dilemma. Fossil fuels are the world's most abundant and lowest-cost fuel source, so countries across the globe need to continue to burn fossil fuels to produce affordable electricity. Yet, because it relies heavily on coal, the most carbon-intensive fossil fuel, power generation is one of the primary sources of carbon dioxide (CO_2) emission, with electricity and heat generation accounting for nearly half (42 percent) of global CO_2 emissions in 2013. [1]

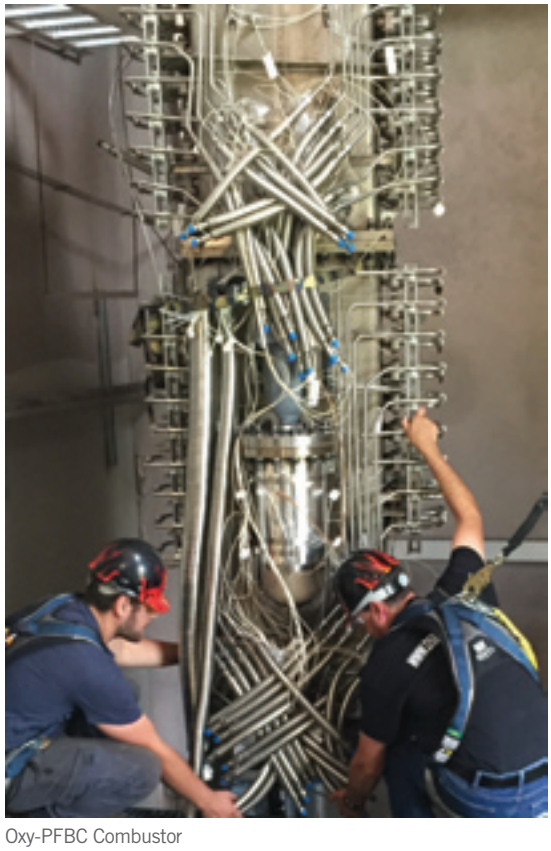
A solution is needed that can significantly reduce the impact of CO_2 and other greenhouse gas (GHG) emissions on climate change. For years, climate researchers have focused on technology solutions designed to achieve large-scale reductions of carbon emissions from fossil-fueled power plants.

When fossil fuels are burned with air, the exhaust gases (primarily nitrogen from the air, CO_2 and water vapor) are emitted into the atmosphere, typically through a chimney, or flue. Carbon capture and storage (CCS) technologies, which are designed to separate CO_2 from the flue gas so that it can be prepared and pressurized for underground storage, or sequestration, are recognized as the most practical method for controlling the by-products of fossil-fueled power plants. The International Energy Agency (IEA) projects that, by 2050, CCS will account for 13 percent of global emissions reductions.[2]

A Range of Approaches to CCS

The recent Paris Climate Conference (COP21) ramped up momentum for research and development (R&D) to advance CCS technologies. The Paris climate-change agreement that resulted from the conference represented a commitment by 195 countries to work to reduce GHG emissions to a level that will keep global temperatures from rising more than 2° C by 2100. The agreement also includes a provision that requires developed countries to significantly increase their clean energy R&D funding over the next five years.

Over the years, researchers have developed a range of approaches to separating CO_2 from the flue gas mixture that is a by-product of power generation. Current technology employs the post-combustion approach to reducing carbon emissions at existing power plants. In this process, flue gases pass through a process in which the CO_2 is separated and stored.



Oxy-PFBC Combustor

Oxy-PFBC: Paving the Way to Low-Cost Carbon Capture

With pre-combustion capture, or integrated gasification combined cycle (IGCC), oxygen is stripped from the atmosphere to produce a nearly pure stream of oxygen gas, which is fed into a gasifier that bakes the coal and releases syngas, a mixture of gases (hydrogen, carbon monoxide, and CO_2). The syngas is subsequently separated into CO_2 and hydrogen. The hydrogen is then combusted in a gas turbine to generate electricity, while the CO_2 is compressed for storage.

The capture and storage of CO_2 using these methods requires a significant amount of energy and cost. A recent report from the U.S. Department of Energy (DOE) projected that implementation of CCS technologies like post-combustion and IGCC will increase electricity costs by more than 75 percent, compared with coal power plants without CCS[4]--an increase in cost that is often referred to as the 'carbon capture penalty.' For carbon capture to be affordable, these high costs—and the high energy penalties associated with them—must be reduced.

Pressurized Oxy-Combustion: Moving the Carbon Capture Needle

The National Energy Technology Laboratory (NETL) of the DOE, in its efforts to support the national objectives of addressing climate change by reducing GHGs, is funding projects through its Advanced Combustion Systems Program to demonstrate two new carbon capture technologies—chemical looping combustion and pressurized oxy-combustion. With these technologies, NETL hopes to meet the cost and complexity challenges of carbon capture.

Pressurized oxy-combustion promises to significantly shrink the carbon capture penalty paid by pre-combustion and post-combustion processes by burning fuel using a pressurized mixture of oxygen and CO_2 instead of air. The nitrogen is removed from the air prior to combustion. This improves efficiency and results in flue gas that is primarily CO_2 and water vapor, enabling simpler and lower-cost CO_2 separation. Pressurization also drives down the size of the equipment, resulting in additional cost savings.

"When fuel is combusted with conventional technology, the exhaust gases are unpressurized and consist mostly of nitrogen, so it's difficult to separate out the constituents," says Don Stevenson, executive director at Gas Technology Institute (GTI), a leading energy and environmental R&D organization that is spearheading the effort to advance the oxy-fired pressurized fluidized bed combustor (Oxy-PFBC), a new oxy-combustion technology.

The GTI Oxy-PFBC plant was recently launched with a ribbon-cutting ceremony for the pilot test facility at CanmetENERGY in Ottawa, Canada. The Oxy-PFBC process introduces an additional element to the pressurized oxy-combustion process. "The technology uses a technique called a fluidized bed," says Stevenson. "It's the enabling technology that allows us to maximize the heat transfer and to package the technology into a single pressure vessel." This is a unique solution. "Other people are looking at pressurized oxy-combustion, but they are not using the fluidized bed."

Ribbon Cutting Kim Rudd and Douglas Hollett

"The combustor was designed by a team of ex-rocket scientists to achieve record-breaking power density," adds Bill Follett, GTI's program manager for the Oxy-PFBC project. "We use oxy-combustion for rapid burning and heat release, but need to remove the heat as rapidly as we create it. The fluidized bed is composed of loosely packed sand-like particles in constant motion. As they hit the steam tubes inside the combustor, they are three times more effective than gas in transferring heat out. It all comes together in a low-cost, compact, integrated package."

The demonstration in Canada will validate performance and plant economics using NETL guidelines. It will also identify technology gaps that need to be filled to advance the technology.

Oxy-PFBC: Paving the Way to Low-Cost Carbon Capture

Game-Changing Benefits

The Oxy-PFBC process offers a number of benefits, one of the most important being the reduction in the cost of carbon capture, which has long been one of the key challenges to U.S. efforts to scale technologies to the levels that are needed to slow global warming. Oxy-combustion enables high-efficiency gas cleanup, while pressurization shrinks the equipment size and the cost. The combustor is one-third the size of a traditional combustor and less than half the cost, saving hundreds of millions of dollars for a commercial-scale plant.

These reductions in equipment costs are reflected in a lower cost of electricity. Compared with pre- and post-combustion technologies, the cost of electricity is reduced by 23 to 30 percent, eliminating up to three-fourths of the carbon capture penalty associated with these technologies. Sale of the purified CO_2 can reduce the penalty even further, possibly eliminating it altogether.

Even more important, pressurized fluidized bed combustion can result in electricity production from coal with near-zero emissions, while biomass-coal blends can achieve negative CO_2 emissions. A commercial-scale plant can capture CO_2 emissions equivalent to removing 145,000 cars from the road.

The DOE has high hopes for the Oxy-PFBC process. A recent NETL press release stated that "this project is a major step forward for CCUS," adding that "the captured CO_2 can then be stored or used beneficially to develop other products, including feedstock and chemicals."[5]

A Powerful Partnership

The Oxy-PFBC demonstration project is a joint effort between the U.S. DOE and its Canadian counterpart, Natural Resources Canada (NRCan). Research is being spearheaded by GTI in collaboration with CanmetENERGY, Linde, Electric Power Research Institute (EPRI), GE, Pennsylvania State University, and University of Ottawa – with support from the NETL, the Canadian Clean Power Coalition, and Alberta Innovates.

At the ribbon cutting event, Kim Rudd of NRCan (with wrench) and Douglas Hollett of the US DOE conduct a ceremonial bolt tightening on the Oxy-PFBC to celebrate construction of the pilot scale plant and the U.S. / Canada collaboration to meet international climate change objectives.

GTI designed the system, fabricated the Oxy-PFBC, and did the system modeling. The Ottawa test facility is hosted by CanmetENERGY, which is the R&D laboratory for NRCan. "Canmet has unique facilities to accommodate the system setup, and the researchers there have valuable knowledge in this area," says Stevenson. "They are familiar with the challenges and are a great resource for helping us work through the integration issues." Linde designed and built the CO_2 capture and cleanup equipment.

The project is an example of the ongoing cooperation between the U.S. and Canada that has driven efforts to generate electricity and heat with zero emissions. "Canada and the United States share a bold vision for our continent," said Kim Rudd, parliamentary secretary to the Minister of NRCan. "We will continue to work together to meet our climate change objectives, increase competitiveness, and support employment opportunities."

The U.S. and Canada, in fact, worked together at COP21 last December to launch Mission Innovation, a 20-country commitment to double each country's respective investments in clean energy R&D over the next five years. "[The Oxy-PFBC project] highlights the importance of the long-standing U.S.-Canadian collaboration on clean energy technology development," said Douglas Hollett, principal deputy assistant for fossil energy at DOE.

Oxy-PFBC: Paving the Way to Low-Cost Carbon Capture

This December, the team will begin to validate the process and conduct extensive testing on various feedstocks with the pilot plant to mature the technology. This will serve to close technology gaps to advance progress toward the DOE carbon capture goal of demonstrating technologies and best practices that can achieve more than 90 percent carbon capture and reduce electricity costs by at least 20 percent relative to current carbon capture technology.

The project received $13 million from the DOE Office of Fossil Energy's advanced combustion program and is managed by NETL.

In addition to the Oxy-PFBC project, GTI is designing, fabricating, and testing a supercritical CO_2 (SCO_2) power-cycle heat exchanger designed to enable the pilot plant to achieve even greater power-cycle efficiencies and lower costs. A steam cycle will reduce the cost of electricity by 23 percent, while an SCO_2 cycle can deliver a 30-percent reduction.

"The conventional approach to power generation uses heat to convert water to steam, which is then used to run a steam turbine," says Follett. "Using supercritical CO_2 instead of steam offers a more efficient method of generating electricity. While supercritical CO_2 is used in a similar manner to steam in a power cycle, it has interesting properties that provide several advantages for lower-cost electricity generation."

Supercritical CO_2 is a form of CO_2 at high temperature and pressure. While it is neither a liquid nor a gas, it has some properties of both. The advantages of using supercritical CO_2 in a power cycle are:

- Its high density drastically reduces the size of turbines for lower cost.
- Its critical pressure is one third of steam, which permits lower operating pressure.
- Unlike steam, it can be pumped like a liquid for higher efficiency without the need for a condenser.

As a result, when the Oxy-PFBC process is coupled with supercritical CO_2, reductions in the overall cost of electricity production with carbon capture can be even greater.

Looking to the Future

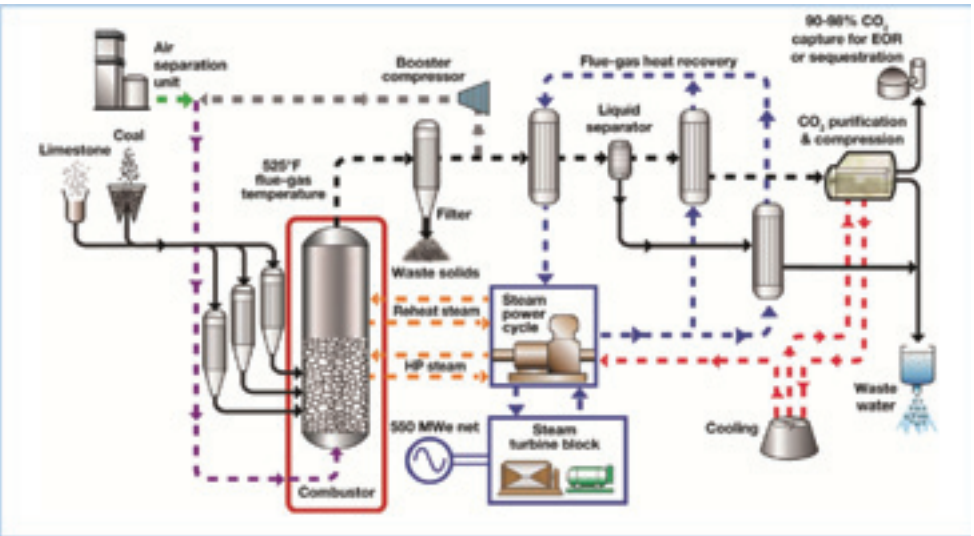
Successful results from the Oxy-PFBC project will serve to jump-start efforts to bring it to commercial scale. According to Stevenson, there are two potential applications for the process: a retrofit and a brand-new plant. "In a retrofit scenario, we could take this system and apply it to an existing power plant by adding air-separation units to produce oxygen, replacing the boiler, and providing steam to the existing power cycle. In this case, there would be no need to replace the turbine."

In the future, fully proven and commercialized supercritical CO_2 will enable the construction of brand-new power plants with a smaller footprint. GTI is currently working with General Electric Global Research and other partners to design, build, and operate a DOE-funded supercritical CO_2 pilot plant test facility in Texas.

Projects like the Oxy-PFBC demonstration offer great promise for nations looking to continue to rely on fossil fuel-based power generation, while also helping them minimize climate change. "As we look ahead, the real potential for this technology is for global application, particularly in the developing world, where countries are heavily dependent on coal," says Stevenson.

"As restrictions from COP21 and subsequent efforts to curb CO_2 become stricter, this will be one of the technologies that many countries will have to turn to, because it provides an affordable way to produce power with full carbon capture."

Oxy-PFBC: Paving the Way to Low-Cost Carbon Capture



The Oxy-PFBC process

Coal is injected and burned with a mixture of oxygen and CO_2 in the fluidized bed (Combustor). Limestone is also injected to capture sulfur. As the coal is combusted inside the pressure vessel, the water moves through the tubes arrayed inside the combustor and the fluidized bed enhances heat transfer to the tubes to turn the water into steam. Steam moves into the turbine to generate electricity Pressurized CO_2 and water exit as flue gas. The water is removed and the CO_2 purification system removes other trace gases. The purified CO_2 is pressurized further and piped out for sequestration (as shown in the top right corner of the figure.)

ABOUT THE AUTHORS

Don Stevenson, Executive Director, Research & Development, leads GTI's Advanced Energy Systems Group that was formed in July 2015 from the acquisition of the terrestrial energy technology portfolio from Aerojet Rocketdyne. His team is responsible for the development and commercialization of advanced combustion and energy conversion technologies for chemicals and power production, as well as emission mitigation, water treatment, and oil recovery.

Don earned a B.S. in Aeronautic & Astronautics from University of Washington and an M.B.A. from Pepperdine University, completed courses toward an Advanced Project Management Certificate Program from Stanford University and participated in the Executive Management Program at University of Virginia Darden School.

William Follett IV is a Program Manager of Fossil Fuel Energy Systems at GTI. He has 29 years of experience in technology development across a broad array of technologies that span the energy, space, underwater, and automotive application areas. Energy applications include coal combustion, supercritical CO2 cycle, and fuel cells. Coming to GTI from Aerojet Rocketdyne, he is responsible for execution and program capture activities that are step-change or transformative technologies in the energy industry.

Mr. Follett earned an M.S. in Mechanical Engineering from Stanford University, and a B.S. in Mechanical Engineering from Texas A&M University.

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Guest Editorial 2

Combining High Performance Computing with Big Data Analytics on the Same Infrastructure

New solutions offer flexibility to run workloads on bare metal, virtualized, or containerized

By Dr. Matthijs van Leeuwen

Three important trends keep coming up in conversations with customers in the high performance computing (HPC) and big data markets. The first is that more and more users want to combine HPC workloads with big data analytics workloads on the same infrastructure. The second trend is the demand for flexibility to run workloads on either bare metal, virtual machines, or, most recently, in containerized environments. The third trend, closely related to the second, is the demand for flexibility to run on-premise and in the public cloud. New technology is providing an infrastructure that can be the foundation for combining high performance computing, big data, and private and public cloud environments, and managing it all through a single-pane-of-glass.

HPC and OpenStack – gaining flexibility to allocate resources

The cloud computing revolution continues to change the way organizations view their IT resources. OpenStack cloud software provides a common, open source platform that can be used by corporations, service providers, researchers, and anyone else that wants to deploy a private cloud. For many HPC users the question now becomes, can I run an HPC workload atop this OpenStack or alongside it? In the past users needed a dedicated HPC cluster, but now the ability to choose either option creates flexibility. Virtualizing the infrastructure using an OpenStack private cloud allows administrators to be far more flexible in allocating resources.

Take an example of a 25-server environment, in which 10 servers must be dedicated to meet the demands of the HPC load. In this scenario, it is difficult to grow or shrink to meet demand if the demands change significantly. With OpenStack, users have far more flexibility to grow or shrink the cluster. One might increase the cluster overnight and decrease it again in the morning.

Running workloads virtualized inside OpenStack can be a big benefit in many settings. Take the example of researchers in the pharmaceutical industry conducting simulations for drug discovery. When one is required by regulation to store results of simulations and be able to produce them years later, one could choose to run inside a virtual machine (VM) and then shut down and store the entire VM, complete with operating system and libraries. The user would know for certain that results can be precisely duplicated, because the software environment is stored exactly as it was. In addition, some users have very different requirements for their operating systems and their versions of libraries, and a completely tailored environment can be offered in a VM.

While offering a variety of benefits, OpenStack can be difficult to configure and manage. In addition, with virtualization there is a performance penalty, typically less than 10 percent. Some users chalk that up to the price one must pay, while others consider it a barrier to adoption. Also, there is a perception that some hardware technologies are not fully supported by OpenStack, but the industry is definitely making huge progress. For example, InfiniBand and accelerators can now be used through virtualization.

Those not using OpenStack are probably turning to other forms of private cloud, which can be quite an expensive proposition. Or, they may just semi-manually manage their VMs on bare metal using customized scripts and smart provisioning. This is not as flexible, can be prone to errors, and perhaps most significantly, makes users very dependent on the system administrator.

Foundation for combining HPC and big data workloads

Figure 1 is a conceptualization of an infrastructure that combines HPC and big data workloads and gives users the choice of working in either a bare metal or virtualized infrastructure – and even burst through into the public cloud.

We start at the bottom with the physical infrastructure of the servers. On top of that basic infrastructure resides a Linux operating system, with a management solution in which the Bright agent is running on every server. Running HPC on top of that foundation would require the use of a cluster management solution like Bright Cluster Manager. The Bright Computing layer offers a single pane of glass management for the hardware, the operating system, the software, and users.

For running big data workloads or adding big data functionality on top of that, one would use Bright Cluster Manager for Big Data, an option that builds, manages, and maintains big data clusters using Hadoop and/or Spark. Bright Cluster Manager for Big Data was specifically designed to combine HPC and big data workloads. When used on a Bright cluster with Intel's HAM + HAL plugins, the system offers a common file system and workload manager across the two platforms.

The scenarios in the *Other* category, for example, server farms, storage clusters, or even a high frequency trading cluster at a bank, also require a similar cluster management solution and infrastructure. For the Private Cloud option, Bright OpenStack adds cloud capability on top of the initial foundation.

Combining High Performance Computing with Big Data Analytics on the Same Infrastructure

Figure 1
New infrastructure is the foundation for combining HPC and big data workloads

The support of Bright Cluster Manager allows users to offload the workload to a public cloud or to a mixed environment, with some servers run on-premise and some in the cloud. It is easy to expand the two options with the single pane of glass solution.

The demand to build an on-premise *private* cloud has become stronger recently, driven in part by security issues. In some industries, legislation requires that certain data remain inside the company's firewall. There are other issues that favor an on-premise solution over a public cloud. For example, the very large datasets involved with big data applications may be impractical to transfer to a public cloud. Finally, cost may be a factor, since public cloud services are often more expensive to use over the long term, when compared to on-premise alternatives.

Moving up the diagram, perhaps the most exciting aspect of the concept is the ability to combine all these options on the same infrastructure. For example, the next step would be to further build on top of the virtualization layer provided by OpenStack.

The chief task of OpenStack is to manage VMs – to stand them up, apply a configuration to the template, move them around, and to manage them. But it is important to realize that OpenStack has no awareness of – and no control over – what happens inside the VM. In other words, it controls the VM itself, but it does not control what goes on inside it. Typically, an operating system runs inside of these VMs, either Linux or Windows. If one wants control and awareness of what happens inside the VM, one could apply the Bright layer on top of these VMs and operating systems.

This means that the software used to build and manage the cloud is the same as that used to manage the cluster built inside that cloud – even though the bottom is based on bare metal, and the top is based on virtual machines. The figure shows that one can continue to build exactly the same infrastructure on top of the VM layer as was achieved with bare metal, including HPC, big data, private cloud, as well as other server types. Finally, this foundation sets the stage for bursting out to the public cloud from within both the physical and virtualized infrastructures. Bright Computing can do all of this out of the box.

The conceptualization shows an approach for combining HPC and big data workloads and giving operators the flexibility to choose between bare metal and virtualized infrastructure. The next step, now in the works, is working with *containers* – simulated virtual machines that may look and feel like a real server from the point of view of owners and users.

Real world examples of HPC and big data clusters working together

The innovative and unique infrastructure depicted in the diagram has been in place for nearly a year at Bright Computing. It is being used to run a private cloud inside a Bright data center, where software developers stand up HPC clusters, big data clusters, and OpenStack clouds. It has also been used by quality assurance engineers to run tests, by support engineers who need to reproduce a scenario experienced at a customer site, and by systems engineers to run demonstrations.

The infrastructure has proven to be extremely flexible, enabling Bright to do a lot more with its resources. The ability to virtualize the clusters enables us to stand up and shut down the large number of clusters needed to serve customers, without having to build out a much larger data center.

Another example is a major pharmaceutical company that was looking to optimize the use of its existing server infrastructure. The company had a substantial group of HPC and big data users and wanted to deploy a private cloud in their data center in which they could mix general IT workloads with HPC workloads. The objective was to make more HPC resources available for researchers to run jobs overnight when the general IT world load was low.

Using Bright OpenStack, the company's administrators were able to provide flexibility and customization to their user base while optimizing the use of existing resources. The solution reduced their need to invest in more hardware because they could use what they already had more efficiently. The initial deployment was so successful that similar deployments are now in use at five other sites.

ABOUT THE AUTHOR

Dr. Matthijs van Leeuwen serves as Chief Executive Officer of Bright Computing, Inc. Dr. van Leeuwen is a Co-founder of SimuGen Limited, and serves as its Chief Operating Officer. He gained research experience at the University of Cambridge. Dr. van Leeuwen is responsible for SimuGen's operational and business development activities. In addition to his UK and Singaporean entrepreneurial activities, he has been very active as a consultant at the Cambridge-MIT Institute and Library House in Cambridge. Most recently, he was a biotech analyst at London-based Imperial Innovations, one of Europe's leading technology commercialisation and investment companies. Dr. van Leeuwen holds a B.Sc. in Biomedical Sciences and M.Sc. in Science & Business from the University of Utrecht.

Taking Lean Manufacturing to the Next Level

Guest Editorial 3

By Alan Swade

Take a moment and consider society's increasing infatuation with fitness. We think about losing bulk, building muscle, increasing speed and stamina – becoming *lean*.

Engineers apply the same mentality to create lean production. Like the lean ideology we apply to ourselves, lean manufacturing often results in becoming smaller. By applying the "less is more" mentality, activities that do not provide value are removed from manufacturing processes, moving production lines faster and more efficiently – ultimately providing customers with high quality, specially configured products with short lead times.

Lean manufacturing isn't a new concept. Originally designed by Toyota[1] in the 1930s, it shifts the focus of the manufacturing engineer from individual machines and their utilization to the flow of the product through the total process. This way, it aims to produce more with less at a faster pace, while requiring less rework and waste.

Lean processes are at the heart of most manufacturing facilities worldwide and continue to gain popularity in other industry sectors, such as distribution and financial services. But technology advancements and internet accessibility have required it to move beyond assembly line production and manifest into lean thinking, lean design and lean management.

This rise of the fourth industrial revolution, driven by advances in technology that combine the physical, digital and biological worlds, provides endless possibilities multiplied by emerging technology breakthroughs in fields such as artificial intelligence, robotics and the Industrial Internet[2]. And while many industries will be impacted by the breadth of these breakthroughs, manufacturing stands to profit immensely. In fact, GE estimates[3] that there will be more than 50 billion connected devices by 2020 and that the Industrial Internet could add $15 trillion to global GDP in productivity gains over the next 20 years. This connectivity will contribute to the technological revolution – or fourth industrial revolution – that will disrupt almost every industry worldwide.

Better products delivered faster

Taking a page from its predecessors, the fourth industrial revolution has the potential to raise global income levels and improve the quality of life around the world[4]. Though consumers have traditionally gained the most from technology advancements, we will soon see supply-side innovations with long-term gains in efficiency and productivity through a drop in transportation and communication costs, as well as more effective logistics and global supply chains.

GE's Brilliant Factories[5], which digitally connect designers, suppliers and production engineers, conceptualize this by bringing the Industrial Internet to Advanced Manufacturing. For example, GE's new capacitor facility in Clearwater, Flor., illustrates how advanced lean manufacturing has become, where facilities around the world are evolving into *Brilliant Factories*. The Clearwater capacitor and instrument transformer facility features sensor enabled machines, automated robotics and sophisticated drying ovens that help increase productivity. Its vertically integrated operations also provide for a consistent reduction of lead and cycle times across a wide variety of product configuration.

The connectivity of the Industrial Internet fuels Advanced Manufacturing, equipping machines with sensors that send information about humidity, temperature, dust level and other factors into the data cloud for storage and analysis. GE's Predix™ Edge software then curates the real-time data to predict outcomes at every stage of the manufacturing cycle, creating a digital thread that connects manufacturing sites and people to customer and community networks throughout the world.

As one of the first sites to embrace this technology, the Clearwater facility has seen a significant reduction in manufacturing time while still possessing enough flexibility to produce various types of capacitors, including high-voltage, direct current (DC) traction and water cooled.

While quality testing has traditionally eliminated defective products, the use of this technology helps determine the likelihood of defects occurring downstream. Proactive steps can then be taken to help ensure quality and throughput. In the past, workers wouldn't know that anything went wrong in the manufacturing cycle until they tested the device, but Predix™ erases that uncertainty and helps fix suboptimal processes before they become expensive. This data allows for reverse-engineering of these successes to improve processes for the entire production.

Lean manufacturing isn't solely defined by process improvement – it also helps reduce resource consumption. Though the facility was created through an extension of an existing transformer factory and the consolidation of two larger legacy facilities – increasing its capacity by 35 percent – lean processes have allowed GE to decrease its overall footprint by nearly 60 percent. The Clearwater facility houses a class 1000 clean room, where the main ingredients used in making capacitors are stored and made. In the clean room, factors like humidity, temperature and air quality can be controlled to help eliminate dust and particle contamination from the manufacturing process. All unused materials are also recycled, helping to minimize waste and contribute to a better environment.

Why capacitors?

The capacitors made at the Clearwater facility, which help bring electricity to homes and businesses, are an example of the Industrial Internet's potential to improve global supply chains, which in turn will supply utilities with these products more efficiently – ultimately helping them provide consumers with a more affordable and reliable power supply. They are used in a range of industries apart from energy, such as railway and induction heating and melting, serving customers from all over the world.

The value capacitors bring to the world is undeniable. In an ideal power system, the power required by end users would equal 100 percent of the generated power, requiring little or no reactive power; however, inductive devices like motors and transformers consume real power, requiring the utility to generate reactive power to send to the end user. This consumes valuable limited transmission capacity, lowers the power factor and significantly reduces efficiency, which increases generation and transmission costs. But with the use of high-voltage capacitor banks, the effects of inductive devices can be diminished by reducing the amount of reactive power flowing through the transmission system. By reducing the need for reactive power, capacitors help to maximize the existing transmission capacity and greatly improve the transmission system's power factor – improving efficiency and reducing the cost of generation and transmission.

The evolution of the energy industry, including increasing growth of HVDC transmission technology and advanced SVC, will fuel the need for capacitors[6]. In addition, capacitors will be required for reactive power management as renewable energy sources, such as wind and solar energy, continue to gain popularity, creating a need for large-scale grid integration. As more and more societies commit to renewable energy integration, the need and demand for capacitors will continue to grow. And the Clearwater factory is leading the industry by creating a system that produces these products quickly, efficiently and with uncompromising integrity.

ABOUT THE AUTHOR

Alan is the General Manager for Grid Solutions' Capacitors product line. In this role, he has the responsibility for the profit & loss and product management of the combined $250 million portfolio. He leads teams of enablers, who manufacture and produce capacitors that maximize electrical transmission capacity, improve efficiency as well as reduce the cost of generation and transmission. Alan has nearly 20 years of experience in GE, holding Sales and Quality positions in Industrial Systems Solutions, as well as P&L leadership roles in Engineering Services and Water & Process Technologies. He holds a Six Sigma Black Belt as well as a Bachelor of Science in Mechanical Engineering from Marquette University and an MBA from the University of Detroit Mercy.

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