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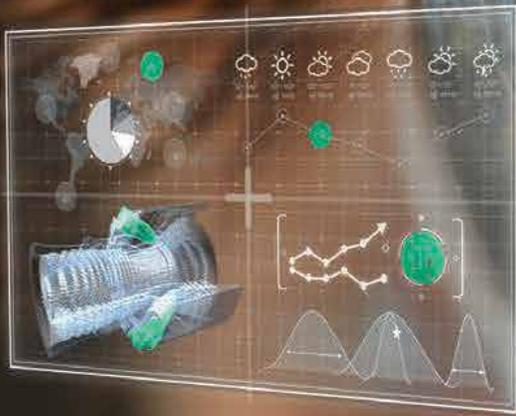
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Dick Flanagan
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It's time to take a look back as we proudly celebrate our 30th Anniversary. World-Gen was launched by Harcourt Brace Jovanovich and two years later acquired by the Flanagan Group in a leveraged buyout from GE Capital in 1990.

It's been a story of a grid of people in companies reshaping the energy industry under deregulation. Deregulation was the industry's first wake-up call: utilities became IPP's and IPP's became utilities. World-Gen reported on the transition globally having received more assignments than any other energy publication.

We are continuing to build editorially by adding staff and by offering 24/7 "Breaking News" from six news feeds. They came to talk to us initially and have renewed annually. World-Gen went digital in 2015 while continuing to print show copies for the five conventions we co-sponsor. AW charts web statistics daily on world-gen.com.

This was all made possible by the companies listed on the front cover. We would like to acknowledge and thank them again for their support and friendship over the years.

Peter Maloney explains Siemens' partnerships aimed to thwart cyber threats posed by digitalizations on page 4.

Gilian Corral shares her takeaways from GE's Minds & Machines Conference on October 25th at Moscone on page 6.

Lyn Corum reports on Cal ISO's 2017 Symposium on October 18th and 19th in Folsom, CA on page 8.

Thom Redding writes about Leclanché's opening a new facility on Purdue University's Polytechnic Center on page 10.

Paul Winters said that partnerships were the key theme at BIO's 14th World Congress held in Montreal on page 12.

Steven Kunsman underscores the advantages of substations going digital on page 14.

Matt Hagen tells us that corporations and startups have signed up for the University of Washington test beds on page 16.

Jim Schretter sees three major forces reshaping the US electric industry on page 18.

Fred Lyon points out that the construction industry has encouraged an alternative to litigation in the form of arbitration on page 20.

Kim Greene comments on building the future at Southern Company with business partners developing breakthrough technologies on page 21.

Back by popular demand, Bob Palmer analyzes the engineering involved in Santa Claus's around the world trip on page 22.

World-Gen is a media sponsor for Power-Gen Week 2017 and will be distributed in Las Vegas, December 5-7.

We are renewing our media sponsorships in 2018 as an online publication with show copies in Feb/March 2018-Class of 2018; May/June 2018-EEI, Intersolar, SPI, Electrify Europe; Sept/Oct 2018-Bueche Directory; Nov/Dec 2018-Power-Gen Week 2018.

Please visit the media kit on world-gen.com for rates and closing dates.

Happy Holidays and Happy New Year!

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SIEMENS' AIMS AT CYBER THREATS

BY PETER MALONEY



Technology can bring great benefits such as gains in efficiency and productivity but, as has become all too obvious lately, those gains can come at a cost, increased vulnerability to cyber attacks.

One has to look no further than recent headlines to see that threat. Whether it is the 2015 attack on Ukraine's electric power grid or the more recent hack of Equifax data that yielded the sensitive financial data of 143 million Americans, cyberattacks underscore the growing importance of cybersecurity.

"We have seen a series of mega attacks; it is a new normal," says Leo Simonovich, vice president of global cybersecurity at Siemens.

The threat is particularly acute in critical infrastructure, whether it is financial services or energy infrastructure such as the electric power grid or the oil patch. And, as technology works its way deeper into everyday life and processes, the threats become more pronounced.

STUDIED BY PONEMON INSTITUTE

A recent study by the Ponemon Institute found that deployment of cybersecurity measures is not keeping pace with the growth of digitalization in oil and gas operations. In the survey, only 35% of

respondents rated their organization's operational technology cyber readiness as high, and 61% said their organization's industrial control systems protection and security is not adequate. A total of 68% of the respondents said their organization experienced at least one cyber compromise.

"Utilities and the oil and gas sector confront sophisticated, persistent and aggressive cyber threats in the operational environment," says Simonovich.

DIFFERENT SYSTEMS A CHALLENGE

The threat is compounded by the fact that there are so many different operating systems that make up modern industrial technology. In addition, there is a growing threat from the proliferation of digital devices and sensors and from what has become known as the Internet of Things (IoT).

Sensors can provide great benefits when they are used in the oil field or on remote section of the electric grid. Those sensors can alert operators to potential problems and can reduce overhead by enabling remote monitoring and control without human intervention. "But the sensors themselves are a significant threat vector," says Simonovich.

Hackers can even get past defense in depth cybersecurity measures via sensors, says Simonovich, "so it is critical to have visibility." In some cases, he says, those devices are "not even in your inventory. It doesn't belong to you or the power company."

"If you can't see those devices, you can't protect against them. It is that simple," says Simonovich.

NO SIGNS OF SLOWING DOWN

The movement toward digitization and the IoT is showing no signs of slowing down. The revenues and efficiency gains

are too compelling. Companies in both the utility and the oil and gas sectors are becoming increasingly digital. As digitization continues, there is a corresponding need to identify cyber threats at their earliest stages.

SIEMENS PARTNERS

With an eye toward addressing those vulnerabilities, Siemens has formed a strategic partnership with PAS Global, a provider of industrial control system cybersecurity solutions. Under the agreement, the partners will provide fleet wide, real time monitoring for control systems.

The partnership is designed to provide the deep analytics required to identify and inventory proprietary assets and to provide the visibility to detect and respond effectively to attacks across the entire operating environment.

"It is generally well understood that you cannot secure what you cannot see," says Eddie Habibi, founder and CEO of PAS Global. "That is why accurate, up-to-date visibility of system inventory is a fundamental element of any cybersecurity solution."

The partners say their agreement enables them to bridge "the visibility gap" for distributed, legacy control assets in order to provide a comprehensive view into fleet security. It will enable them to gather detailed configuration data down to the sensor and enable customers to secure proprietary systems in multi-vendor environments.

Despite the vulnerabilities that have been built up over the past several decades as companies have added layer after layer of technology, the benefits of digitization are too great to reverse course, says Simonovich. The world is becoming more interconnected, he says, and Siemens response is to build up its cyber defenses and the defense capabilities it can offer clients.

In addition to the PAS partnership, in May Siemens entered into a strategic partnership with Darktrace, which bills itself as an enterprise and industrial immune system technology company. The partner-

(continued page 17)

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GE'S DIGITAL REVOLUTION

BY GILIAN CORRAL



Imagine a smart utility that assesses damage and allocates crews to vulnerable areas, before a storm hits. Picture critical facilities as batteries, networked, intelligent, and ready to come online in a power failure. In the wake of Hurricane Maria destroying 80% of Puerto Rico's transmission lines, wildfires destroying thousands of acres in Northern California wine country, and Houston, Texas reeling from catastrophic flooding from Hurricane Harvey, leveraging the industrial internet to prepare the grid and critical assets for climate threats was front of mind for leaders at this year's GE Minds + Machines conference.

Now that GE's industrial internet platform, Predix, has had a couple of years of real world application, industry professionals are starting to see proof of what was imagined at the first Minds + Machines conference. "Just a few short years ago, the idea of a digitized, industrial company was just that – an idea," said John Flannery, Chairman and CEO of GE. "Today, this is a reality."

The IDC forecasts Internet of Things (IoT) spending to reach almost \$1.4 trillion by 2021. This year, the IoT is expected to grow 16.7% and reach \$800 billion in spending, the highest investments including manufacturing operations at \$105 billion, followed by freight monitoring at \$50 billion and production asset management at \$45 billion.

At this year's Minds + Machines conference, GE executives joined industry customers such as Exelon and New York Power Authority, as well as Microsoft CEO Satya Nadella on the stage to bring the message not of why, but "how we all can deliver on the promise of digital," in Flannery's words.

"DELIVER ON THE PROMISE OF DIGITAL"

According to GE, Predix has seen significant expansion, now boasting 960 partners, 33,000 developers, hundreds of thousands of managed assets, and 100% year-over-year growth in Predix-powered orders, and is not slowing down anytime soon. With the acquisition of ServiceMax in January, GE added increased field service management capacity to Predix; 120 million assets are now serviced by ServiceMax.

As Bill Ruh, Chief Digital Officer of GE, explained, GE Digital seeks to curate a transition for its customers from focusing solely on "mastery of assets" to full-operations networking and ultimately, whole-business transformation. "Master the asset, master the operations, and begin to move into business innovation," Ruh said. GE envisions moving its customers towards a "Common Asset Model", starting with asset data flowing into Predix, increasing reliability and efficiency through machine learning and modeling with the Digital Twin, and driving data and modeled predictions from the cloud back to the edge to inform services in the field. As Ruh pointed out, having computing capacity at the edge is critical, as connectivity in the field is not always available in the time and place it's needed.

Towards this end, as Ruh explained, GE is creating a "partner ecosystem", including a strategic partnership with Hewlett Packard to enable edge computing capacity with HP Enterprise, and a newly announced partnership with Apple to bring native iOS applications on top of Predix for enhanced mobile capacity. Predix's cloud

processing power will soon be enhanced with Microsoft Azure compatibility, for public release November 30th.

As GE builds out its digital ecosystem with its own applications and increased integration with existing applications, its architects envision a third capacity for Predix: rapid application creation. Patrick Franklin, GE's Corporate VP of Predix, introduced a new feature at Minds + Machines: Predix Studio, a low or no code learning environment for building apps and extensions in minutes with machine modeling algorithms baked in.

As the industrial internet of things (IIoT) market matures, its value is being proven to companies through a growing collection of business cases. What is potentially game changing, however, is how the IIoT through platforms like Predix is creating a digital bridge across entire industry sectors, with the potential to enable and accelerate each sector's transformation and ultimately, convergence.

RISE OF THE DIGITAL UTILITY

Throughout Minds + Machines, the message was resoundingly clear: an evolution of the grid is coming, and utilities have been slow to embrace it. The next generation grid will be greener, smarter, multi-flow, and connected. With the plummeting costs of solar, storage, and electric cars, the customer-producer (or "prosumer") will demand a grid that can handle not only increased needs for electricity in place of gasoline, but also connectivity to mobile devices, demand responsiveness to intermittent renewable generation, all the while maintaining reliability and affordability.

Minds + Machines opened this year with the heralding of this next-gen utility: "I'm so excited to be here today to tell you about our journey of becoming the first, I repeat, the first digital utility in the United States," said Gil Quiniones, President and CEO of New York Power Authority (NYPA). NYPA is building digital twins of 10,000 buildings in New York state with plans to double this by 2020. NYPA is also creating digital twins of its power plants within an Integrated Smart Operation Center that will double as an emergency

(continued page 23)

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THE CALIFORNIA REVOLUTION

BY LYN CORUM, CLASS OF 2003



The electric industry is undergoing a revolution and electric transportation will be the savior. This was the conclusion of panel speakers at the California Independent System Operator's 2017 Symposium on October 18 and 19, held at Cal ISO's headquarters in Folsom, California.

With the proliferation of renewable resources, the energy industry is witnessing the growing electrification of the economy, and in particular the need to transform the transportation sector due to the changing electricity supply curves.

Meanwhile, managing the volatility of renewables is causing the reevaluation of gas-fired power plants. Decentralization of the grid along with the need to regionalize the distribution of supplies were additional themes among speakers in the six panels.

THE ELECTRONOMY

John Danner, a professor at the University of California Berkeley's Energy Institute at Haas and Princeton University coined a word to identify the new reality – "the electronomy" meaning an electrified economy.

Mark Rothleder, vice president of market quality and renewable integration at Cal ISO, explained that we are looking at supply in a different way. "We now have more

supply than demand [in the middle part of the day] and a few hours later, we have less supply than demand. How can we take advantage of this? We need to provide grid reliability using frequency response, voltage control and leverage energy for other industries [like transportation]."

James Sweeney, director of Precourt Energy Efficiency Center at Stanford University, said if we have high positive and high negative prices on the grid, we need to communicate this to users via rate design so the users can take advantage of those prices and use their electricity to their advantage.

Steve Chadima, senior vice present, external affairs, Advanced Energy Economy, added that we can supply our excess to other states where there is fossil fuel such as coal which should be replaced. "We have to go to where the carbon is and use our markets."

Chadima also discussed the politicization of energy as a topic, both nationally and in our state which is affecting Cal ISO's ability to attract electricity export business, and involvement by other western utilities in the Western Imbalance Market. He described a conversation with a public utility commissioner from a nearby state who told him, "We're not turning over the control of our grid to the governor of California."

Chadima's point is that there has to be a way to reframe the conversation to attract regulators in other states to our energy oversupply. He said it revolves around economics and while there are technical challenges, "We can work on these things out of the limelight."

Sweeney agreed that we need to have an integrated western grid. The demand side operating behind the grid has to operate with real time pricing and you need software to control the real time system, he said.

CLEAN ENERGY FINANCING

The lunchtime speaker, Michael Liebreich, founder and chairman of the Advisory Board, Bloomberg New Energy Finance, said international investment in clean energy has now reached almost \$300 billion a year, but the trend is flattening. China and Japan have slowed their investments. China is having difficulty integrating wind and solar into their grids, and Japan is experiencing levels of curtailment, he said.

In the US, the White House announcement that we're pulling out of the Paris Agreement is sending mixed signals, Liebreich said. He believes, however, that the US will likely hit its Paris targets irrespective of the pronouncements.

The recent notice of rulemaking from the Department of Energy with the goal of preventing coal plant retirements is also troubling. Liebreich asked the gathering, "Do you know of anybody who will build a coal plant? He cited as an example, the Luminant announcement that it was shutting down its Texas coal plant. "This is the best response to "Make America Great Again," he joked.

Liebreich also predicted that prices will escalate to 70 cents/watt from about 30 cents/watt if the International Trade Commission recommends and President Trump approves Suniva's request for tariffs on imported crystalline silicon photovoltaic modules and cells. "It's annoying, but the industry will ride through," he said. (As this column was being written, the ITC issued three remedy recommendations ranging from a licensing fee to as much as a 35% tariff on CSPV modules. None of the recommendations came close to the Suniva proposal.)

Liebreich further predicted by 2040 more than \$6 trillion will be spent on renewables and by that date, there will be no more coal. "The age of gas will not happen. Instead it will be the source of flexibility," he said, and pointed to the deep penetration of renewables, in both Europe and the US, and especially in California.

So what are we going to do with all this supply? Liebreich said he doubted demand

(continued page 17)



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LECLANCHÉ EXPANDS IN NORTH AMERICA

BY THOM REDDING, SENIOR VICE PRESIDENT, LECLANCHÉ NORTH AMERICA



Leclanché's new facility within the Purdue Polytechnic Enterprise Center.

At about the same time back in 1909 when Georges Leclanché, the inventor of the dry cell battery, started his battery company in Yverdon Les Bains, Switzerland, the Remy brothers of Anderson, Indiana were constructing a new plant complex for the Remy Electric Company which would become the largest manufacturer of automotive electrical equipment under the ownership of General Motors and known as Delco-Remy.

ABOUT DELCO-REMY

Ultimately, Delco-Remy became one of the world's largest manufacturers of automotive batteries, but no batteries were ever produced at their Anderson, Indiana plant complex. Anderson had the opportunity to become the home of Delco batteries, but the town fathers turned the opportunity down because Anderson's coal-powered electrical plant did not have the capacity to generate the power needed to run the new battery plant. So, Remy Electric had to launch its battery manufacturing business in Muncie, Indiana instead.

Fast forward 89 years, and battery

development and manufacturing have finally arrived in Anderson. Leclanché, now one of the world's leading energy storage solution companies, announced the opening of its North American subsidiary's new research and manufacturing facility located within Purdue University's "Polytechnic Center" in Anderson, Indiana. The Polytechnic Center is housed in what was Remy Electric plant #3.

PURDUE POLYTECHNIC CENTER DESIGN

The Purdue Polytechnic and Flagship Enterprise Center is an all-encompassing, educational complex consisting of academic, lab spaces and mini-manufacturing operations. It was designed to create hands-on interaction and engagement with high-tech Indiana companies. The facility allows for collaboration and exposure to entrepreneurship and innovation that are represented by Purdue and the newer companies which have their roots in Anderson's manufacturing history.

The former sprawling Delco-Remy facility is steeped in automotive and electrical manufacturing history where, at one time,

more than 7,000 men and women were employed in the manufacture of starting motors, distributors, ignition switches, alternators and horns – but never batteries until today.

Leclanché's new 10,000 square foot facility within the Purdue Polytechnic Enterprise Center houses office, research and development, testing and manufacturing floor space – along with a customer demonstration area. The company's North American headquarters, located in Dallas, hosts management, sales and marketing personnel.

As an Indiana native and a product of the area's manufacturing and R&D roots, I see the Enterprise Center at Purdue Polytechnic as a catalyst that is bringing together Purdue University's incredible resources and engineering traditions with new innovative technologies.

I recently told an Indiana business publication, covering our ground opening, that while this facility once saw tremendous advances in automobile engineering, it's now becoming the home of future renewable energy storage solutions that will power our homes, businesses and cars in a carbon-free environment.

THREE MAJOR PROJECTS

Leclanché has been a pioneer in lithium battery technology and now produces a wide range of energy storage solutions for utilities/electrical grids, microgrids, warehouse forklifts as well as solutions for transport such as electric buses, fast charging stations for electric cars and marine applications. Leclanché North America was formed in 2016. The company currently has three major projects underway in North America including energy storage systems for grid ancillary services in the Midwestern U.S. and Ontario, Canada, and a recently announced network of electric vehicle fast-charging stations along a por-

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PARTNERSHIPS ARE KEY TO GROWTH

BY PAUL WINTERS



The Biotechnology Innovation Association (BIO) held the 14th annual BIO World Congress July 23-26, 2017 in Montreal, hosting 954 business executives, academics and policy influencers and giving a platform to 227 speakers during three days of educational sessions. Partnerships were a key theme of the discussions at the event, both during private partnering sessions and the seven tracks of education sessions. Partnerships can provide financing to move new technologies from the research to the development, demonstration and deployment stages. They can also create economies of scale for feedstock and product supply chains that improve the bottom line for all partners.

Biomass has traditionally been the major focus of the BIO World Congress, since it can play a role in energy generation, chemical and biofuel production, as well as biobased products. The challenges in building a biomass supply chain are well known. Jordan Solomon, managing director & CEO of Ecostrat Inc., provided a fresh perspective to World Congress attendees, by detailing the impact of these challenges on financing for new projects. The lack of experience and verifiable data on biomass supply chains creates additional risk for biomass projects – which contributes to higher debt costs

that inhibit project development, according to Solomon.

Partnerships between companies and business sectors that benefit from the biomass supply chain can help to mitigate the risks. Sandy Marshall, executive director of Bioindustrial Innovation Canada (BIC), provided an example to World Congress attendees. BIC is building a biobased manufacturing cluster in Sarnia-Lambton, Ontario, that creates partnerships among companies – as well as universities and researchers – that have a stake in the biomass supply chain. Large businesses can bring business and financing know-how to the clusters, attracting startups and minimizing some of the risks associated with new technologies. The startups can provide outlets and potential new markets for some of the byproducts of the large companies that utilize biomass.

Biomass is not the only focus for the industrial biotech audience, though. Increasingly, industrial biotech companies are looking to convert waste streams – such as carbon oxides or even municipal solid waste – into value-added products. Partnerships can provide small industrial biotech startups with a low-cost feedstock. Large companies can lower their disposal costs and their environmental impact.

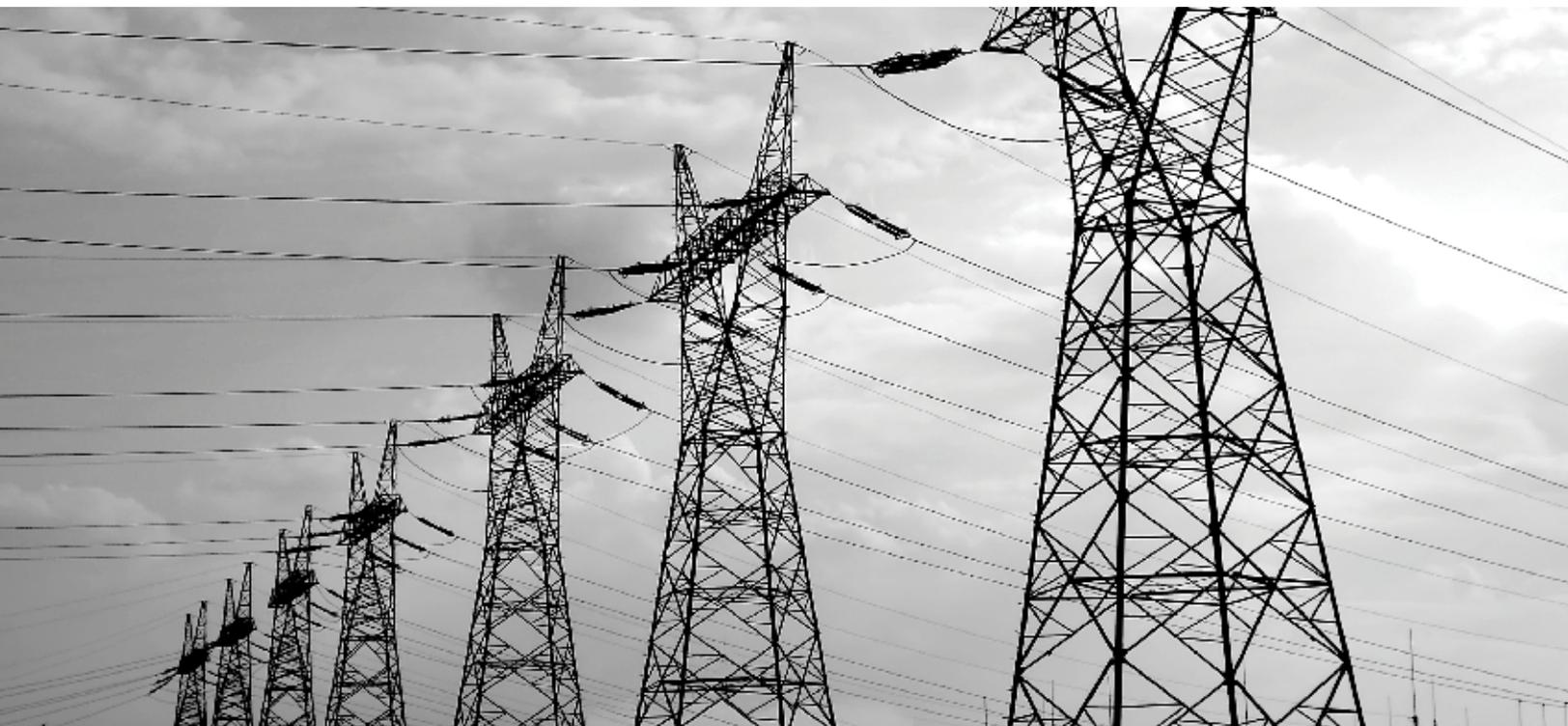
At the start of the event, BIO released a new report, *Industrial Biotechnology: A Unique Potential for Pollution Prevention*, detailing the trends toward capture and reuse of carbon – off-gasses from industrial plants – as direct inputs for bioprocessing. Companies may be able to bring new products and applications to market more quickly if they can partner with existing production infrastructure and supply chains. Existing infrastructure helps overcome the engineering and supply chain challenges facing all new technologies. Industrial biotechnology holds the potential to reduce waste and toxic

byproducts in manufacturing, to achieve measurable improvements in biomass sustainability, and to reutilize carbon. The new BIO report details the industry's progress over the past decade.

Jim Lane of Biofuels Digest, who has regularly attended the BIO World Congress, observed that policy makers and consultants are focusing on the economic success of new technologies and partnerships rather than the environmental and societal benefits. Paul F. Bryan, an independent business consultant based in California who formerly worked for the U.S. Department of Energy, provided insight on the impact this is having on companies. According to Bryan, the economics of some biofuel and biobased product manufacturers were based on monetization of greenhouse gas reductions or other societal and environmental benefits. His advice to World Congress attendees was to focus investment and R&D activity on the biomass production and conversion value chains most likely to be scalable and profitable in the long run.

The BIO World Congress on Industrial Biotechnology has become a major hub for the formation of new partnerships. During the Montreal event, 893 delegates representing 535 companies participated in 2,130 partnering meetings. The number of partnering meetings facilitated by BIO's One-on-One Partnering™ system represented a 9 percent increase from 2016. BIO's World Congress will celebrate its 15th anniversary July 16-19, 2018, at the Pennsylvania Convention Center in Philadelphia.

Photos of the 2017 BIO World Congress are available on the official BIO Flickr account (<https://www.flickr.com/photos/biophotos/sets/721576886557252626>). Videos of the award presentations are available on BIO's YouTube channel (<https://www.youtube.com/playlist?list=PLsjOpOsfS0TJY46oSATAbHmalRmB3wFR>), in the 2017 World Congress Highlights: Montreal, Canada playlist.



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TODAY'S SUBSTATIONS GOING DIGITAL

BY STEVEN A. KUNSMAN, ABB



Today's utility-scale wind and solar farms are always accompanied by a substation or two nearby. Equipment in the substation transforms voltage and governs the interface to the transmission grid. The substation plays a critical role and essentially acts as the motherboard of the power industry, controlling and directing power on demand, essentially making sure the lights stay on.

To do so, electrical substations have traditionally utilized miles of copper cabling for point-to-point connections measuring currents and voltages and controlling the circuit breakers for power switching and protecting the substation equipment. However, copper is expensive, has limited capacity for one measurement or a single control signal (important for power delivery and condition monitoring), and also introduces potential safety risks. This conventional design and aging control equipment results in costly testing and maintenance, and restricts the communication of important information useful for identifying an asset's health and determining when equipment maintenance is required.

If operators were able to leverage digital technology and power system real time information availability, it would mean significant improvements in grid reliability, increased safety, and reduced power interruptions.

Enter the digital revolution. Digital substations reduce the electrical connection between high-voltage equipment, let the

grid run more efficiently, and create a safer site. This is done by replacement of copper signal wires with fiber-optic connectivity. Additionally, the industrial internet of things (IIoT) is able to offer data on demand to optimize overall substation performance — often letting operators work from the comfort and safety of an offsite office.

Digital substations are not a new idea to the power industry, but the technology has been slow to adopt because of old processes, regulations, and an aging transmission grid. Times are changing, however, thanks to advances in fiber optic communications and digital technologies.

From copper wires to digital pathways Every copper wire in a substation is a potential electrical shock risk, whether it is from a current transformer, a potential circuit, or a 125 volts DC (Vdc) control wire. The secondary circuit on a highly inductive current transformer poses the largest safety concern. A potential hazard results when an energized current transformer wire is unknowingly disconnected.

From inductive circuit theory, current flowing through an inductive circuit does not change instantly from five amps to zero. When the open CT circuit occurs, the inductive circuit can produce hazardous high voltage conditions leading the safety threat. Depending on the secondary load, high voltages may lead to flashovers and arcing, which puts substation personnel at risk of serious injury. Then there is possible equipment damage and downtime from arcing, which means lost power and revenue.

GOING DIGITAL

Digital substations are gaining traction as commercial installations are validating the new technology and its benefits. There are several reasons for this: new high-performance digital sensors and stand-alone merging units that are easy to install, and

cost and installation time savings from fewer copper wires.

High-voltage measurement has improved to offer more reliable sensors with greater accuracy, better performance and the ability of direct digital outputs to the process bus. By going to digital, the sensors preserve signal integrity and ease of connections through fiber communications. Also, unlike previous optical sensors, which were less reliable in some cases, new fiber-optic current sensors combine the optical-current with redundant systems. Redundancy ensures fault tolerance and in the event one system goes down the redundant system is active. Digitalization provides excellent availability, accuracy, stability and performance.

Another advantage is that this modern sensor contains no oil that is typical in a conventional CT so it is environmentally friendly and extremely safe. Standalone merging units that bridge the gap between analog conventional instrument transformers (ITs) and the digital process bus. This is important because older, conventional substations were never built for a digital network, and IT replacement for substation retrofits are costly. So, stand-alone merging units allow for the utilization of the existing CT and PT while upgrading the rest of the protection and control system to digital technology realizing the same associate benefits.

COMMUNICATING OVER FIBER

Faster, more efficient communication is an important benefit of going digital. It generally means quicker response times, maintenance and service, and increased system availability. This is partially done by replacing copper wires with fiber-optic connectivity.

However, to realize full value, a digital substation needs more than just digital sensors feeding data into control centers. It

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LEADING THE EVOLUTION OF ELECTRICITY

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REVIEW

CORPORATIONS BEGIN TESTING

BY MATT HAGEN, UW CLEAN ENERGY INSTITUTE

Seattle, WA - Global corporations, U.S. solar companies, and Washington startups have signed up to test their cleantech at the Washington Clean Energy Testbeds, created by the University of Washington (UW) Clean Energy Institute (CEI), during the facility's first six months of operation. Companies using the Testbeds include Microsoft, Washington's PureSolar, and several UW spinout companies. This diverse group of customers and UW's faculty and students use the open-access facility's unique suite of instruments to manufacture prototypes, test devices, and integrate systems.

"With this robust roster of Testbeds users, CEI is building a community of cleantech and advanced manufacturing innovators that will help Washington and the world accelerate the development of new technologies in solar harvesting, energy storage, and grid integration," said Washington Clean Energy Testbeds technical director Devin MacKenzie. "We're grateful to have this caliber of customers and look forward to helping them advance their critical technologies."

CEI opened the 15,000-square-foot Washington Clean Energy Testbeds in February with funds from the Washington State Legislature. CEI's goal for the facility is to reduce the time and capital needed

to translate research discoveries into scalable energy products. To achieve this, CEI designed the Testbeds to centralize the instruments and expertise required for developing new manufacturing approaches, making prototypes, then rigorously testing and refining them for market readiness. The facility's open-access model also allows for speed, as the application process to use the facility only requires an initial consultation with Testbeds' management to ensure project feasibility and safety. Furthermore, users keep full ownership and control of their intellectual property. This operating model and the Testbeds' set of capabilities distinguish it from other U.S. energy research and testbed facilities available to the public.

"The Washington Clean Energy Testbeds have everything we need as an early-stage company—enabling us to move into the solar marketplace with confidence in our products," said PureSolar CEO Rich Phillips. "Working in this UW CEI facility has been seamless and the in-house researchers have helped us continue to be on the leading-edge of PV manufacturing."

"The Washington Clean Energy Testbeds provide a unique set of fabrication tools and expertise that enable small companies to explore, evaluate, and char-

acterize new materials and processes without the need for large and uncertain capital expenditure," said MicroConnex's vice president of engineering and technology Steve Leith. "For a small company like ours, the 'try before you buy' environment and opportunity to engage as a collaborator or a user, offer much needed flexibility in how we execute our tech development road map."

In addition to expanding the Testbeds' user base since its opening, CEI has added new instruments and capabilities to the facility. The 30-foot-long multistage roll-to-roll printer for solar cells, batteries, sensors, optical films, and thin-film devices custom built for the facility and funded by the Washington Research Foundation (WRF), arrived in late spring and is now operational. The instrument is one of the most advanced roll-to-roll systems in the world and the only one of its kind in the United States. CEI commissioned the instrument to support the development of low-cost materials and processes for ultra-low-cost solar cells that could be manufactured at large scales with a dramatically lower carbon footprint than silicon.

Other recent equipment acquisitions include a solar simulator and multiple environmental test chambers. The solar simulator is a large-scale photovoltaic performance measurement system capable of full module testing conforming to industry standards. The environmental test chambers allow for rigorous testing of energy system performance and lifetimes on the prototype and full module scales.

Altogether, the printing, coating, and testing capabilities at the Testbeds provide a unique platform for advancing cleantech manufacturing.

For more information on the Washington Clean Energy Testbeds, visit www.wcet.washington.edu.

ABOUT THE CLEAN ENERGY INSTITUTE

The Clean Energy Institute (CEI) at the University of Washington (UW) was founded in 2013 with funds from the state of Washington. Its mission is to accelerate the adoption of a scalable clean energy

(continued page 22)



UW researchers using the Washington Clean Energy Testbeds' FOM Solar-X3 roll-to-roll printer.

SIEMENS' AIMS AT CYBER THREATS CONTINUED FROM PAGE 4

ship aims to bring cutting edge cyber defense for operational technology (OT) to electric utilities and the oil and gas industry.

By combining Darktrace's systems with Siemens' OT security expertise, the partners say they will give customers the ability to more quickly detect and respond to cyber attacks.

"As OT environments become more digital, they open a new and glaring vulnerability in organizations of all sizes," Nicole Eagan, CEO of Darktrace, said when the partnership was announced.

Both the Darktrace and PAS partnerships are aimed at the increasing cyber security as field deployed technology, or OT, continues to converge with control room technology, or IT.

"The OT in most companies is similar to a house whose doors and locks are not locked," says Simonovich. "You must assume there will be a breach. Are you prepared to respond and remediate?" "The key," he says, "is prevention."

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THE CALIFORNIA REVOLUTION CONTINUED FROM PAGE 8

response and storage and exportability in current plans will likely absorb all the supply. "We will manage it with transportation," Liebreich said. There is not a manufacturer who is not developing or already manufacturing EVs and he predicted the price point for EVs "everywhere in the world" will cross over with internal combustion vehicles between 2025 and 2029.

ELECTRIFICATION DISRUPTIVE?

In another panel, Jurgen Weiss, principal in The Brattle Group, said the electrification of the economy is disruptive and will have different impacts on different sectors. Predicting tremendous shifts in value-added incentives, he said, "My sense [it will be] in the transportation side. Many drivers will seek electrification, including driverless EVs. That industry will go through a radical transformation.

Karen Mills, associate counsel, California Farm Bureau Federation, said "We're seeing this already, like robots are milking cows. It's about labor implications and costs. We will see more of that depending on cost effectiveness. I think electrical demand will go up as a result of technology changes."

Not surprisingly, Ralph DiNola, CEO of New Buildings Institute concluded that "buildings can be the nexus of the clean energy economy. The grid optimization [could occur with] builders taking opportunities to design buildings that optimize the supply curve."

RETIRE GAS PLANTS

Finally, views from Cal ISO. Mark Ferron, a member of Cal ISO's Board of Governors, said, "If we go to 50% renewables, gas will be a minority fuel. That means scrutinizing any new additions to gas generation. "Identify the plants that ramp and have flexibility and at the same time look at the fleet and decide what's no longer necessary and plan for the orderly retirement of plants."

David Olsen, also a member of the Cal ISO Board of Governors, agreed with Ferron that sustained orderly retirement of gas plants is in order. Current capacity is at about 25% and meeting local capacity needs with other than gas requires us to think of net operating capacity. "It's important to think about these challenges because nothing is worse than blackouts," he said.

Olsen followed up with a discussion of decentralization. He said the disaggregation of electric services is inevitable. The demand is for more locally controlled power, with system architecture that allows home systems to interact with microgrids, all of which can aggregate and optimize demand.

"Decentralization promises much greater energy security and resilience," Olsen said. As more and more power is generated locally, large scale solar and wind will have to be integrated.

Finally, Olsen returned to the topic addressed in earlier sessions. "Almost every western utility is thinking of regionalization. There will be many fewer power plants [and we will be] relying on renewables. This requires ready access to a much larger region since wind is mostly in the Rockies while solar is in the west."

And then a return to the importance of electrifying transportation. Ferron opined that electrifying transportation and buildings is the most exciting thing happening in the electric sector. He agreed with Michael Liebreich, the luncheon speaker, saying two thirds of cars will be electric by 2030. "We need to think about when these vehicles are resting and hooked into the grid, whether at night or at the workplace. We need to think about the turnover in vehicle stocks and we need to think about how to finance that turnover."

If the reader would like to view and listen to all of the Symposium sessions, and there is much more that was said, go to www.caiso.com and click on "Stakeholder Symposium" on the home page.

THE PATH FORWARD

BY JIM SCHRETTER, PRESIDENT BEACON ENERGY LLC



World-Gen's Class of 2002

One of the greatest hockey players of all time, Wayne Gretzky said, "...skate to where the puck is going to be, not to where it has been." Perhaps good advice for us in the US electricity industry, not to dwell on the past or standstill but embrace change.

LONG TERM CHANGES

Within 10-15 years, three major forces will likely reshape the US electricity industry: 1) supply changes in the growth of low cost renewables, distributed resources, and storage, 2) the demand for more customer choices, and 3) the emergence of a modern grid with integrated supply and response resources. As a result, US electric utilities in 20 years will likely have a different regulatory compact than today.

DEMAND CHANGES

Commercial and industrial customers are increasingly seeking sustainable energy, lower direct electricity supply costs and better security of supply. Since 2010, 9 GW of supply, as reported by Advanced Energy Economy ("AEE"), has been contracted directly by companies in the US. The AEE also reports that 71 of the top Fortune 100 companies has sustainability goals and 12

states have adopted green energy tariffs for direct green energy purchasing. If a California PUC report is accurate, by the mid-2020's 85% of the retail load in CA could be served by community choice aggregators or an alternative supplier to the utility.

SUPPLY RESOURCES

Technological innovation and competition over the last 8 years has driven down solar costs by 85% and wind energy costs by 66% (LCOE). As a result, the growth of renewables continues to dominate capacity additions in the world. According to the International Energy Agency ("IEA"), during 2016 new solar PV capacity was 74 GWs with 54 GWs of new wind compared to a total of 86 GWs net for new coal and gas combined and projections for 2022 show a 43% increase for new renewable capacity growing to 920 GWs between 2017-2022.

Our sources of electricity have fundamentally shifted toward solar PV and wind. China represents about 50% of new PV demand and 60% of worldwide PV supply with the US regarded as second in demand by IEA.

Energy storage costs are likely to dramatically go down in the next decade, driven by GW size factories constructed for the wave of electric vehicles, mainly in overseas markets. By the mid-2020's electric vehicle costs are expected to be lower than internal combustion ("IC") engine costs with many countries slated to phase out IC vehicles. The resulting storage cost improvements will assist distributed resources with implications for petroleum markets and world politics.

All of this puts pressure on the modern US grid. The grid will evolve to handle intermittent resources, cyber security and to accommodate customer choices including demand response. Yet, real time T&D information will be critical for new distributed resources to capture their full economic

value. And new sensors for grid stability, big data gathering and analysis of supply and demand, and new control methods including artificial intelligence are likely to transform the wires business.

Utilities confronted by the rise of distributed resources, customer demands and the emergence of a new grid will make decisions, along with regulators, on how utilities will be compensated. Stranded costs and exit fees will likely be questioned. A new utility compensation mechanism with more of an emphasis on wires and less on incentives related to generation will need to be designed.

SHORT-TERM CHANGES

In the short-term, we are confronted by US solar tariff uncertainties and panel pricing/availability, possible federal tax law changes, R&D funding questions, DOE directives to provide coal and nuclear uplift support and other uncertainties that may slow some of the transitions. Therefore, the speed of industry change is not to be assumed.

LEADERSHIP

In this environment, it is important to design new utility rate structures early, create mutual wins or be caught at center ice. Developers are challenged to avoid a race to the bottom in returns and instead race to better value. Innovation, R&D and new value-added services will be critical to the financial returns of the winning developers and industry participants. Betting on the solar decline curve, and accepting loss leader returns may not be the wisest choices, despite past successes.

Wayne Gretzky was right that in hockey you can succeed with forethought by being at the right place at the right time. Our challenge in the US electricity industry is in analyzing future needs by successive time segments and having winning shots for each period.

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TRENDS IN POWER PLANTS DISPUTE RESOLUTION

BY FRED LYON, LYON FIRM, CLASS OF 2003



In a 2016 article in the New York Times, federal judges lamented that no one wants to go to trial any more. The number of civil (and criminal) matters that actually result in full blown trials continues to drop dramatically as litigants realize that the expense, length, and inefficiencies of “a day in court” seldom is worth the risk and uncertainty. Nearly a millennium after the Magna Carta reinforced a citizens’ right to go to court to establish their privileges, these same citizens are now turning to other, more creative forums to enforce their rights.

This reality is evident in the electric utility industry, especially in connection with the disputes that often characterize the construction of major capital projects. Utilities are deeply skeptical of the risk associated with litigating a complex construction dispute, especially given the possibility of an anti-utility bias on part of a jury of ratepayers.

Recognition that the cost of litigation can consume 30 to 50 percent of the amount in dispute in legal and expert fees has encouraged utilities and contractors alike to seek more economic forms of dispute resolution short of full blown, bet the company litigation. Delays alone can con-

sume three to five years in getting to trial with the attendant dilution of resources, both financial and personal. And once you end up in a court room, recent well-publicized jury trials remind everyone that justice is unpredictable at best and occasionally irrational at worst.

For over a 100 years, the construction industry has encouraged an alternative to litigation in the form of arbitration. Arbitration has been seen as a faster alternative to the court system with decisions made by industry experienced professionals rather than less reliable and unpredictable judges and juries. However, arbitration through the years has calcified, now too often resembling the litigation which it was intended to replace. Discovery and delays have crept into the system and those professional organizations charged with administering arbitration have earned reputations for inefficiency and inordinate expense. And utilities are suspicious of arbitration has having an anti-owner bias.

As a result in recent years, parties have often opted to first try to mediation as an alternative to either arbitration or litigation. Mediation does not provide a winner or loser (“a good settlement is one where neither party is happy”) but instead is an intense negotiation facilitated by a skilled mediator who exposes both parties to the strengths and weaknesses of their cases. By the end of the day (or several days in the case of more complex matters), the parties ideally recognize that everyone’s interests are best served by a mutually derived settlement rather than an arbitrary result imposed by a third party far less familiar with the issues and relationship between the parties. And the dispute does not play out in public with attendant negative publicity.

But even mediation can on occasion fail to produce resolution in line with the parties’ expectations. The process most often fails when the mediator is unsuccessful in

educating both parties on the realities of their respective cases and the prospect for success in arbitration or litigation. More than anything, this dictates that the parties select a skilled mediator who is prepared to provide both sides with a realistic evaluation of the case. Short of that evaluation, mediation can heighten expectations with a resulting thud of disappointment when it does not result in resolution.

Litigation, arbitration, mediation – none perfect in resolving an energy-related construction dispute. The industry recognizes this reality and continues to strive for ways to control dispute. While traditional forms of dispute resolution have proven too often inefficient, utilities and their contractors are not standing still. Instead they continue to seek creative ways to address dispute that allow the parties to control their own destiny economically and efficiently.

Savvy utilities and contractors alike realize that the best way to control dispute is proactively. Rather than pretending that dispute will not occur, the parties anticipate its likelihood from the very beginning – in the document that provides the rules of engagement for their relationship, the contract. More and more often, utility construction contracts now contain agreed upon rules for how disputes will be addressed when (not if) they arise. The advantage of a contractually agreed upon dispute resolution process is that the parties can create it themselves, with agreed upon deadlines, decision makers, and discovery, avoiding the frustrations of systems created and controlled by others less familiar with the issues.

The only limit to these contractually created dispute resolution systems is the imagination of the parties. Often they involve time constrained structured negotiations, starting at the project level, eventually elevating through management to a point where executives with authority can resolve the dispute without litigation. In the event that does not occur, then mediation is often mandated.

The best contractual dispute resolution systems will build into the contract a private form of arbitration that the parties themselves control. For example, at the

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SOUTHERN'S FUTURE

BY KIM GREENE, EXECUTIVE VICE PRESIDENT AND CHIEF OPERATING OFFICER, SOUTHERN COMPANY



World-Gen's Class of 2015

Southern Company looks a lot different today than it did a decade ago.

As I like to tell people – we're not your grandfather's utility. We understand the world is changing, and we must change with it. We have strategically positioned ourselves to be an industry leader in innovation as we build the future of energy. Our footprint now spans 19 states and we serve more than 9 million customers.

But as we've expanded and evolved, we've also held closely to some of our company's important fundamentals that serve as our foundation. Southern Company has always had and continues to have an awesome responsibility to the customers and communities we are privileged to serve. As we provide clean, safe, reliable and affordable energy, we also raise the standard of living through better jobs, higher wages and a stronger economy.

Yet even as we continue in this commitment, we are taking additional steps today to better serve our customers tomorrow. From investing in natural gas infrastructure and renewables to electric transportation and distributed energy resources, we are refining our longstanding business model for success in the next century.

One of our recent business partners,

Bloom Energy, is deploying its breakthrough fuel cell technology on the premises of some of the world's largest companies, including Apple, Google, Home Depot and Kaiser Permanente. Last year, Southern Company and our subsidiary PowerSecure announced a strategic alliance with Bloom Energy to combine their fuel cells with our energy storage technology. Together, we are offering an innovative, proprietary solution to meet customers' unique resiliency, sustainability and affordability requirements.

We're also changing the way customers use energy. We recently unveiled our Smart Neighborhood in Birmingham, Ala. Equipped for tomorrow and efficient today, this state-of-the-art community of 62 homes will feature emerging energy-efficient technologies, materials and appliances, and a community-scale power system.

Because customers today want energy solutions that fit their lifestyle, Smart Neighborhood is a research and demonstration project where energy usage and performance data are collected from the homes' innovative features including HVAC systems, heat pump water heaters and other technologies. This information will help us to understand how the features can improve the way homes are built, the way homes function, and how services can be tailored to provide new and creative energy solutions.

But the work doesn't stop at the customer premise. We're also developing a microgrid to supply power to the Smart Neighborhood that will incorporate solar, battery and natural gas generation sources. We plan to continue to enhance our customers' experiences and ensure they have more control over their energy use at the same time.

With one foot firmly rooted in our foundational principles and the other strategically placed in the growth of our future, we are committed to investing in robust

research and development to solidify our commitment to our customers.

I couldn't be prouder of our team as we build the future of energy.

TODAY'S SUBSTATIONS GOING DIGITAL CONTINUED FROM PAGE 14

needs autonomous intelligence shared between substation equipment and the network control center, and this is where the industrial internet of things comes into play.

One of many benefits with IIoT means data can be collected via sensors on equipment in the field through cloud-based software, filtered, and analyzed in real time, 24/7. Algorithms can then help to provide insight for predictive and prescriptive maintenance and risk reduction that continually optimize the grid and improve a substation's efficiency and cost effectiveness.

What's more is IIoT can prove just as useful for the end-user and utility customers as it can at the digital substation and control center. IIoT can obtain, analyze, and predict electricity use and enhance consumer experiences by ensuring the lights stay on when needed. In this way, power is saved, as are utility costs.

As power-generation sources become increasingly distributed, intermittent, and volatile, achieving high levels of control and performance requires a more intelligent and reliable grid. This is now possible thanks to advances in grid automation technology in recent years, including the development of digital substations. A fully digital substation is smaller, more reliable and has reduced life-cycle costs. It also offers increased safety and efficiency.

Add in the industrial internet of things, and that digital data can be optimized for safe and efficient use for utilities and customers.

ENGINEERS SUIT UP

BY BOB PALMER

AROUND THE WORLD WITH SANTA CLAUS

There are approximately two billion children (persons under 18) in the world. However, since Santa does not visit children of Muslim, Hindu, Jewish or Buddhist (maybe in Japan) religions, this reduces the workload for Christmas night to 15% of the total, or 378 million (according to the population reference bureau).

At an average (census) rate of 3.5 children per household, which comes to 108 million homes, presuming there is at least 1 good child in each, Santa has about 31 hours of Christmas to work with, thanks to the different time zones and the rotation of the earth, assuming east to west (which seems logical). This works out to 967.7 visits per second. This is to say that for each Christian household with a good child, Santa has around 1/1000th of a second to park the sleigh, hop out, jump down the chimney, fill the stocking, distribute the remaining presents under the tree, eat whatever snacks have been left for him, get back up the chimney, jump into the sleigh and get on the next house.

Assuming that each of these 108 million stops is evenly distributed around the earth (which, of course, we know to be false, but will accept for the purposes of our calculations), we are now talking about 0.78 miles per household; a total trip of 75.5 mil-

lion miles, not counting bathroom stops or breaks. This means Santa's sleigh is moving at 650 miles per second, or 3,000 times the speed of sound.

The payload of the sleigh adds another interesting element. Assuming that each child gets nothing more than a medium sized LEGO set (two pounds), the sleigh is carrying over 500 thousand tons, not counting Santa himself. On land a conventional reindeer can pull no more than 300 pounds. Even granting that the "flying" reindeer can pull 10 times the normal amount, the job can't be done with eight or even nine of them. Santa would need 360,000 of them. This increases the payload, not counting the weight of the sleigh, another 54,000 tons, or roughly seven times the weight of the Queen Elizabeth (the ship, not the monarch). A mass of nearly 600,000 tons traveling at 650 miles per second creates enormous air resistance.

This would heat up the reindeer in the same fashion as a spacecraft reentering the earth's atmosphere. The lead pair of reindeer would absorb 14.3 quintillion joules of energy per second each. In short, they would burst into flames almost instantaneously, exposing the reindeer behind them and creating deafening sonic booms in their wake. The entire reindeer team would be vaporized within 4.26 thousandths of a second, or right about the time Santa reached the fifth house on his trip.

Not that it matters, however, since Santa, as a result of accelerating from a dead stop to 650 miles/second in .001 seconds, would be subjected to acceleration forces of 17,000 g's. A 250 pound Santa

which seems ludicrously slim considering all the high calorie snacks he must have consumed over the years would be pinned to the back of the sleigh by 4,315,015 pounds of force.

So is there really a Santa Claus?

Merry Christmas and Happy New Year!

CORPORATIONS BEGIN TESTING CONTINUED FROM PAGE 16

future that will improve the health and economy of our state, nation, and world. To accomplish this mission, CEI supports the advancement of next-generation solar energy and battery materials and devices, as well as their integration with systems and the grid. The institute creates the ideas and educates the people needed to generate these innovations, while facilitating the pathways to bring them to market. cei.washington.edu

ABOUT THE WASHINGTON CLEAN ENERGY TESTBEDS

The Clean Energy Institute (CEI) created the Washington Clean Energy Testbeds to accelerate the development, scale-up, and adoption of new technologies in solar harvesting, energy storage, and grid integration. This open-access facility for academic researchers and businesses houses labs for manufacturing prototypes, testing devices, and integrating systems.

LECLANCHÉ EXPANDS IN NORTH AMERICA CONTINUED FROM PAGE 10

tion of the Trans-Canada Highway.

Initial planning for the facility began two years ago when the State of Indiana began to plant the seeds for growth in energy technology and manufacturing industry segments.

Our Anderson facility is expected to inject new life and vision into the company which, over the last ten years, has grown well beyond its storied history of creating

the first dry cell battery. For Leclanché North America, the future is bright with many opportunities to leverage its battery energy storage technology for reducing the carbon foot print for energy production, transportation and industrial applications. If George Leclanché and the Remy brothers had compared notes back in 1909, they certainly would not have seen the future of batteries as we see them today.

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Class of 2018

February/March 2018

TRENDS IN POWER PLANTS DISPUTE RESOLUTION CONTINUED FROM PAGE 20

outset of the contracting relationship, the parties will agree on a mutually selected panel of potential arbitrators who will resolve disputes as they arise. Ideally one arbitrator (among several identified) will be able to decide a dispute during the course of the project. The parties agree to submit the dispute to this arbitrator usually on the paper without the need for live testimony. If the arbitrator feels that testimony is necessary, he can order it on a limited basis. Given the experience and familiarity of the

arbitrator with the project, this approach is most likely to produce a fair result consistent with the parties' expectations. And the parties can avoid the pitfalls of more traditional after the fact arbitration.

Modern energy construction is too complicated to leave resolution of its disputes to outside third parties. Utilities and contractors alike owe it to the process – and to each other – to spend time during the contract formation process to create a mutually endorsed system for resolution of

disputes that allows all concerned to build the project and to preserve their relationships. Contractually creating such a system is a foundation of any well built power plant.

ABOUT THE AUTHOR

FRED LYON is a construction attorney and mediator with over thirty five years' experience in contract drafting and dispute resolution. He currently has offices in Florida, Washington DC, and New Orleans.

GE'S DIGITAL REVOLUTION CONTINUED FROM PAGE 6

operations center. Within this center, NYPA plans to digitize the entire grid of NY state, end-to-end. This digital transformation will be no small feat, as NYPA is the largest state-owned utility in the U.S.

"There are three major trends that are disrupting the electric utility: decentralization, digitization, and electrification," Quiniones said. The traditional one-way flow of energy from power plant to grid to customer is transforming rapidly into a "more decentralized, multi-flow, intelligent energy network," Quiniones pointed out. Embedded in this three-way disruption is the increase of renewables on the grid; part of NYPA's inspiration to digitize is Governor Cuomo's mandate to source 50% of the state's electricity from renewable energy by 2030.

By investing in a network of buildings-as-batteries, digital power plants, and a multi-flow smart grid, NYPA is pushing the IIoT over industrial boundaries, and it's not alone. In its July 14, 2017 report, the IDC predicted investments in cross-industry use cases, such as smart buildings and connected vehicles, to reach \$86 billion this year and rank towards the top of IoT segments over the next five years.

Exelon, an early IIoT adopter, announced with GE plans to deploy the Predix portfolio across Exelon's six electric utilities nationwide, representing more than 10 million customers, according to a GE

press release. By analyzing historical data and weather modeling in relation to assets and local conditions, Predix will enable Exelon to predict outages, conduct preventative maintenance to critical infrastructure, and deploy resources faster and more precisely when a storm hits.

"The world that we are navigating will be increasingly be one that has to be solved at a system level," Russell Stokes, President and CEO of GE Power, said to reporters. As Stokes noted, systems thinking is especially important in managing grid assets: today's grid challenges require understanding not just a single asset, such as a wind turbine, but also how to dispatch it in relation to when other renewable assets come online, and how all generation assets work in tandem to produce the terawatt hours of energy needed to power today's world.

INDUSTRIAL EXISTENTIAL CRISIS

Rising to meet the challenges and opportunities of the digital awakening of the grid, electrification of the transportation sector, and rise of the prosumer will require nothing short of a transformation of utilities and companies, and industry is far from ready. According to a recent survey conducted by GE of key IT and operations staff and execs, although 80% of decision makers surveyed believe the IIoT will transform their company or industry, only 8% have

embedded the digital industrial transformation into their core business.

The disruption will challenge companies to take a hard look at their organizational culture. "The company that just builds machines will not survive," John Flannery said. Flannery sees the digital transition as "fundamentally an existential issue for our industrial world." It is clear on which side of this digital transformation GE will remain with Flannery at the helm: "We are all in, in terms of digital," he said. "We are taking on the total transformation of industry, a new kind of industrial revolution."

For those that embrace it, disruption can create enormous opportunity. Citing a World Economic Forum study, Bill Ruh drew attention to the \$6.8 trillion opportunity in digital transformation over the next 10 years, of which \$700 billion will be Asset Performance Management-driven.

When four years ago GE began its journey into the IIoT, customers were asking, "why are you doing this?", Ruh related. Two and a half years later, that question changed to, "how are you doing this?" At this year's Minds + Machines, Ruh challenged the audience of industry execs and practitioners to eye the 6.8 trillion dollar prize and ask themselves, "what am I going to do about it?"

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