Testimony before
The U.S. House of Representatives Committee on Science, Space, and Technology, Subcommittee on Energy and Subcommittee on Research and Technology
Thursday, July 12, 2018

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Chairman Weber and Chairwoman Comstock, Ranking Members Veasey and Lipinski, Representative Tonko and members of the Committee, it is an honor to share GE's perspective on innovative machine learning-based approaches to big data science challenges to promote a more resilient, efficient and sustainable energy infrastructure. I am Matt Nielsen, a Principal Scientist at GE's Global Research Center in Upstate New York specializing in the application of these digital technologies for GE's Power, Renewables and Aviation businesses.

Between GE's Power and Renewables businesses, GE has a $44 billion energy portfolio that powers 1/3 of the planet. And 40% of the world's energy is managed by our software. GE's energy assets include everything from gas and steam power, nuclear, grid solutions and energy storage to onshore and offshore wind and hydro power. Our application of advanced technologies has allowed us to achieve the world record in combined cycle gas turbine efficiency and recently introduce the world's largest offshore wind turbine, the 150M-6MW Haliade X.

GE Global Research was the first industrial research lab established in the United States in 1900 and today remains the cornerstone of innovation for the General Electric Company. We are home to one of the world's most diversified, interdisciplinary research organizations, with ~1,000+ scientists and engineers (~600 hold PhDs.) working at our research campus in Niskayuna, NY. It is at Global Research where GE's research activities in artificial intelligence (AI) and machine learning are being led to support our business interests and to unleash these technologies to help solve the world's toughest problems.

The nexus of physical and digital technologies is revolutionizing what industrial assets can do and how they are managed. One of the single most important issues industrial companies are grappling with is how to most effectively integrate the use of AI and machine learning into their business operations to differentiate the products and services they offer. GE has been on this journey for more than a decade, recognizing early on the impact digital technologies could have in taking our products and services to the next level of efficiency and performance.

A key learning for us has been the importance of tying our digital solutions to the physics of our machines and to our extensive knowledge on how they are controlled. To work in the industrial world, AI and machine learning technologies must be coupled with the laws of physics, or known truths about machines and the environment in which they operate.

My testimony focuses on a few industrial applications of AI and machine learning that GE is driving with our customers and with federal agencies like the U.S. Department of Energy to address key challenges with cybersecurity related to critical power assets and to enable a new services paradigm that minimizes and strives to eliminate unexpected disruptions in the operation of power generation assets. We call it zero unplanned downtime. Both examples would not be possible without this unique combination of physical and digital technologies.

The Industrial Internet of Things (IIoT)

The digitization of major industrial sectors including energy, aviation, transportation and healthcare represent the next frontier of the digital revolution we already have experienced in finance, entertainment and telecommunications. This current wave is being powered by the exponential growth in computing power and digital technologies that is allowing us to connect and control billions of machines. To illustrate this leap in technology, just consider that a typical gaming system you can buy for your kids for a few hundred dollars packs the same processing power as a $10 MM supercomputer from the late 1990s.

At GE, one of the chief manifestations of AI and machine learning is happening through GE's Digital Twin technology. Digital twins are living, digital models of industrial assets, processes and systems that use AI and machine learning technologies to see, think and act on big data to drive higher business value and outcomes for GE and our customers. GE's Twins learn from a variety of sources that include sensor data from the physical machines, systems or processes themselves, fleet data and industrial domain expertise from human engineers. These models continuously learn as new data comes in from one or more of these sources, enabling a real-time view of the condition of your assets at any point in time.

To date, GE scientists and engineers have created ~1.2 million Digital Twins of our industrial components, assets and processes that represent a broad cross-section of the energy, aviation, transportation and health care sectors. GE's Digital Twin is the platform for product lifecycle management from inception and design through operations and maintenance and all the way to decommissioning and repurposing of assets. In power specifically, the application of Digital Twins is enabling GE to revolutionize the maintenance and operation of our assets and drive new, innovative approaches in critical areas such as cybersecurity.

GE's Digital Ghost – Building the World's 1st Industrial Immune System

Cyber threats to Industrial control systems that manage critical infrastructure such as power plants are growing at an alarming rate. Between 2015 and 2016, the number of cyberattacks increased by 110%[1]. While we continue to see advances in IT and OT technologies to prevent attacks from getting through, GE is working with the Department of Energy (DOE) on a $4.1 million cost-shared program to build the world's first industrial immune system for electric power plants that could not only detect and localize cyber threats but automatically act to neutralize them, allowing the system to continue operating safely and efficiently.

[1] https://securityintelligence.com/attacks-targeting-industrial-control-systems-ics-up-110-percent/

The creation of an industrial immune system that monitors a power plant's assets 24/7 seeks to replicate the human body's response of automatically detecting and acting to stop a virus invading the body. To replicate this effect with industrial systems, a team of cross disciplinary engineers from GE Global Research and GE's Power business are pairing a complete Digital Twin of the power plant system (embedded with AI and machine learning technologies) with Industrial controls to trigger an automatic detection and response to cyber threats when a power system is under attack.

The premise for this industrial immune system to work is to understand the machine's physics. Around the Research Center we like to say, "you can't fool the physics." In other words, the Digital Twins, or digital models we create must mimic the actual physics of the power plant system itself. Fortunately for GE Global Research, we have both the digital and physical experts to design such a system.

Using sensors and controls, we're creating an immune system that will rapidly be able to detect and localize where a cyber threat is occurring using advanced AI techniques. But then, our cyber protection system will enable the power plant system itself to automatically respond by neutralizing the effects of the threat. Of course, we want the detection and response to cyber threats to be as fast as possible. This is another way we're using AI and machine learning. We can construct "reduced order" models, or mathematical models that can be executed very fast and quickly identify what's happening in the system. This allows fast detection of anomalies and the generation of rapid decisions on optimal settings to protect assets.

This simply can't be done without combining a deep knowledge of both the physics of the system with an extensive knowledge of industrial controls. Industrial controls are the brains of machines that control how they operate. Taking optimal control actions depends on getting the best data insights through AI and machine learning technologies.

The program with the DOE is ongoing. To date, we have demonstrated the ability to rapidly and very accurately detect (99% accuracy) and localize simulated threats. We are also making progress on designing a system that can automatically act to neutralize threats. It is a great example of the tremendous value public/private research partnerships can advance technically risky, universally needed technologies that stay a step ahead of cyber attackers and strengthen the resilience of our energy infrastructure.

Uninterrupted Power... Zero Unplanned Downtime

Along with improving resilience, AI and machine learning technologies are enabling us to improve the performance and competitiveness of GE's energy businesses and our customers. We're using AI and machine learning to improve GE's energy services portfolio, helping our customers optimize and reduce unplanned downtime with their power assets.

Through GE's Asset Performance Management platform, we can help our customers avoid disruptions by providing deep, real-time data insights on the condition and operations of the plant while at the same time factoring in predictive, forward looking forecasts for energy demand, weather and other factors that operators should account for to optimize overall plant management. This is another example that illustrates how critical it is for the digital solutions using AI and machine learning be linked to concrete physics-based models and data.

Using AI, machine learning, and digital twins, we can better predict when critical assets require repair or have a physical fault. This allows our customers to move towards a condition- based vs. schedule- based maintenance system, meaning assets can be brought in only when a repair is needed. For example, we can use machine learning to quickly and efficiently compare how a machine is operating versus known, standard operations. If there are deviations between the two, critical repairs can be identified, prioritized and compared to previously known system outage schedules allowing a more optimized maintenance planning process.

Recommendations

The examples I have shared and GE's extensive developments with AI and machine learning for complex industrial systems like power plants have given us firsthand experience and insights into what it takes to successfully integrate these technologies into our nation's critical energy infrastructure. With this perspective, I share the following recommendations:

1. ***Continue funding opportunities for public/private partnerships to expand the application and benefits of AI and machine learning across the energy system.*** The Digital Ghost/cybersecurity solution discussed earlier pertained only to power plants and just scratches the surface of neutralization. More research is needed to get to a mature cyber-attack resilient controls system for power plants. We think the application of this solution could be expanded to more distributed energy systems that involve renewable and gas power as well. We encourage the Congress to continue funding opportunities through the DOE for public/private partnerships with industry to bolster cybersecurity protections for critical power infrastructure.

2. ***Present and future R&D programs in AI and machine learning require both physical and digital experts.*** In the consumer internet, the value of data is measured in quantities not quality. For example, with online retail and advertising companies, it's the increasing quantity of data on people's shopping or search habits that supports their business models by allowing them to more accurately predict what any one individual might want to buy or purchase. In the industrial space, it is critical to match your digital solutions to the true physics of a physical machine or system. It's about finding the right data that helps you achieve a desired business outcome. As mentioned in the Digital Ghost/cybersecurity example, the ability to detect, localize and neutralize cyberthreats is tied to the physical understanding of the power plant.

3. ***Continue to invest in the nation's high- performance computing (HPC) assets and expand opportunities for private industry to work with the National Labs.*** The DOE and National Labs have done a tremendous job with maintaining and enhancing the nation's high-performance assets and in creating more collaborative opportunities with industry. The incredible computing power these systems offer is a powerful tool for industry in scientific discovery.

   We are still working to fully leverage our current computing capability, but we are certain that continued advances - particularly in exascale and quantum computing - will serve to create new advances in AI and machine learning – a potential source of competitive advantage for US industry. It also will help accelerate future industrial applications of AI and machine learning. Quite simply, it offers a competitive advantage for US industry.

Conclusion

We appreciate the opportunity to testify and offer our perspective on how the development of AI and machine learning technologies can meet the shared goals of creating a more efficient and resilient energy infrastructure.

One final thought is to reinforce a theme I have emphasized throughout my testimony, and that is the importance of having teams of physical and digital experts involved in driving future AI and machine learning solutions. I can personally speak to this firsthand, being a scientist that started my career as a physicist and is today applying my physical expertise in a digital role building digital twins of industrial assets.

In our opinion, you can have the best software developer in the world, but their solutions won't deliver the intended business outcome unless it's tied to real physical data and industrial domain knowledge to guide it.

Thank you and I look forward to answering any questions.

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Matt was born and raised in Michigan, where he attended undergraduate school at Alma College. In 1999, he received his PhD in Physics from Rensselaer Polytechnic Institute (RPI), located in Troy, NY.

During his dissertation research, Matt worked with General Electric to help develop electronic materials for high frequency RF applications. After graduation, he was able to join full-time and worked on a variety of efforts from electronic packaging to wide band gap semiconductors. Matt later led a large research program developing technology in the area of photonics, more specifically ultra-fast optical communications and three-dimensional optical storage materials and systems. Matt was also Lab Manager for the Electrophysics and Materials organization, where he initiated new efforts in bio-electronics and monitoring applications.

Matt currently has the position of Principal Scientist with a research focus on Digital Twin and specifically computer modeling/simulation of physical assets, using first-principle physics and machine learning methods. Applications using the Digital Twins include performance optimization and cyber-security.

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