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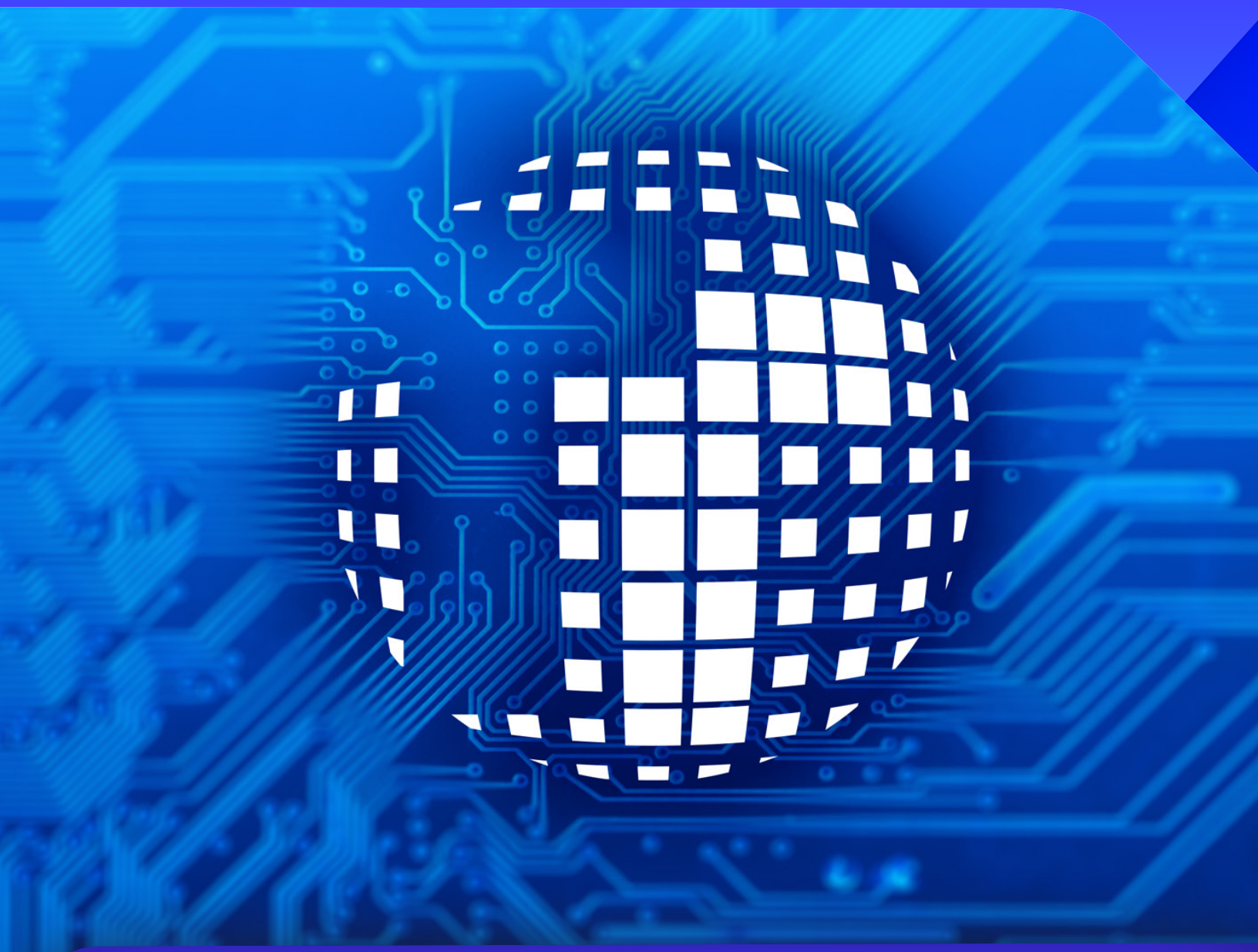

TECHNOLOGY TRANSFER AWARDS:

Generation Success Stories 2022

TECHNOLOGY TRANSFER AWARD

SUCCESS STORY

DTE's Random Forest Algorithm Expands for Environmental Controls with EPRI's AI Initiative

DTE Energy (DTE) identified a novel machine learning algorithm to troubleshoot and diagnose system upsets affecting a power plant's ability to meet air quality compliance. DTE and EPRI integrated this novel approach into a Window's desktop application with potential for broad applicability across the power industry.

LOSS OF EXPERTISE, CHANGING OPERATIONS

A diminishing experienced workforce and changes to plant operations have left a void of subject matter expertise at many power stations. For DTE Energy (DTE) these challenges added to the difficulty of meeting opacity air quality compliance at a coal-fired generating unit.

To help address these challenges, DTE Energy (DTE) investigated and tested various machine learning methods and identified a novel random forest (RF) algorithm with the potential to aid in analysis of opacity upset events. Random forests, which had not been widely used in power generation, can be applied to solve classification or regression type problems. RFs use decision trees, which are simplified algorithms that are suited to modeling complex multi-dimensional interactions.

COLLABORATIVE DEVELOPMENT

Seeing the value for the industry, EPRI and DTE gathered a technical team that included Oakland University researchers and an engineering software company to develop an RF standalone desktop app to help plant engineers and operators with detection and prediction issues affecting air quality control systems. To enhance and expand the initial app, EPRI continued development under EPRI's AI Initiative.

APPLICATION AND VALUE

The RF algorithms were applied to diagnose combustion and flue gas system upsets at two DTE plants. In one case, identifying the underlying cause of a system upset helped the plant to curtail derating one of their units, thereby avoiding the need to purchase replacement power. The estimated savings from this one event was to shorten the duration of approximately 3,000 gross MWh per day derate by rapidly identifying the root cause of the process upset (saving approximately 125 MW gross for a two-week period or roughly $186K based on average spot market replacement power cost for 2019). Other benefits included the optimization of precipitator down power rapping to prevent process upsets during peak hours.

VERSATILE DIAGNOSTIC TOOL

The application of the RF approach shows promise as a diagnostic tool that plant engineers can use to quickly analyze complex processes, gain insights on potential causes, and save scheduling repair time.

The final product can help users to quickly rank, identify and investigate potential solution paths to complex process problems. For instance, the analysis is not specific to any equipment or process; rather, the focus is on identifying the features that most influence a user-selected dependent variable.

In plant process systems, these can be linked to emissions controls (selective catalytic reduction, electrostatic precipitators, flue gas desulfurization, etc.). In water chemistry, these could be linked to several upstream process variables.

In boiler performance, the analysis can focus on variables that affect temperatures. The key ingredients for application of this tool are that several variables and large data sets are available for analysis.

RELATED EPRI PRODUCTS

REPORT TITLE	PRODUCT ID
Application of Novel Random Forest Approach for Environmental Controls: Development Status	3002021062
Machine Learning for Analysis of Power Plant Environmental Controls: Novel Random Forest Development	3002023918

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TECHNOLOGY TRANSFER AWARD

SUCCESS STORY

NYPA and Southern Company's Hydrogen-Natural Gas Blend Reduces CO_2 Emissions

New York Power Authority (NYPA) and Southern Company (SC) have successfully demonstrated that hydrogen can be safely blended with natural gas in gas turbines at gas turbines configured originally for natural gas fuel only operation. Blending hydrogen with the natural gas stream reduces plant CO_2 emissions, providing a pathway for de-carbonization that utilities can take with their existing gas assets, potentially accelerating the timeline to decarbonize.

HYDROGEN BLENDING TO REDUCE CO_2 EMISSIONS

Hydrogen fuel in gas turbines is seen as a promising bridge to a low-carbon future power system. Because it contains no carbon, hydrogen as a fuel directly reduces the carbon emitted by the gas turbine. Although hydrogen fuel has a long history of use in gas turbines, much of the experience until now has been in older turbines with low power ratings and efficiencies.

Many aspects of H_2/NG blending in modern GTs—such as hydrogen supply, blending system, control changes and gas turbine life and operability —have not been well under-stood due to a lack of practical experience. Emissions of NOx, a regulated pollutant, with hydrogen have also been a topic of research and debate.

DEMONSTRATION PROJECTS

NYPA and SC conducted separate H_2/ NG blending projects that featured many firsts. NYPA was the first to demonstrate a hydrogen project burning up to 44% by volume H_2 with NG in an existing fossil-fuel-fired simple-cycle GT generation plant. SC was the first to demonstrate a hydrogen project burning up to 21% by volume in an existing large combined-cycle gas turbine with a dry low NOx combustion system.

NYPA substituted renewable green hydrogen for a portion of the NG used in to generate power in the LM-6000 PC Sprint GT (48 MW) in the Brentwood Power Station on Long Island. The project team evaluated different concentrations of 100% high-pressure hydrogen blended with NG, ranging from 5-44% by volume, and assessed the blend's effect on unit performance, reduction of greenhouse gas emissions, and environmental impacts, including nitrogen oxide emissions.

SC blended a high-pressure hydrogen gas source with NG to a blending ratio of nearly 21% by volume of hydrogen in the in the McDonough power plant's combined-cycle 230 MW M501G GT at the full base loaded firing temperature and at minimum load, which was extended by approximately 10% lower load with hydrogen blending (exhibiting one of the flexibility benefits of hydrogen blending), within NOx emissions compliance and with no measured impact to gas turbine hardware which would impact its maintenance intervals.

These tests represent the first important steps in achieving hydrogen power generation operation at scale to support the energy transition to a decarbonized future. It is evident that these tests were of short duration relative to typical operation of these power generation assets and additional validation is necessary to bring longer term operation to fruition. Research will be needed not only for operational aspects but on the impacts to maintenance over time, needs

for operation personnel training and procedures, updates to fuel systems and balance of plant equipment, and capability expansion investigations into areas such as startup and shutdown on hydrogen, amongst many other items.

BENEFITS

NYPA and SC have proven the capability of modifying an existing GT asset to be used in burning a blend of NG and hydrogen to generate cleaner, safe, and reliable power. These demonstrations confirmed the viability of high percent hydrogen blends that can materially reduce CO_2 emissions. They provide industry and society a view to the use of hydrogen as a potential fuel gas source in modern turbines to reduce carbon emissions and allow further flexibility in GT operation. These results will inspire further tests and operation of high hydrogen fuel blending.

The process of blending and burning hydrogen gas in a GT was materially improved through these projects. Lessons learned, including proper materials, proper safety protocols, leak testing, controls changes and others, were developed and will serve to benefit SC and NYPA and others for many years.

NYPA will continue its planning process to decarbonize the remainder of its fossil-fueled fired generation assets.

SC will be able to use this knowledge in future projects that may go further in scope, including permanent installations using onsite-produced hydrogen. SC and EPRI are already looking at the feasibility of other SC plants performing similar or more complex hydrogen projects due to the success of the McDonough Hydrogen Demonstration.

RELATED EPRI PRODUCTS

REPORT TITLE	PRODUCT ID
Taking Gas Turbine Hydrogen Blending to the Next Level	3002023706
Southern Company Hydrogen Blending Test Report: Mitsubishi Power 501G 20% Hydrogen Test	3002025835
Hydrogen Cofiring Demonstration at New York Power Authority's Brentwood Site: GE LM6000 Gas Turbine	3002025167
Executive Summary: Hydrogen Cofiring Demonstration at New York Power Authority's Brentwood Site: GE LM6000 Gas Turbine	3002025166

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TECHNOLOGY TRANSFER AWARD

SUCCESS STORY

Chevron and Vistra Deploy EPRI's Digital Twin Technologies to Gas Turbine Maintenance and Dispatch

Two members successfully deployed EPRI digital twin (DT) technologies in their gas turbine (GT) fleet, Chevron for managing regular maintenance activities, and Vistra for enhancing GT dispatch. Both members were able to achieve measurable monetary improvements through the deployment of these tools, improving their daily plant operations and marketing options.

ENSURING GT RELIABILITY AND PERFORMANCE

Gas Turbines are an important yet complex and aging generating asset within utility fleets. Ensuring peak operational reliability and performance will maximize output to ever more critical grids.

A digital twin is a virtual model of a real-world process or asset that can be used for simulation, testing and performance optimization. The blending of the virtual and physical worlds allows data analysis and system monitoring to identify problems early, prevent downtime, and investigate the impacts of potential hardware or software changes by simulations. Digital twin technology enables operators and engineers to monitor and analyze the real-time data and performance of a GT, and then use this information to simulate and predict its future performance. The technology can help improve the efficiency, reliability, and safety of gas turbines, and can reduce maintenance costs and downtime by identifying potential issues before they occur.

In theory, a digital twin allows companies to have a complete digital trajectory throughout the lifecycle of an asset, ranging from design and development to maintenance and service phases. Through the continuous analysis of physical data of an asset, a digital twin can help to identify failures by detecting precursors earlier than most other systems. The physics-based approach allows the digital twin to adapt to new operation modes easily.

DIGITAL TWIN RESEARCH

Over the past seven years EPRI has been developing digital twin replicas of simple and combined cycle GTs to provide owners and operators with improved capabilities that typically reside in the domains of original equipment manufacturers and third-party service providers.

APPLICATION ON GT FLEETS

Chevron deployed digital twin (DT) technology for portions of their 7EA, LM2500, and 6B gas turbine fleet to better detect anomalous behavior and monitor when to perform regular maintenance activities. The P216/P217 Gas Turbine Digital Twin tool was developed for these gas turbines using Chevron's assistance and data. Chevron successfully used the technology to detect instrumentation issues and isolate the performance impact of compressor washes. This improved reliability and availability, which is key to operations. Chevron implemented the technology through integration with their historian and through a standalone desktop entitled "Wash Calculator," which implements the DT in an Excel file that they can run themselves. Using the DT to identify compressor washes on a condition-based basis reduces cycles on the GT and prevents needless wash events. The ability to output missing parameters, such as DWATT (for mechanical drive units) and FQG (fuel flow, where it is suspected to be

incorrect or not measured) enables them to focus on facility optimization and carbon reduction where they otherwise might not have a line of sight.

Luminant utilized the learnings from Chevron's DT work to develop, test, and deploy EPRI's Optora Dispatch Optimization Software, which leverages artificial intelligence (AI) and DT to give engineers an easy-to-use performance characterization tool, and is now in production as the Gas Turbine Digital Twin Self-Calibration Tool. The software was tested using Luminant's gas turbine fleet which was part of the early EPRI work on fleet level Digital Twins.

Luminant assisted in thoroughly testing the DT tools and has compared them to their in-house approaches for time and accuracy. Luminant also deployed the DT for fault detection in their historian and was able to identify a post-outage performance loss and compressor fouling events. These two activities can improve dispatch decisions for better grid response and maintain reliability of GT assets.

BENEFITS

Digital twins allow for greater precision in unit performance, which adds significant value. Overall, including the digital twins in their processes has helped Chevron and Luminant develop their commercial strategy for the fleet. Both members were able to achieve measurable monetary improvements through the deployment of these tools, improving their daily plant operations and marketing options—where both of these impact areas can realize tens of thousands of dollars in savings for operations and hundreds of thousands or more in gains from market effects. These tools will help the industry to operate the assets more efficiently and optimize the available assets towards defined goals such as reliability and fuel efficiency. This will help to optimize the operation of current and future asset mixes and further the understanding of asset capabilities.

RELATED EPRI PRODUCTS

REPORT TITLE	PRODUCT ID
Digital Twin Implementation: Applications for Fleet Tracking and Increased Virtual Sensing	3002018031
Digital Twin Implementation: Applications for Fault Signature and Virtual Sensor Development for Enhanced Monitoring	3002016248
Digital Twin Self Calibration Tool: Guideline for Gas Turbines v1.0	3002022197
Gas Turbine Digital Twin Autocalibration Tool (DTACT) v1.2.0	3002024128
The EPRI Gas Turbine Digital Twin – a Platform for Operator Focused Integrated Diagnostics and Performance Forecasting	3002023071

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TECHNOLOGY TRANSFER AWARD

SUCCESS STORY

Four Utilities Publish Outage Guide for Gas Turbine Maintenance Outages

Member utilities in conjunction with EPRI developed and demonstrated key guidance for improving the overall quality control and quality assurance of planned hot gas path (HGP) outage activities for GE 7EA gas turbines.

The efforts of the utilities—DTE Electric Company (DTE), Great River Energy (GRE), Tri-State Generation & Transmission Association (Tri-State), and Tennessee Valley Authority (TVA)—resulted in the publication of the *7EA Hot Gas Path (HGP) Outage Guide* (3002022786) and the development of an accompanying GE 7EA Outage Quality Checklist to be released later this year.

IMPROVING QUALITY OF PLANNED MAINTENANCE OUTAGES

Planned maintenance outages account for over 70% of gas turbine (GT) unit unavailability. Improper reassembly procedures and wrongly applied maintenance practices can increase outage times and costs, and may result in catastrophic failure and loss of human life.

Owner/operator concerns have grown regarding the quality of GT planned maintenance outages, particularly regarding the tasks of inspection, reassembly, and re-commissioning.

RESEARCH

To lessen their dependence on outside service providers, with their limited availability of qualified maintenance personnel for this GT design, from 2020 to 2021 DTE, GRE, Tri-State and TVA in collaboration with EPRI developed and demonstrated key methods and guidance for improving the disassembly, inspection, reassembly, and re-commissioning GE 7EA gas turbine units during planned HGP outages, including:

1. Key maintenance activity checklists that include disassembly and reassembly hold points, verification points, and witness points with acceptance criteria.
2. Inspection techniques and quality control criteria for the rotating, stationary, combustion and structural turbine parts, including expected dimensions, typical findings, and field repair methods with GO- or NO-GO acceptance criteria

APPLYING GUIDANCE AND METHODS

The developed guidance and methods were applied at three subsequent GE 7EA HGP outages – Tri-State in 2020, TVA in Spring 2021 and Great River Energy in Summer 2021. Following these demonstrations, DTE, GRE, Tri-State and TVA worked with the EPRI team to revise and publish a comprehensive *GE 7EA Hot Gas Path Outage Guide* (3002022786) in December 2021.

BENEFITS

The GE 7EA HGP outage guide aims for optimal execution of outage and maintenance activities, which can reduce unit downtime.

For outage team members, the manual serves as shared language and expectations, thus minimizing uncertainties in decision-making. For discussions with the OEM, owners/operators have credible data to challenge the OEM's criteria, such as whether to refurbish or repair rather than replace a component. Therefore, owners/operators can im-

plement real-time corrective actions to mitigate premature component failures resulting from improper reassembly procedures, reduce outage times to correct wrongly applied maintenance practices, eliminate costly replacement of repairable parts, meet emission compliance requirements, avoid unit capacity derating, improve gas turbine performance, and avoid catastrophic failures and possible loss of human life. Avoided costs from these types of failures are on the order of $100Ks to $1Ms per event. Most typically, damage from these events range for $2M to $5M per event, but can easily exceed $10M for a single event.

Owners/operators can use the guide to develop in-house expertise. For example, TVA typically spends nominally $700K per 7EA outage, and $60K is spent on technical oversight and QA/QC by third-party service providers. In 2021 TVA had four hot gas path/major outages for their 7EA gas turbine fleet, thus spending about $240K on outside oversight. With the outage guide, TVA staff can now oversee 7EA outages without having to pay third-party providers. TVA gains little gas turbine core knowledge using outside service providers. Implementing this outage guide within TVA Regional Engineering provides an additional step to developing existing staff into technically sound gas turbine centerline subject matter experts.

The knowledge developed throughout this project assisted DTE, GRE, Tri-State and TVA to plan, manage, and document the quality control and quality assurance of HGP outages at four GE 7EA power plants, including DTE's Belle River station (Michigan), GRE's LJS station (Minnesota), Tri-State's Knutson station (Colorado), and TVA's Lagoon Creek & Kemper County Stations.

While the 7EA HGP outage guide is derived from these members' experiences, it can be applied to the more than 5000 units throughout the world. Furthermore, the process and resulting outage guide has served as an approach for other gas turbine models.

RELATED EPRI PRODUCTS

REPORT TITLE	PRODUCT ID
7EA Hot Gas Path (HGP) Outage Guide	3002022786
Field Guide: Siemens 501F Outage Quality Checklist	3002020846
GT26 Overhaul Technical Support Manual, Volume 1—Outage Planning: Inspections, Quality Control Process, and Field Service Instructions	3002019992
GT26 Overhaul Technical Support Manual, Volume 2— Part 1: Combustion Component Inspection Forms and Guides	3002019993
GT26 Overhaul Technical Support Manual, Volume 2—Part 2: Rotating Component Inspection Forms and Guides	3002019995
GT26 Overhaul Technical Support Manual, Volume 2—Part 3: Stationary Component Inspection Forms and Guides	3002019996
GT26 Overhaul Technical Support Manual, Volume 2—Part 4: Structural Component Inspection Forms and Guides	3002019997
GT26 Overhaul Technical Support Manual, Volume 3—Commissioning Procedures: Cold and Hot Commissioning for GT26 Units	3002019998
GT26 Overhaul Technical Support Manual Web Application (GT26 App) V1.0	3002012593

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TECHNOLOGY TRANSFER AWARD

SUCCESS STORY

Improving Flexibility in India Through Assessment and Benchmarking

NTPC Limited, India's largest electric utility, helped develop and provided training for an assessment and benchmarking tool to support flexible operation of fossil generators. Applying the tool has enabled NTPC to prioritize research allocation and actions to achieve greater flexibility while maintaining reliability, safety, affordability, and environmental responsibility.

CHALLENGES OF FLEXIBLE OPERATION

India's 2030 energy commitments include

- 500 GW of Non-fossil energy capacity
- 50% Renewable energy
- 45% Economy-wide carbon intensity

The continued increase in variable renewable power generation has placed new constraints and costs on conventional steam generators in utility power systems. In particular, increased cycling of thermal units (flexible operation) to balance the uncertainty associated with variable generation can affect reliability and exacerbate damage mechanisms such as thermal transients, vibration, and corrosion. These conditions may need further assessment and improved monitoring processes to help mitigate potentially costly equipment damage and to promote safe, efficient and event-free operations.

FLEXIBILITY RESEARCH

EPRI has developed, demonstrated, and advanced flexibility improvements via new technologies, hardware, software, and cost-effective operating and programmatic practices for enhancing efficiency, flexibility, and maximum reliability in fossil power plants. In addition, EPRI has identified and quantified effective solutions for operation along with performance issues associated with adverse effects of these improvements on baseload and flexible operations, heat rate and fuel quality.

NTPC (formerly National Thermal Power Corp.) supported EPRI with a DOE collaborative project to help develop, demonstrate and disseminate a publicly available high-level flexibility and assessment benchmarking tool that has now been shared globally under EPRI guidance in multiple countries and in the hands of more than 150 companies. Without NTPC's leadership, engagement and support, the benefit of the tool would not have been realized.

APPLICATION TO NTPC FOSSIL GENERATION FLEET

The original NTPC stations where application was completed comprise approximately 9GW of critical generating assets across the NTPC fleet. Each station participated in the assessments to identify challenges and roadblocks, and the results were used to develop a fast-paced approach to improve NTPC's fleet optimization strategy. The work continues across NTPC's fossil generation fleet. With India's ambitious goals of integrating 175GW of renewable generation in 2022 and 300GW by 2030, these conventional steam generating units are key to balancing the electric grid in India.

BENEFITS

The conventional steam plants using this tool are the primary source of dispatchable generation that has and will continue to allow for the fast pace of India's energy transformation.

RELATED EPRI PRODUCTS

REPORT TITLE	PRODUCT ID
Flexible Operations Cost Management Tool: Conventional and Combined Cycle Units	3002020714
Operational Flexibility: Failure Mitigation Strategies Handbook	3002024255
High-Level Flexibility Assessment and Benchmarking Tool: Conventional Steam Generators	3002019900
Generation Flexibility Program Guidance: Conventional and Combined Cycle Units	3002024227
2018-2022 Generation Flexibility Conference: 5 years of Proceedings	3002024228
2018-2022 Generation Flexibility Conference: 5 years of Proceedings	3002025491
Interrelationships of Heat Rate and Flexibility: NERC GADS - Assessment of 40 years	3002023069
Methods to Understand the Effect of Heat Rate and Flexibility in Real-Time	3002020715
Handbook of Economic Flexible Operation of Coal and Gas-Fired Power Plants	3002023833

The tool methodology developed with NTPC provides adaptability for fuel specific challenges (and variances in asset age and condition), while also enhancing awareness and prioritization of issues/roadblocks.

Initially, the quantifiable benefits were achieved by using the user-friendly templates to identify more than 200 common issues and obstacles across six NTPC stations. Since then, the template tool and assessments have helped establish a foundational process for development of their flexibility improvement program at additional plants, preparing them for forecasted variability and demands for flexible generation.

NTPC has demonstrated the capability to turn down unit load to 40% with low-rank high-ash Indian coals and be able to meet more aggressive ramp rates with conventional coal generation, considering that fast-start combined-cycle plants are not common in the Indian energy mix. Since 2020, NTPC has demonstrated the ability to reduce minimum load by 15% from their design technical minimum load with low-rank and high-ash coals. NTPC is also simultaneously striving to meet lower emissions and flexibility through load range and ramp rate improvements.

Furthermore, in 2022 NTPC helped disseminate the training for the tool that has reached hundreds of stakeholders in India through knowledge transfer workshops providing instructional guidance, leveraging the past case studies to validate the tool's application, methodology and supporting industry dissemination for the benefit of society as a whole.

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TECHNOLOGY TRANSFER AWARD

SUCCESS STORY

Duke Energy Optimizes Cyber Security for Generation Fleet

Duke Energy implemented a risk-informed operational technology (OT) security program that has strategically enhanced security for the generation fleet while saving millions of dollars. The approach, spearheaded by Duke Energy's Generation Regulated and Renewable Energy (RRE) Cyber Strategy team, is being used as a model for the company's other OT lines of business.

IMPLEMENTATION CHALLENGES

Traditional cyber security industry standards inform methods that should be applied to protect, detect, respond, and recover digital devices but do not explain how to implement the controls. Often, utilities are left to determine which controls to apply and how to use them. This can be a daunting task, especially with a small staff and fixed budget. Each new control method will have ongoing costs and maintenance to ensure it remains effective.

CYBER SECURITY PROGRAM GUIDE

Recognizing the challenges of implementing cyber security controls, EPRI developed a guidance document, *Risk-Informed Cyber Security Program Guide for Electric Generation Facilities: Generation Cyber Security* (3002018753). Duke provided input and was instrumental in developing the risk-informed cyber security program optimization methodology presented in the report. The methodology identifies the most effective and cost-efficient cyber countermeasures based on vulnerability and threat assessments.

The methodology's goals are to:

- Identify security gaps through assessments
- Optimize cyber security based on risk (both enhancing and reducing as appropriate)
- Determine how to implement countermeasures

APPLICATION

Duke and EPRI applied the methodology, which used industry observations and best practices to guide the assessment of Duke Energy's cyber security program, focusing on overall strategy and governance, asset and configuration management, and vulnerability and patch management.

The programmatic assessment provided a step-by-step, systematic roadmap to implement the recommendations, along with several time- and cost-saving recommendations to increase the overall OT cyber posture. The assessment also identified stronger areas where less intervention was needed. The Duke Energy Generation RRE Cyber Strategy team has implemented the results of EPRI's Risk-Informed Cyber Security Program Optimization Methodology assessment to shape the remainder of its cyber security program development.

VALUE/BENEFITS

EPRI's risk-informed methodology and associated assessment supported Duke Energy's strategic vision to enhance security while optimizing costs by providing an effective, efficient, and comprehensive roadmap. Applying EPRI's tailored approach

was valuable in increasing Duke Energy's cyber security maturity and assisting Duke Energy in reducing cyber security risk in Duke Energy Regulated and Renewable Energy (RRE) generation. Duke Energy is utilizing the cyber security strategy to make capital and operational investments based on the assessment results.

As of May 2022, the RRE Generation Cyber Security Program is being implemented across RRE. For example, this risk-based approach was applied when scoping a recent Intrusion Detection System (IDS) project, allowing the team to prioritize and optimize investments in cyber defenses for generation industrial control systems. This resulted in identifying five instances where investments were deferred for facilities that are later in their lifecycle, therefore avoiding approximately $1.5M in upgrade costs while maintaining a secure cyber posture. This also allowed resources to focus on increasing the security posture of more strategic assets that are important to Duke Energy's long-term vision for their operating fleet. The gaps and improvement areas identified by EPRI's cyber security assessment were used to develop additional actions as part of Duke Energy RRE cyber security program development. Duke Energy incorporated recommended improvements, including clarifying program scope and applicability, mapping of cyber controls to a framework, and developing formal processes for change control, patch management, vulnerability response, and assessment or audit documents.

RELATED EPRI PRODUCT

REPORT TITLE	PRODUCT ID
Risk-Informed Cyber Security Program Guide for Electric Generation Facilities: Generation Cyber Security	3002018753

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TECHNOLOGY TRANSFER AWARD

SUCCESS STORY

LG&E and KU Applies EPRI's Solar Grazing Research to Improve Vegetation Management

Louisville Gas and Electric Company and Kentucky Utilities Company (LG&E and KU), part of the PPL Corporation family of utilities, applied EPRI research on using grazing for vegetation management at solar facilities to achieve economic and environmental benefits that extend to local agriculture and communities.

LG&E and KU is now leading the effort to demonstrate the feasibility of using sheep and native plants to manage vegetation at solar facilities. As the first utility to research dual grazing and native vegetation, they have laid the groundwork for utility companies to make their solar facilities more sustainable by supporting local agriculture and native biodiversity while reducing vegetation management costs.

NEED FOR SUSTAINABLE VEGETATION MANAGEMENT AT SOLAR FACILITIES

Vegetation management is a challenge for large scale solar facilities. Many solar farms plant non-native cool season grasses that, if left to grow uncontrolled, can cast shade on the solar panels and reduce the farm's energy output. Traditional techniques such as mechanical mowing or applying industrial herbicides are costly and labor intensive. Alternative, sustainable vegetation management practices are needed at solar facilities to help reduce costs while also protecting local biodiversity and agriculture.

Using small ruminants such as sheep to control vegetation is a viable alternative to traditional vegetation management.

SOLAR GRAZING RESEARCH

EPRI designed a study and methodology to evaluate the establishment, cost, and environmental benefits of using sheep grazing and native pollinator habitat to manage vegetation at a solar farm. Results show that both economic and environmental benefits can be achieved through innovative vegetation management practices at solar facilities, setting a new standard for the solar industry.

Data collected from this study provides insights into costs associated with sustainable land management for future solar developments. The research provides practical guidance on the use of sheep as part of a vegetation management plan that includes information on stocking densities, grazing durations, resting periods, and recommendations for rotational grazing plans to improve weed management.

APPLICATION

After refining grazing and vegetation management methods at a 10-megawatt solar farm near Harrodsburg, Kentucky in the EPRI study, LG&E and KU Energy (LG&E and KU), implemented vegetation management research at the utilities' second solar farm, located near Simpsonville, Kentucky.

BENEFITS

Native vegetation improves ecosystem functioning by reducing soil erosion, decreasing water runoff while increasing water infiltration, improving soil quality and serving as a sink for carbon. Solar grazing offers new opportunities for local agriculture by keeping lands in production and offers the potential to reduce vegetation management costs.

In the LG&E and KU study, using rotational grazing across the 2020 and 2021 growing seasons, sheep managed vegetation at acceptable heights without negatively impacting solar infrastructure or impeding access to infrastructure for routine maintenance.

Weed pressure from Johnson grass, an invasive species in Kentucky, was reduced and the time spent mechanically controlling this species decreased by 87% in 2021. Traditional mechanical mowing costs at this site were estimated at $14,000 for 10 acres in 2020. The cost of using sheep to graze the same 10 acres, excluding initial start-up costs, was estimated at $11,570 ($1,157/acre) in 2020 and $9,070 ($907/acre) in 2021. Cost reductions were attributed to greater efficiency in management resulting from fewer site visits and less mechanical string trimming required to control weeds along the fence lines of paddocks. Grazing also offers increased safety benefits by reducing damage that mechanical mowing equipment causes by throwing rocks and cutting wires. The use of sheep grazing has almost eliminated the need for mechanical vegetation management at the site while the native vegetation is also supporting native pollinators.

LG&E and KU's leadership approach to vegetation management is a model for sustainable solar moving forward. The state of Kentucky has started a solar vegetation management training program that will take place at LG&E and KU's solar farm and solar developers are being encouraged by the state to participate in the program. Utilities from across the country have toured the vegetation management research project and several plan to implement the research at their own solar farms.

RELATED EPRI PRODUCT

REPORT TITLE	PRODUCT ID
Solar Grazing: Viability of Grazing Sheep for Vegetation Management, Year 2	3002023328

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TECHNOLOGY TRANSFER AWARD

SUCCESS STORY

Duke Energy and EPRI Develop Wind Turbine Reliability Methods for Forecasting O&M Budget

Duke Energy (Brookfield) collaborated with EPRI on developing advanced wind turbine reliability methods for forecasting optimum operations and maintenance (O&M) budgets for the utility's entire wind fleet. The effort, which included conducting reliability assessments on specific turbine makes and models in Duke's fleet as well as critical components and failure locations, provided insights to inform O&M budgets and assisted Duke with critical wind farms and turbine models identification, supplier selection, serial defect identification and rectification.

ENHANCING WIND TURBINE RELIABILITY

Enhancing the reliability of wind farms and turbines—and being able to proactively address potential problems before they lead to unplanned outages—is essential if electricity is going to power transportation, heating and cooling and an expanding list of industrial uses. But reliability enhancement is also of critical importance to the operators of wind farms who depend on continuous turbine uptime and predictable O&M costs to maximize revenues.

EPRI Wind Program 206 advisors supported research to develop advanced reliability techniques and demonstrate these generic methods for wind turbine drivetrain (gearbox and generator) applications (EPRI Product IDs 3002021422 and 3002019008). Duke shared historic 2.6GW wind fleet reliability data from 22 wind farms (covering the 2008–2022 time period) with EPRI. This data includes 7 turbine OEMs, 12 turbine models, 21 suppliers and 60 system models.

APPLYING RESULTS

Using this data, EPRI connected specific components, systems and supplier/OEM reliability to the geographic location of wind turbines. Based on this innovative approach, EPRI predicted optimum O&M budget considering best-case and worst-case scenarios using advanced reliability mixture models. This reliability-based O&M budget forecasting has historically been lacking in the wind industry.

O&M COST SAVINGS AND RELIABILITY IMPROVEMENT

Supplier selections using reliability data can save $2M–$4M based on an average cost/replacement of a generator and gearbox at around $225,000 and $400,000, respectively, and reduction in failures across a 200-MW wind farm over the remaining 15–20 years. This cost estimate includes component, crane, and labor/travel. These O&M cost savings reduce the cost of energy, providing value to the overall wind industry and the public. Table 1 captures some of the of the top cost-benefits of the implemented actions.

Duke's collaboration with EPRI has enabled better insights into major component health and reliability across the fleet and understanding turbine platforms failure rates. This effort, paired with Duke's inhouse major component predictive capabilities, has led to an improved understanding of the drivetrain components' health and risk, and a reduction in failure rates enabled by early detection and mitigation of catastrophic failures.

Table 1. Cost benefits for implemented actions

WIND FARM ISSUES	IMPLEMENTED ACTIONS	FINANCIAL BENEFITS
Low-quality parts	Supplier selections based on not just cost and availability but also reliability	$2M–$4M O&M cost savings at a typical wind farm by avoiding early failures and replacements
Major component expenses	Cost avoidance using condition-based maintenance tools in conjunction with reliability forecasting	$1M–$2M in cost savings/avoidance through predictive initiatives and maintenance and asset strategy optimization
Inadequate O&M budget allocation	Identifying critical wind farms that have higher failure rate assisted in allocating budget, parts and resources in a timely manner. This resulted in reduced downtime	Increase in annual energy production by $150,000–$200,000/year

Advanced reliability methods provided Duke both granular and macro perspectives on their wind fleet. This work has successfully demonstrated the value of collaborative efforts and encouraged more utilities and operators to participate in EPRI's reliability data collection initiative, paving the path to more successful projects.

RELATED EPRI PRODUCT

REPORT TITLE	PRODUCT ID
Wind Network for Enhanced Reliability (WinNER) Web-Based Tool	3002020805
Wind Turbine Gearbox Reliability Assessment: Value of Increased Reliability and Reduced Operations and Maintenance Costs	3002021422
Wind Turbine Reliability Assessments for Efficient Operations: Reliability Projections Valuable for Reducing O&M Costs	3002019008
Wind Turbine Generator Reliability Analysis to Reduce Operations and Maintenance Costs	3002026844

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About EPRI

Founded in 1972, EPRI is the world's preeminent independent, non-profit energy research and development organization, with offices around the world. EPRI's trusted experts collaborate with more than 450 companies in 45 countries, driving innovation to ensure the public has clean, safe, reliable, affordable, and equitable access to electricity across the globe. Together, we are shaping the future of energy.

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