Agenda

PJM Fuel Security Briefing

The National Press Club
529 14th St. NW, 13th Floor
Washington, DC 20045

Nov. 1, 2018, 10:30 a.m.

Agenda and Speakers

1. Introduction, 10:30-10:35 a.m.
   Susan Buehler, chief communications officer

2. CEO Remarks, 10:35-10:40 a.m.
   PJM President and CEO Andrew L. Ott

3. Fuel Security Report, 10:40-10:50 a.m.
   Michael Bryson, vice president – Operations

4. Q&A, 10:50-11 a.m.
   Andrew L. Ott and Michael Bryson

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FOR IMMEDIATE RELEASE

PJM Completes Fuel Security Study as Part of Resilience Initiative

Results Confirm Grid Reliability, Identify Stress Points to Address Through Competitive Markets

(Valley Forge, Pa. – Nov. 1, 2018) As part of PJM Interconnection's ongoing initiative to assess the resilience of the electrical grid, today the nation's largest grid operator released a summary of its study examining one critical element of grid resilience – fuel supply.

PJM's fuel security analysis results found that the system serving 65 million people in 13 states and the District of Columbia is reliable and can withstand extended periods of highly stressed conditions.

"The findings underscore that PJM is reliable today. But in this study we are also looking into the future, to stress-test our system to reveal future vulnerabilities and make sure we are resilient under many different conditions," said Andrew L. Ott, president and CEO of PJM.

The study was designed to test the grid's limits to endure high-impact, long-term disruptions to generators' fuel supply. The study also identified scenarios in which the system would face power outages, applying extreme, but reasonably plausible assumptions for weather, customer demand, generator retirements and fuel availability.

"These results indicate that assessing generator fuel security should be a priority for PJM and its members," Ott said. "We will continue to look for opportunities to address resilience through the competitive wholesale electricity markets, in this case, by valuing resources that have secure fuel supplies."

PJM's analysis stressed the system using more than 300 different scenarios that could occur from 2023 into the future. Testing conditions ranged from typical winter operations to extreme, but reasonably plausible scenarios. The analysis found that in a sustained period of cold weather with typical customer demand, PJM's system can operate reliably over an extended period of stress.

As with any stress test, the analysis was intended to identify tipping points at which stressed conditions begin to impact the PJM system. By subjecting the system to a series of extreme, but plausible scenarios, PJM found stress points, starting in 2023, which could result in material levels of generation unavailability and load shedding.

"We found that in extreme scenarios, the more the grid was stressed, the more important fuel supply characteristics, location of the fuel supply disruption and demand response became," said Michael Bryson, vice president of operations. "We believe that some changes to the system in the future – both market-based and operational – are warranted. As with any stress test, there are extreme cases, and building to mitigate or eliminate risk must be balanced with costs."

– MORE –

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The study identifies key variables to the security of the grid's fuel supply. They include:

- Availability of non-firm gas service
- Ability of the fuel-oil delivery system to replenish oil supplies during an extended period of extreme cold weather
- Physical breaks at key locations on the pipeline system
- Customer demand (load)
- Generator retirements, replacements and resulting installed reserve margin
- Use of operating procedures to conserve fuel during peak winter conditions

Resilience is how grid operators manage the risk of high-impact disruptions that go beyond what is examined today under existing standards. These disruptions can happen simultaneously and persist for a long period. Operators must prepare for, be capable of operating through and be able to recover from these events as quickly as possible, no matter what the cause. PJM's resilience initiatives range from protecting the grid against coordinated physical or cyberattacks to ensuring the availability of system restoration resources that can respond after a major event.

In PJM's March 2017 paper, "PJM's Evolving Resource Mix and System Reliability," PJM recognized that important resilience questions have been raised by the shift in fuel mix and technology types. The Fuel Security Analysis addresses those questions pertaining to the fuel supply chain.

PJM will work with its stakeholders, starting this month, to examine these findings and explore market-based solutions to address concerns about the long-term security of the fuel supply. PJM expects to have a problem statement presented to stakeholders in early 2019, with any potential market rule changes targeted for filing with FERC in early 2020.

PJM also urges national consideration of fuel security issues through the resilience docket opened by FERC, as the issues raised by PJM are not necessarily limited to the PJM region. "Policy guidance from FERC would certainly help the process," Ott said.

PJM will continue to work with the gas pipeline industry to improve coordination in communications, refine contingencies and further improve shared understanding of pipeline and grid operations and how they interface. PJM will also collaborate with the fuel-oil and fuel-oil-transportation industries to increase transparency of on-site fuel inventory levels in addition to replenishment rates and capabilities.

PJM Interconnection, founded in 1927, ensures the reliability of the high-voltage electric power system serving 65 million people in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia. PJM coordinates and directs the operation of the region's transmission grid, which includes over 84,042 miles of transmission lines; administers a competitive wholesale electricity market; and plans regional transmission expansion improvements to maintain grid reliability and relieve congestion. PJM's regional grid and market operations produce annual savings of $2.8 billion to $3.1 billion. For the latest news about PJM, visit PJM Inside Lines at insidelines.pjm.com.

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Fuel Security

Analyzing Fuel Supply Resilience in the PJM Region

Summary of Results, Conclusions and Next Steps

Highlights

- PJM's fuel security analysis is the next step in ensuring the resilience of the grid, focusing on one of its most important elements – fuel supply.
- The PJM system is reliable today and will remain reliable into the future.
- In the analysis, PJM stress-tested the fuel delivery systems serving generation in the PJM region under extreme scenarios to identify when the system begins to be impacted and to identify key drivers of reliability risk.
- In order to enhance the fuel security of the grid into the future, PJM believes market-based mechanisms for retaining or procuring resources with the necessary attributes should be explored.

Analysis and Results:

- PJM looked five years into the future, using a 2023/2024 system model, to analyze more than 300 different scenarios ranging from typical operations to extreme scenarios, considering elements like generation retirements, customer demand, fuel delivery and fuel disruptions.[1]
- In a 14-day period of cold weather with typical winter load and generation retirements announced as of Oct. 1, 2018, PJM's system can withstand an extended period of stress while remaining reliable. Even in an extreme scenario, such as an extended period of severe weather combined with high customer demand and a fuel supply disruption, the PJM system would still remain reliable.
- As in any stress test, the analysis was intended to discover the tipping point when the PJM system begins to be impacted. Looking five years into the future, under escalated retirement scenarios combined with extreme winter load, the system may be at risk for emergency procedures and load loss.
- Key elements such as on-site fuel inventory, oil deliverability, location of a fuel supply disruption, availability of non-firm natural gas service, pipeline configuration and demand response become increasingly important as the system comes under more stress.
- The development of demand response programs has helped to provide more options for PJM operators and reduced, though not eliminated, the vulnerability of the system to fuel supply disruptions.

Actions:

- While there is no imminent threat, fuel security is an important component of ensuring reliability – especially if multiple risks come to fruition. The findings underscore the importance of PJM exploring proactive measures to value fuel security attributes, and PJM believes this is best done through competitive wholesale markets.
- PJM will continue to engage the Federal Energy Regulatory Commission (FERC) in the national consideration of fuel security issues addressed in FERC's resilience docket.[2]

[1] The analysis is neither meant to be predictive of future conditions nor meant to imply that analyzed scenarios are unavoidable.
[2] https://www.pjm.com/-/media/documents/ferc/filings/2018/20180309-ad18-7-000.ashx

Focus on Fuel Supply

Electricity is a public necessity and is critical to the public health and welfare of the nation. Keeping power available whenever and wherever it is needed is the number one priority of PJM Interconnection and other grid operators. In the last several years, changes in the energy industry and increased cyber and physical threats to the grid and the fuel supply chain serving that grid have introduced a heightened focus on risk. Grid operators around the world find themselves contending with new challenges, including a rapidly changing fuel mix, stressed fuel delivery systems, extreme weather, cyberattacks and physical security threats. As a result, the security of the fuel supply – one component of the resilience of the power grid – has become an increased area of focus.

Fuel Security as a Resilience Effort

Resilience is how grid operators manage the risk of high-impact disruptions, which can happen simultaneously or persist for a period of time. Operators must prepare for, be capable of operating through and be able to recover as quickly as possible from these disruptions, no matter the cause.

There are many dimensions of resilience that span the markets, operations, planning and supporting infrastructures of the grid. In PJM's March 2017 paper, "PJM's Evolving Resource Mix and System Reliability," PJM recognized that the shift in fuel mix and changes in technology raised important fuel security questions. This spurred PJM to undertake an analysis of risks to fuel supply, which is summarized in this document. PJM will publish a detailed report on this analysis, including the background, method, approach, analysis results, conclusions and next steps in December 2018.

Analysis: Assumptions and Scenarios

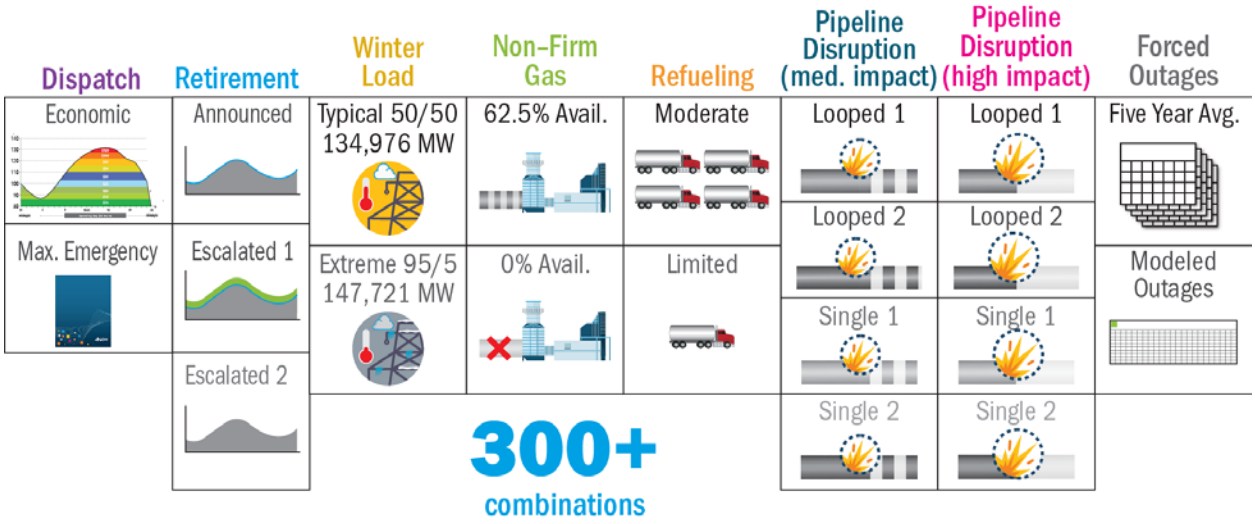
PJM designed its analysis to stress-test the grid under a series of extreme, but plausible events. As in any stress test, the analysis was intended to discover the tipping point at which the PJM system begins to be impacted.

PJM studied more than 300 different scenarios that could occur during an extended period of cold weather, varying elements such as customer demand (also called "load"), fuel availability, oil refueling frequency, generator forced outage rates, retirements and natural gas pipeline disruptions (Figure 1).[3]

In order to develop a robust and plausible set of assumptions, sensitivities and scenarios, PJM analyzed historical weather data spanning more than 45 years, researched previously completed studies, issued supplemental surveys to PJM generation owners, and met extensively with industry groups, generation owners, various companies in the fuel supply chain in the PJM region, government agencies and other system operators.

[3] The impact of available demand response, renewables and energy storage was incorporated in the analysis for all scenarios.

Figure 1: Overview of Assumptions



Why Winter Demand?

PJM selected a 14-day period of cold weather for the analysis. Though PJM consistently sees its highest customer demand during the summer, the greatest strain on fuel supply and delivery occurs in the winter. This is primarily because during the winter, the needs of commercial and residential heating are competing with natural-gas-fired and dual-fuel generators (which generate more than 30 percent of the energy produced in PJM) for natural gas, oil, pipeline transportation and oil deliveries.

Retirements, Load and Disruptions

In the analysis, PJM simulated typical winter load on the system,[4] looking five years into the future and taking into account the announced retirements,[5] new generation slated to be in operation by 2023 and interstate pipeline build-out. This allowed PJM to analyze the assumptions against what it would experience in a typical winter.

PJM then layered in additional assumptions to stress-test the system under more extreme conditions, asking questions such as: "What if the peak load is much higher than usual?", "What if there is a pipeline break at a critical location?", "What if deliveries of fuel don't come in as scheduled?", "What if there are more generator retirements than expected?"

[4] "Typical winter load" is that which would occur about 50 percent of the time and represents a peak demand of approximately 134,976 MW. "Extreme winter load" is that which would occur only about 5 percent of the time and represents a peak load of approximately 147,721 MW.

[5] Retirements announced by Oct. 1, 2018.

The key variables included in the analysis were:

- Availability of non-firm gas service
- Ability of the fuel-oil delivery system to replenish oil supplies during an extended period of extreme cold weather
- Physical breaks at key locations on the pipeline system
- Customer demand (load)
- Generator retirements, replacements and resulting installed reserve margin
- Use of operating procedures to conserve fuel during peak winter conditions

Results: Reliable Under All but the Most Extreme Scenarios

The results of the analysis are summarized in Figure 2 and Figure 3. Each box represents a single scenario, which is color-coded by level of operational procedure. Boxes include all operational procedures up to and including the one indicated by color. For instance, a yellow-colored square would indicate an operational reserve shortage, and some level of demand response would have already been deployed; voltage reduction and load shed would not have occurred.

Labels indicate the following:

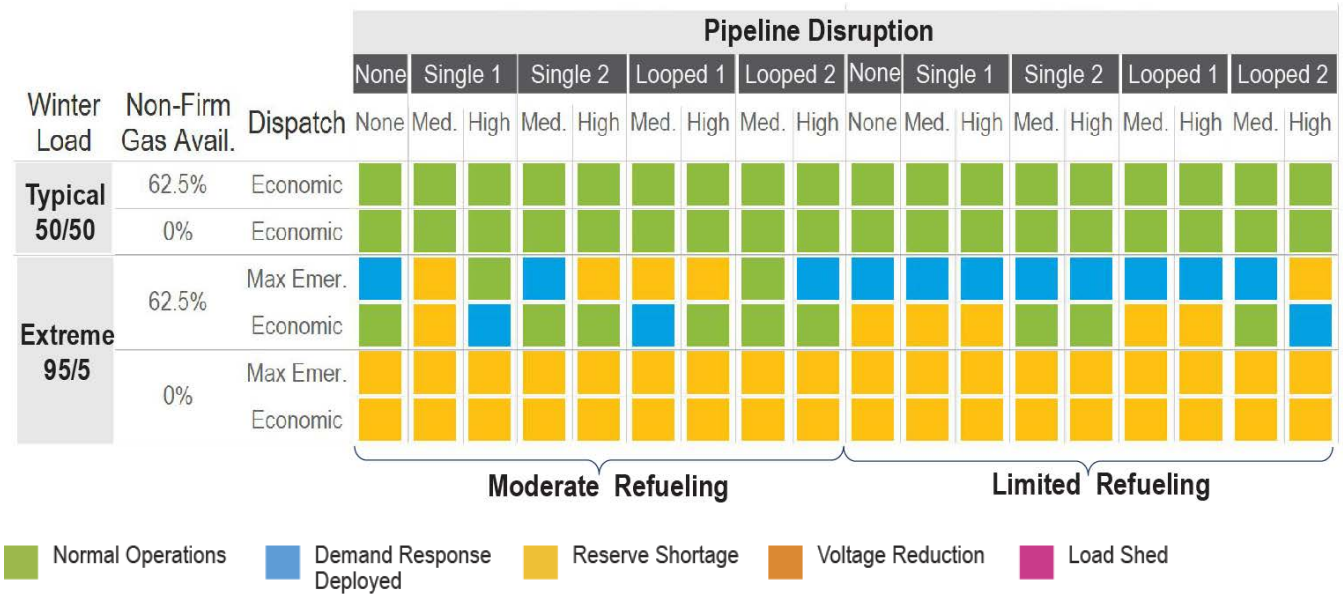
- Winter Load: Typical (134,976 MW peak) or extreme (147,721 MW peak)
- Non-Firm Gas Availability: 62.5 percent or 0 percent available
- Dispatch: PJM's usual economic dispatch or a maximum emergency dispatch
- Moderate/Limited Refueling: Amount of oil refueling
- Single 1/Single 2/Looped 1/Looped 2: Names assigned to simulated pipeline disruptions
- Medium/High: Severity of simulated pipeline disruptions

Announced Retirements, Typical and Extreme Winter Load

The analysis showed no issues on the system in a prolonged period of cold weather with typical winter load,[6] accounting for announced retirements[7] and new generation slated to be in operation by 2023 (Figure 2). Even in a scenario such as extreme winter load[8] combined with a pipeline disruption at a critical location on the pipeline system from which a significant number of generators are served, PJM's system would still be reliable. While there could be reserve shortages in the extreme winter load scenarios, the grid would remain reliable and able to continue to deliver electricity reliably under these extreme conditions.

[6] "Typical winter load" is that which would occur about 50 percent of the time and represents a peak load of 134,976 MW.
[7] Retirements announced by Oct. 1, 2018.
[8] "Extreme winter load" is that which would occur only about 5 percent of the time and represents a peak load of 147,721 MW.

Figure 2: Results: Announced Retirements, Typical and Extreme Winter Load



Escalated Retirements, Typical and Extreme Winter Load

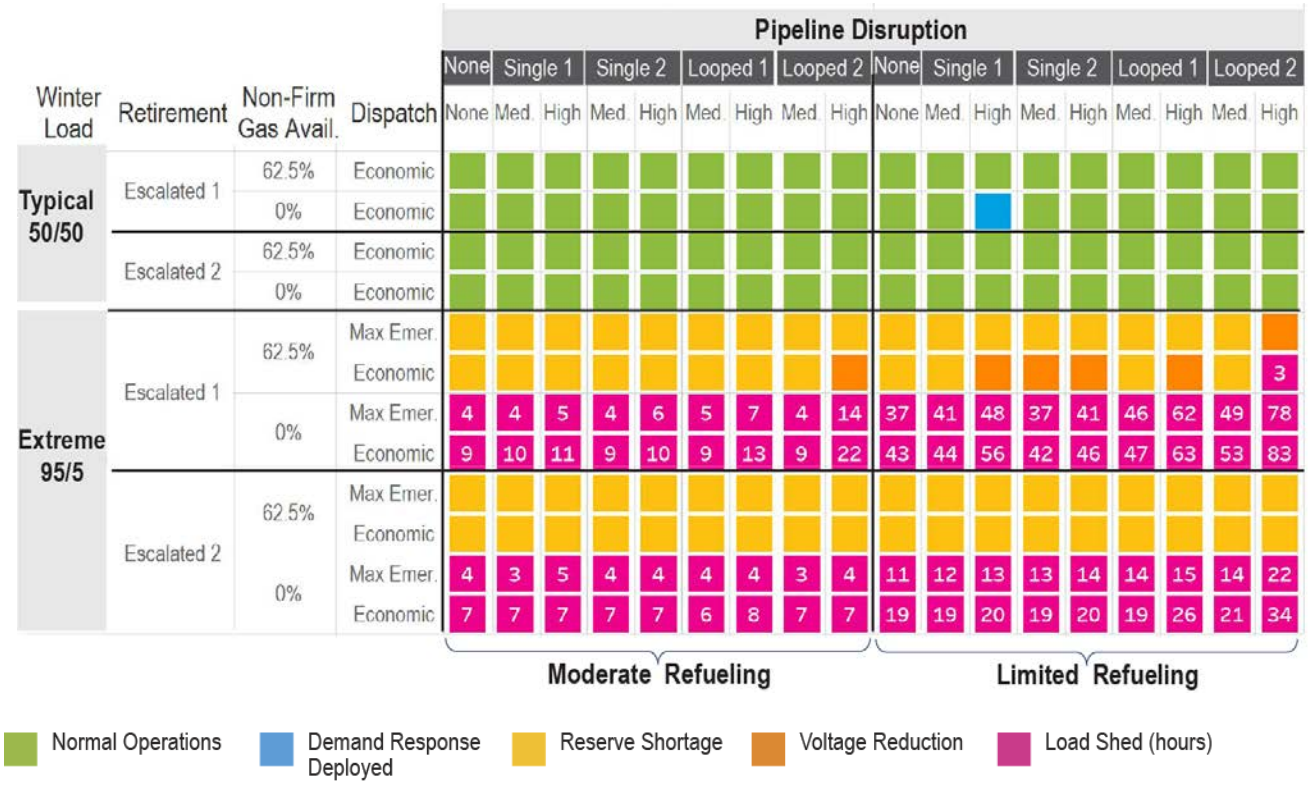
For the more extreme scenarios, PJM analyzed two separate generation retirement scenarios, termed Escalated 1 and Escalated 2. Both Escalated 1 and Escalated 2 included securing enough capacity to meet PJM's installed reserve margin reliability requirement.[9] Escalated 1 modeled generation retirements of 32,216 MW by 2023, with 16,788 MW of capacity added to meet the installed reserve margin requirement. Recognizing that as units retire, market signals could slow the rate of further retirements, Escalated 2 modeled generation retirements of 15,618 MW by 2023 with no capacity replacement.

When combined with extreme winter load, PJM's analysis indicates that the two escalated retirement scenarios have similar results that indicate the system may be at risk for emergency procedures and load loss. A summary of the results of the extreme scenarios with escalated retirements is shown in Figure 3.

PJM acknowledges that its reserves have historically exceeded the installed reserve margin reliability requirement. The escalated retirements are, by design, a stress analysis. The goal is to simulate the retirement of different levels of resources that are financially at risk while maintaining the current installed reserve margin reliability requirement of 15.8 percent. In the Escalated 1 analyses, PJM retired beyond the reliability requirement and replaced up to the reliability requirement. In the Escalated 2 analyses, PJM simply retired up to the reliability requirement and did not replace any of the retirements. The range of retirements analyzed represents possible bounds of retirement levels, recognizing that market signals would limit retirements between those bounds.

[9] In the Escalated 1 scenario, 16,788 MW of replacement resources were added to meet the 15.8% installed reserve margin reliability requirement. In the Escalated 2 scenario, a level of retirements (15,618 MW) was assumed that resulted in meeting the 15.8% installed reserve margin reliability requirement and therefore no replacement resources were added.

Figure 3: Results: Escalated Retirements, Typical and Extreme Winter Load



In looking at more than 300 scenarios, it is clear that key elements such as availability of non-firm gas service, oil deliverability, pipeline design, reserve level, method of dispatch and availability of demand response become increasingly important as the system comes under more stress.

In particular, the combination of the following factors contributes to potential load loss events:

- The level of retirements and replacements
- The availability of non-firm gas service
- The ability to replenish oil supplies
- The location, magnitude and duration of pipeline disruption
- Pipeline configuration

While there is no imminent threat, fuel security is an important component of ensuring reliability – especially if multiple risks come to fruition. The findings underscore the importance of PJM exploring proactive measures to value fuel security attributes, and PJM believes this is best done through the competitive wholesale markets.

Next Steps

This document is intended as a summary of PJM's fuel security analysis and results. In December 2018, PJM will publish a paper on the analysis detailing the background, method, approach, analysis results, conclusions and next steps.

Results from the analysis were also reported in PJM's Nov. 1, 2018, Special Markets & Reliability Committee meeting. Based on these results, PJM will begin a stakeholder process to discuss potential solutions.

To continue stakeholder engagement, PJM will:

- Host a follow-up Special Markets & Reliability conference call on Nov. 26, 2018, to address additional questions that may arise as stakeholders review the study results.
- Host a Special Markets & Reliability meeting on Dec. 20, 2018, to discuss the additional detail provided in the paper.
- Introduce a Problem Statement and Issue Charge for stakeholder consideration in the first quarter of 2019 with any potential market rule changes targeted for filing with FERC in early 2020.

PJM will also continue to engage FERC in the national consideration of fuel security issues addressed in FERC's resilience docket.[10]

[10] https://www.pjm.com/-/media/documents/ferc/filings/2018/20180309-ad18-7-000.ashx

MEDIA ADVISORY

FOR IMMEDIATE RELEASE

PJM to Release Results of Fuel Security Analysis Nov. 1

(Valley Forge, Pa. – October 31, 2018) – PJM Interconnection President and CEO Andrew Ott and Michael Bryson, vice president – Operations, will release the results of PJM's fuel security analysis, part of its ongoing initiative to focus on a resilient electric grid. A briefing will begin at 10:30 a.m., Nov. 1 at the National Press Club, Washington, D.C.

PJM, operator of the nation's largest electrical grid covering 13 states and 65 million people, undertook the study earlier this year to determine whether dependence on any one type of fuel delivery system in the generation of electricity would pose any long-term risks to the resilience of the grid. The study results will address that question.

The results of the analysis will also be discussed at a special session of PJM's Markets and Reliability Committee on Nov. 1. PJM will issue a news release with a summary document immediately following the session.

Please register for the 10:30 a.m. briefing. If you cannot attend in person, a conference line is available to listen over the phone.

For background on PJM's fuel security analysis, read President and CEO Andrew Ott's column on *PJM Inside Lines*.

Who: PJM President and CEO Andrew L. Ott and Michael Bryson, vice president – Operations
What: PJM Fuel Security Analysis Results News Conference
When: Nov. 1, 10:30 a.m.
Where: The National Press Club, 529 14th St NW, Washington, DC 20045
Registration

Toll Free Participants: 833-832-2121
Toll/International Line: +1 706-902-0489

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PJM Inside Lines

New initiative continues PJM quest for better fuel security

MAY 1, 2018

By Andy Ott, president and CEO

As we sit here today, we know the PJM grid is reliable, fuel secure and diverse. But we also face a legitimate question – are we going to find ourselves in a situation where we are overly dependent on one fuel delivery system?

In our continued commitment to reliability and resilience, we launched our fuel security initiative Monday with the publication of Valuing Fuel Security.

We all are aware of the dynamics in the PJM footprint. The market is appropriately attracting significant investment in new, more efficient technology to deliver energy at the lowest reasonable cost for consumers.

The energy market is working as it should for consumers; it is highly competitive and is attracting investment and development of new, more efficient generation sources. That's good for prices and for energy efficiency.

But, the energy industry and the fuel mix are evolving. This includes retirements because of market forces or aging fleet. While coal and nuclear retirements have been in the news, less-efficient gas plants also have retired.

In our 2017 study PJM's Evolving Resource Mix and System Reliability, we found that the PJM system could remain reliable under an array of future supply portfolios. The scope of that analysis did not, however, include an assessment of the resilience of the fuel delivery systems with various potential portfolios, nor the risks associated with significant disruptive events. We think that's important.

Through this new initiative, we will assess potential vulnerabilities and develop criteria to address any future fuel security concerns.If needs are identified, we will work to incorporate fuel security attributes into the fuel-neutral, competitive discipline of the wholesale market.

The process we launched Monday will involve three phases:

- Identify system vulnerabilities and determine attributes such as on-site fuel requirements, dual fuel capability or others that ensure that peak demands can be met during extreme scenarios.
- Model those vulnerabilities as constraints in PJM's capacity market, similar to the way we would model existing transmission constraints on the power grid, allowing for proper valuation of needed attributes in the market.
- Test the criteria to address specific security concerns determined by federal and state agencies, stakeholders and states, to look at critical physical and cybersecurity assets – or winter or summer events that strain the system.

The intent of the vulnerabilities assessment is to stress-test the system under various fuel supply disruption scenarios, to better understand potential future reliability concerns.

We also see this initiative as a continuation of our work on capacity performance; capacity performance has improved generation performance across the board.

What we are talking about here goes beyond what a single generator can prepare for. We are looking at the broader threat to capture the broader vulnerabilities of entire fuel delivery systems instead of looking at the risk entailed by one generator.

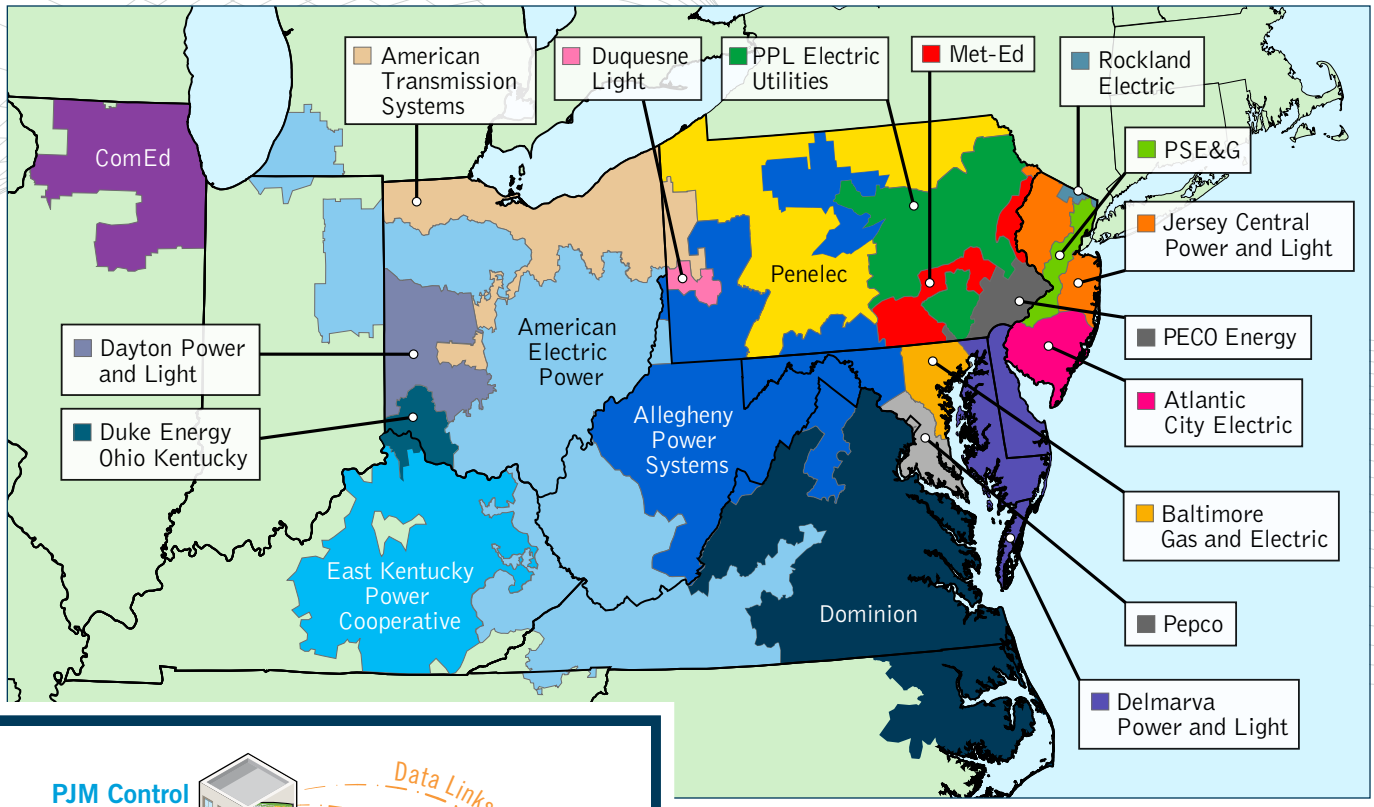
We want to examine the risks of increased reliance on any one type of fuel delivery system. Does that reliance introduce potential resilience risks that are not included under any existing reliability standards?

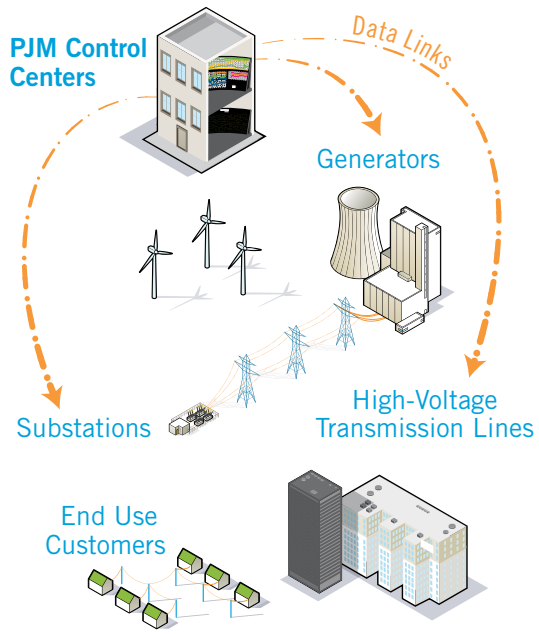
We will look at the criteria to value and price fuel security, promoting competition among different fuel delivery system types to meet any fuel security needs in a particular location at the lowest reasonable cost.

That value then can be incorporated into PJM's existing market mechanisms, with reforms to be in place for next year's capacity auction, if necessary.

In short, we want to identify the risks, value fuel security attributes of generating units and establish a market mechanism that will promote competition among all fuel delivery system types to meet established fuel security needs.

We don't think there is an emergency today. If we did, we'd be the first to raise our hands. We need, however, to act with expediency because these threats are real. We need to look at our infrastructure to ensure that it remains reliable and resilient.





Keeping the Lights On

We're sometimes called air traffic controllers of the power grid. PJM monitors and coordinates more than 1,379 electric generators and over 84,042 miles of high-voltage transmission lines. Just like air traffic controllers, we don't own the equipment we direct. Others own the power lines and power plants.

Power generators, utilities and power marketers coordinate their operations through PJM. Doing so makes major electric outages less likely to occur and reduces power costs.

PJM – At a Glance

PJM Interconnection coordinates the movement of electricity in all or parts of 13 states and the District of Columbia. We work quietly behind the scenes. Our job is to ensure there is enough electricity for the 65 million people in our region.

Key Statistics	PJM Today
Millions of people served	65
Miles of transmission lines	+84,042
Generation capacity in MW	178,563
Square miles of territory	243,417
Area served	13 states + D.C.

High Technology

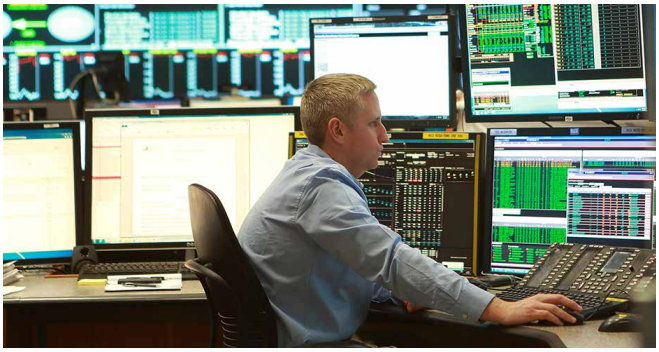
Our operations are based on skilled knowledge workers and banks of powerful computers. Expert staff constantly monitor the grid at PJM's high-tech data, communication and control centers. As usage of electricity shifts up and down throughout the day, PJM balances supply and demand by telling power producers how much energy to supply.

Our engineers and information technology experts study hundreds of "what if" scenarios. They prepare to deal with virtually any event – from extreme weather conditions, emergencies and equipment failures, to the more easily anticipated cycles of days, weeks and seasons.

Power Markets

PJM administers competitive wholesale markets for large blocks of electricity – similar to the way the stock market works. Our markets are internet based. Utilities and other electricity suppliers use them to make short-term purchases of power for their customers. Our markets attract renewable power sources, such as wind, to the region.

We administer demand response programs. Demand response allows customers to be paid for reducing their electricity usage during system emergencies or periods of higher power prices.



Planning

Managing the future needs of the electric system is an integral part of PJM Interconnection's role as a regional transmission organization. PJM conducts a long-range Regional Transmission Expansion Planning process that identifies what changes and additions to the grid are needed to ensure reliability and the successful operation of the wholesale markets. PJM's open and extensive review process ensures that all interested parties, including state regulatory agencies, have an active role in planning for future electricity supply and reliability needs.

A Long History

Founded in 1927, PJM Interconnection is an independent, federally regulated organization headquartered near Valley Forge, Pa.

Visit our learning center at **learn.pjm.com**

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