Fuel Security Monitoring Methodology

BACKGROUND

The timeline below outlines PJM's previous Fuel Security efforts and the path to the current monitoring methodology, including previous reports[1] and working through the Fuel Security Senior Task Force[2]. This document details the methodology PJM will use to continue monitoring fuel security.

2015 – 2017	• PJM produces a series of reports on impacts of the changing landscape of the power industry, including a report evaluating the changing resource mix in PJM and reliability attributes.
Apr 2018	• PJM releases a brief outlining its intent to perform further analysis on the topic of fuel security and its proposed approach to the process.
Nov / Dec 2018	• PJM releases the results of its analysis and simulations and presents the data to its stakeholders, identifying some potential risks and vulnerabilities associated with fuel security.
Feb / Mar 2019	• Problem Statement & Issue Charge presented to and approved by PJM stakeholders, identifying fuel security as an important component of reliability and resilience.
Apr – Dec 2019	• Fuel Security Senior Task Force conducts additional analysis to evaluate options and provide recommendations to the larger PJM stakeholder body.
Dec 2019	• MRC votes to sunset the FSSTF and continue to monitor parameters considered in the fuel security analysis and report to the MRC.
Feb 2020	• OC Work Plan updated to include periodic Fuel Security updates.

---

[1] https://www.pjm.com/-/media/library/reports-notices/fuel-security/2018-fuel-security-analysis.ashx
https://www.pjm.com/~/media/library/reports-notices/special-reports/20170330-pjms-evolving-resource-mix-and-system-reliability.ashx

[2] https://www.pjm.com/committees-and-groups/closed-groups/fsstf.aspx

FUEL SECURITY RESOURCE ADEQUACY ASSESSMENT

The resource adequacy-based fuel security assessment will be conducted once a year as an assessment of the 5-year ahead Regional Transmission Expansion Plan (RTEP) portfolio.[3]

The RTEP portfolio is finalized in February/March of every year. Data collection on the inputs to the Fuel Security assessment can begin in parallel or prior to that period. The inputs into the Fuel Security assessment are detailed in the following subsections. These inputs will be updated by rolling in the most recent information for each of them.

Portfolio

The assessment will be conducted using the most recent Regional Transmission Expansion Plan (RTEP) portfolio which is targeted for 5 years into the future.

Cold Snap Definition & Load Shapes

For the purposes of this analysis, PJM defines a cold snap as a series of 5 or more contiguous days where the average RTO wind-adjusted temperature (WWP) in each of such days is less than 21.5°F. The RTO WWP for a given day is calculated as a load-weighted average across 30+ weather stations in the current PJM footprint, and across the 24 hour readings of each day. The 21.5°F threshold corresponds to an estimate of the 90th percentile value of historical daily RTO average WWP values.

Hourly load shapes for the winter season in the targeted delivery year (5 years into the future) will be derived based on the weather of each historical cold snap. The procedure to derive the hourly load shapes is consistent with the PJM Load Forecast model and considers:

- A peak load forecast model employed to determine the “peak load” of each load shape
- An hourly load forecast model employed to determine the relationship between the hourly loads (the “shape”) in each load shape.
- The forecasted “shape” is then adjusted so that the shape’s peak is equal to the forecasted “peak load.”
- The hourly loads in the adjusted forecasted shape are capped at the highest load in the winter peak load distribution (“CP1 distribution”) for the winter season in the targeted delivery year.

In the 2019 FSSTF analysis, 47 winter load shapes (one for each year in the period 1972-2018) were examined. Each one of them was assumed to be equally likely. The LOLE for each of the historical winter periods was calculated as follows: for winter periods without Cold Snaps, the LOLE was assumed to be zero; for the rest of the winter periods, the LOLE was the sum of the LOLE for each of the Cold Snaps in the winter period. Based on the availability and suitability of resource performance data (for thermal and intermittent resources), Cold Snaps were grouped in two categories: Recent and Old. The modeling of other inputs in the assessment varies depending on this categorization, as described in the subsections below.

Upcoming fuel security assessments will add data from new cold snaps as they occur, and use the same approach to weight the winter load shapes (i.e., equal weight) and to calculate the LOLE of each winter load shape. The underlying assumption for the LOLE calculation is that LOLE during the winter season can only occur under a Cold

[3] https://www.pjm.com/planning/rtep-development/powerflow-cases

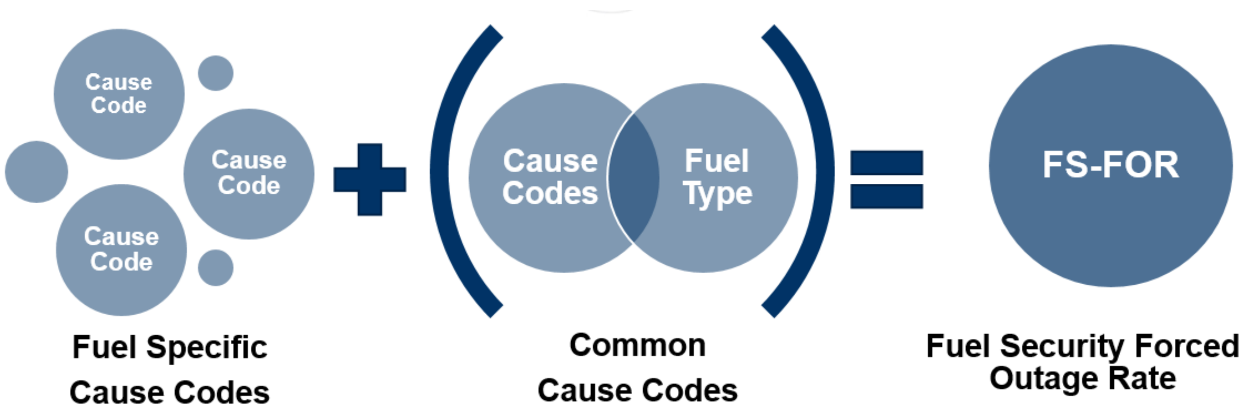
Snap, a weather condition where both, peak demand and the likelihood of fuel security related forced outages, increase. Further details on the procedure to calculate LOLE are documented later in this document.

Fuel Security Forced Outages

The Generating Availability Data System (GADS)[4] is a NERC established data collection system with required data submission for conventional generators 20 MW and greater. Each event is unique and has an event type that describes the outage or derate and a cause code that describes the mechanism triggering the event. Traditionally, GADS data is used to calculate generator forced outage rates. A subset of cause codes identified as related to fuel security risks were selected to calculate more granular Fuel Security Forced Outage Rates (FS-FOR) by fuel type, as shown in the Equation 1 and examples below. These rates will be calculated for coal, natural gas, nuclear, hydro and oil resources.

The GADS cause codes selected for this calculation are shown in **Error! Reference source not found.**~~Table 1~~ in the Appendix. These cause codes will be reviewed annually and updated as needed.

$$(1) \quad \text{FSFOR}_{Fuel\ Type} = \frac{\sum \text{MW Forced Out}_{Fuel\ Specific\ Cause\ Codes} + \sum \text{MW Forced Out}_{Common\ Cause\ Codes}}{\sum \text{Installed Nameplate MW}}$$



To capture the relationship between the amount of Fuel Security Forced Outages and temperature/load during a cold snap, an hourly pattern of FS-FOR at the RTO or zonal level is required. This hourly pattern can then be analyzed in conjunction with the hourly load shapes derived using the historical cold snaps.

The hourly FS-FOR patterns are developed so that are consistent with the hourly load shapes: for recent cold snaps, for which adequate historical GADS data is available, the corresponding historical actual hourly FS-FOR patterns will be used. The patterns are derived by fuel type and represent hourly ICAP unavailability percent values. For old cold snaps, for which adequate historical GADS data is unavailable, the hourly patterns from the recent cold snaps will be used, assigning equal weight to each of them. Daily peaks will be aligned to determine the positioning of the recent FS-FOR hourly patterns relative to the load shapes of the old cold snaps. Data from the recent cold snap will be used

[4] NERC GADS Website: https://www.nerc.com/pa/RAPA/gads/Pages/GeneratingAvailabilityDataSystem-(GADS).aspx

on a rolling basis to fill in any data gaps that may exist (for instance, data gaps can occur if the duration of an old cold snap is greater than the duration of any of the recent cold snaps).

Renewable Capacity Factors

Hourly capacity factors for solar and wind resources will be analyzed to determine how these resources are performing in cold snaps or other events. FS-FOR may be calculated for wind and solar resources in the future as cause codes and related data becomes available for units greater than 20MW.

$$\text{Capacity Factor} = \frac{\text{Actual Hourly Output}}{\text{Total Installed Nameplate}}$$

An approach similar to the one used for FS-FOR will be employed to capture the likely performance of wind and solar resources during cold snaps. Hourly capacity factor (CF) patterns will be developed based on historical actual data from recent cold snaps. Capacity factor is defined as the amount of actual MWs produced by the wind (or solar) fleet divided by the total amount of nameplate wind (or solar) capacity.

The hourly capacity factors are developed so that are consistent with the hourly load shapes and with the same considerations regarding the availability of adequate data described above for the development of FS-FOR hourly patterns.

Random Forced Outage Rates (R-FOR)

In addition to the Fuel Security Forced Outage Rates (FS-FOR), the Random Forced Outage Rates (R-FOR) of units will be modeled in the analysis. R-FOR are analogous to the regular forced outages rates modeled in the Reserve Requirement Study. However, they are not identical because, to avoid double-counting, the R-FOR of each unit is calculated excluding outages associated with cause codes captured by the FS-FOR. The R-FOR are translated into hourly patterns by deriving two metrics, the mean time to failure (MTF) and the mean time to repair (MTR), and performing Monte Carlo analysis (1,000 replications) as described in the following steps:

1. For each thermal unit (and hydro units), it is assumed that there are two states:
   - On (unit is online producing its maximum output)
   - Off (unit is offline, on a forced outage, producing zero output)
2. The time a unit spends in either of the above two states is assumed to be a random variable with an exponential distribution. The cumulative density function (CDF) of the exponential distribution is:

   $$F(x) = 1 - e^{\frac{-x}{\alpha}}$$

   where α is the mean of the distribution (i.e., the mean time a unit is online or the mean time a unit is offline)
3. The mean time a unit is online (or mean time to failure, MTF) and the mean time a unit is offline (or mean time to repair, MTR) are estimated from historical GADS data (the most recent 5-year period, to be consistent with assumptions in the RRS).
4. If a random number R is drawn, then the time-in-state, T, can be computed using the CDF of the exponential distribution

   $$T = -\ln(R) * \alpha$$

5. A series of random numbers are drawn, 1,000 times, to derive 1,000 different online-offline patterns for each unit covering the entire duration of the simulated period.

Application of Generic Disruptions

The cause and potential impact (i.e., generation loss) of a fuel security-related resilience event will be difficult to predict. Therefore, the resource adequacy fuel security assessment will use Generic Disruptions to simulate the impact of such an event. In the 2019 FSSTF analysis, disruptions of size X MW (where X is varied from 0 MW to 10,000 MW) were simulated. The duration of the disruption was assumed to be 5 days. The size and duration of the disruptions are not stochastic (i.e. no probabilities were estimated for size and duration). The timing of the disruption was modeled stochastically by considering all potential overlapping patterns between the disruption and each Cold Snap, with each potential overlapping pattern assumed equally likely.

Conditional LOLE Calculation

The assessment will calculate LOLE conditional on the occurrence of generic disruptions of variable size (and a duration of 5 days). This conditional LOLE calculation must reflect the conditions in all the simulated scenarios. The total number of simulated scenarios is a function of the number of Monte Carlo replications for R-FOR, the number of cold snaps, the duration of each cold snap, and if the cold snap is labeled as recent or old.

For example, the total number of scenarios examined for a cold snap of 10 days under a disruption of 5 days is:

- If the cold snap is one of the four most recent cold snaps: 1,000 (R-FOR) x 1 (FS-FOR and CF) x 14 (Timing of Disruption) = 14,000. There are 14 potential ways in which the 5-day disruption can overlap with the 10-day cold snap. In general, for an N-days cold snap and an X-days disruption, the timing of disruption can occur in N + X – 1 possible ways.
- If the cold snap is one of the older cold snaps: 1,000 (Random FOR) x 4 (FS-FOR and CF) x 14 (Timing of Disruption) = 56,000. As mentioned earlier, because of unavailability of adequate FS-FOR and CF data during old cold snaps, each of the FS-FOR and CF patterns during the 4 recent cold snaps has to be analyzed.

The procedure to aggregate the partial LOLE results yielded by the simulation of each of the cold snaps is as follows:

- Calculate the conditional RTO LOLE (in days per winter) for each of the Cold Snaps under a Disruption of size X MW.
- Aggregate the results by winter
    - If a winter did not have a cold snap, the conditional LOLE for the winter is assumed to be zero
    - If a winter had only one cold snap, the conditional LOLE for the winter is the conditional LOLE of the cold snap

- If a winter had more than one cold snap, the conditional LOLE for the winter is the sum of the conditional LOLE values of the cold snaps

- Calculate the average of the conditional LOLE values corresponding to the winter periods. For instance, in the 2019 FSSTF analysis, a total of 47 conditional LOLE values were averaged (one for each winter in the period 1972-2018)
- Repeat the above steps for disruptions of different size (in the 2019 FSSTF analysis the disruption was varied from 0 MW to 10,000 MW)

Note that the final LOLE value for a given portfolio is conditional on the occurrence of the generic disruption. In other words, the LOLE value does not account for the probability of occurrence of the generic disruption. Also, to calculate the LOLE of the portfolio for the entire delivery year, the conditional LOLE value resulting from this assessment should be adjusted to account for the probability of occurrence of the 5-day generic disruption and then added to the LOLE outside of the winter period. For instance, a portfolio with reserves at the IRM has an LOLE equal to 0.1 days/year from the summer period *plus* the conditional LOLE resulting from this assessment adjusted for the probability of occurrence of the 5-day generic disruption.

Locational Assessment

Locational assessment will be performed on an as-needed basis largely following the same procedure outlined above for the RTO. However, there are some differences. Load and generation performance data (R-FOR, FS-FOR, CF) will be specific to the zone under study. Furthermore, an additional input data is required: the amount of imports from the rest of RTO into the zone under study.

If data for one of the inputs is not available for a specific zone, RTO data will be employed. For instance, if solar hourly capacity factors are not available for a zone (because the zone has not had any solar resources historically), then the RTO solar hourly capacity factor will be employed in the zone's assessment.

Results

The result of the analysis will be presented in tables and graphs for the RTO (and selected zones) illustrating a portfolio's LOLE conditional on the occurrence on a 5-day generic disruption of size X MW coincident with a cold snap.

APPENDIX

Table 1: GADS Cause Codes for Fuel Security-FOR

Cause Code	Fuel Type	Description
9200 & 9201	Coal	High Ash Content (OMC & non-OMC)
9210 & 9211	Coal	Low Grindability (OMC & non-OMC)
9220 & 9221	Coal	High Sulfur Content (OMC & non-OMC)
9230 & 9231	Coal	High Vanadium Content (OMC & non-OMC)
9240 & 9241	Coal	High Sodium Content (OMC & non-OMC)
9250 & 9251	Coal	Low BTU Coal (OMC & non-OMC)
9270 & 9271	Coal	Wet Coal (OMC & non-OMC)
9280 & 9281	Coal	Frozen Coal (OMC & non-OMC)
9130	Coal	Lack of fuel where operators is not in control of contracts, supply lines, or delivery of fuels
9131	Coal	Lack of fuel (interruptible supple of fuel part of fuel contract)
9290 & 9291	Coal	Other Fuel Quality Problems (OMC & non-OMC)
7112 & 3274	Coal	Ice blockages at intake structures
7199	Coal	Other water supply/discharge problems
9135	Coal	Lack of Water
3273	Coal	Debris in circulating water from outside sources
3280	Coal	High Circulating Water Temperature
9000, 9001, 9020, 9025, 9030, 9031, 9035, 9040	Coal	Natural Disasters (Flood, Drought, Lightning, Geomagnetic Disturbance, Earthquake, Tornado, Hurricane, Other Catastrophe)
9134	Coal	Fuel Conservation
9205	Natural Gas	Poor quality natural gas fuel, low heat content
9130	Natural Gas	Lack of fuel where operators is not in control of contracts, supply lines, or delivery of fuels
9131	Natural Gas	Lack of fuel (interruptible supple of fuel part of fuel contract)
9290 & 9291	Natural Gas	Other Fuel Quality Problems (OMC & non-OMC)
7112 & 3274	Natural Gas	Ice blockages at intake structures
7199	Natural Gas	Other water supply/discharge problems
9135	Natural Gas	Lack of Water
3273	Natural Gas	Debris in circulating water from outside sources
3280	Natural Gas	High Circulating Water Temperature
9000, 9001, 9020, 9025, 9030, 9031, 9035, 9040	Natural Gas	Natural Disasters (Flood, Drought, Lightning, Geomagnetic Disturbance, Earthquake, Tornado, Hurricane, Other Catastrophe)
9134	Natural Gas	Fuel Conservation
9500	Nuclear	Regulatory (nuclear) proceedings and hearings – regulatory agency initiated
9502	Nuclear	Regulatory (nuclear) proceedings and hearings – intervener initiated
9710	Nuclear	Investigation of possible nuclear safety problems

2010	Nuclear	Fuel failure, including high activity in Reactor Coolant System or off-gas system
2030	Nuclear	Fuel limits – peaking factors
2032	Nuclear	Fuel limits – minimum critical power ratio (BWR units only)
2033	Nuclear	Fuel limits – maximum average planar linear heat generation rate (BWR units only)
2037	Nuclear	Other fuel limits (excluding core coast down, conservation, or stretch)
9130	Nuclear	Lack of fuel where operators is not in control of contracts, supply lines, or delivery of fuels
9131	Nuclear	Lack of fuel (interruptible supple of fuel part of fuel contract)
9290 & 9291	Nuclear	Other Fuel Quality Problems (OMC & non-OMC)
7112 & 3274	Nuclear	Ice blockages at intake structures
7199	Nuclear	Other water supply/discharge problems
9135	Nuclear	Lack of Water
3273	Nuclear	Debris in circulating water from outside sources
3280	Nuclear	High Circulating Water Temperature
9000, 9001, 9020, 9025, 9030, 9031, 9035, 9040	Nuclear	Natural Disasters (Flood, Drought, Lightning, Geomagnetic Disturbance, Earthquake, Tornado, Hurricane, Other Catastrophe)
9134	Nuclear	Fuel Conservation
7100	Hydro	Upper reservoir dams and dikes
7101	Hydro	Lower reservoir dams and dikes
7102	Hydro	Auxiliary reservoir dams and dikes
7110	Hydro	Intake channel or flume (excluding trash racks)
7111	Hydro	Intake tunnel
9130	Hydro	Lack of fuel where operators is not in control of contracts, supply lines, or delivery of fuels
9131	Hydro	Lack of fuel (interruptible supple of fuel part of fuel contract)
9290 & 9291	Hydro	Other Fuel Quality Problems (OMC & non-OMC)
7112 & 3274	Hydro	Ice blockages at intake structures
7199	Hydro	Other water supply/discharge problems
9135	Hydro	Lack of Water
3273	Hydro	Debris in circulating water from outside sources
3280	Hydro	High Circulating Water Temperature
9000, 9001, 9020, 9025, 9030, 9031, 9035, 9040	Hydro	Natural Disasters (Flood, Drought, Lightning, Geomagnetic Disturbance, Earthquake, Tornado, Hurricane, Other Catastrophe)
9134	Hydro	Fuel Conservation
9260 & 9261	Oil	Low BTU oil (OMC & non-OMC)
9130	Oil	Lack of fuel where operators is not in control of contracts, supply lines, or delivery of fuels
9131	Oil	Lack of fuel (interruptible supple of fuel part of fuel contract)
9290 & 9291	Oil	Other Fuel Quality Problems (OMC & non-OMC)
7112 & 3274	Oil	Ice blockages at intake structures

7199	Oil	Other water supply/discharge problems
9135	Oil	Lack of Water
3273	Oil	Debris in circulating water from outside sources
3280	Oil	High Circulating Water Temperature
9000, 9001, 9020, 9025, 9030, 9031, 9035, 9040	Oil	Natural Disasters (Flood, Drought, Lightning, Geomagnetic Disturbance, Earthquake, Tornado, Hurricane, Other Catastrophe)
9134	Oil	Fuel Conservation