NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

Ensuring Energy Adequacy with Energy-Constrained Resources

December 2020
White Paper

Problem Statement

Unassured fuel supplies,[1] including the timing and inconsistent output from variable renewable energy resources, fuel location, and volatility in forecasted load, can result in insufficient amounts of energy on the system to serve electrical demand and ensure the reliable operation of the bulk power system (BPS) throughout the year.

Background

Electricity is fundamental to the quality of life for nearly 400 million citizens of North America. Electrification continues apace as new applications are developed for use in advanced technologies; for example, advanced computing now permeates every aspect of our economy, and policy makers are seeking to electrify transportation and heating in order to decarbonize the economy. The BPS is undergoing an unprecedented change that requires rethinking the way in which generating capacity, energy supply, and load serving needs are understood.

Historically, analysis of the resource adequacy of the BPS focused on capacity over peak time periods. Assessment of resource adequacy focused on capacity reserve levels compared to peak demand because resources were generally dispatchable and, except for unit outages and de-rates, were available when needed. Reserve margins were planned so that deficiency in capacity to meet daily peak demand (loss of load expectation or loss-of-load probability) occurred no more than one-day-in-ten-years.[2] Reserve margins are calculated from probabilistic analysis using generating unit forced outage rates based on random equipment failures derived from historic performance. The targeted level has historically been one event in ten years, based on daily peaks (rather than hourly energy obligations). Additional insights were traditional gained by also calculating loss-of-load hours and expected unserved energy based on the mean-time to repair unit averages. Review and clarification of such traditional metrics are needed to understand their assumptions and put forward additional meaningful measures that support key aspects of capacity and energy delivery.

Key Assumption

A key assumption in the above analysis has been that fuel is available when capacity is required to provide the requisite energy. This is not surprising as generally fuel availability was assured with either long-term

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[1] Some examples area lack of firm natural gas transportation, pipeline maintenance or disruption, compressor station failures, and emission limitations on fossil fuels. All resources have some degree of fuel uncertainty due to unavailability, including coal (onsite stock-piles can be frozen) and nuclear (during some tidal conditions, affecting cooling intake).

[2] The method determining Planning Reserve Margins was historically based on only one data point (or hour), which is the peak load of the day. The inability to meet this single hour peak was considered an event for one day.

fuel contracts (commodity plus transportation capacity), on-site storage (e.g. oil, coal, and reservoir-based hydro), and/or with required periodic and predictable fuel replacement (e.g. nuclear). With diverse, dispatchable resource technologies, capacity from other technologies could mitigate impacts if fuel for one resource type became unavailable.

Changing Times

However, the era of virtually unlimited fuel is ending. Transitioning from coal and nuclear resources to wind, solar, natural gas (including dual fueled), and hybrid resources creates a more complex scenario; wherein, fuel assurance and forward energy supply planning becomes increasingly important. Generating capacity alone is not sufficient to ensure the reliable operation of the BPS. Policy efforts to increase the contribution of renewable energy has resulted in a higher emphasis on the “on call” availability of capacity to supply energy to serve net demand. Production flexibility from these balancing resources has already become important and will become critically important in the future. Operational uncertainty is increasing due to the types of, and conditions under which, energy, and by implication, fuel, is available or acquired; examples of these uncertainties are resources solely dependent on the availability of wind and solar, which are similar to run-of-river hydro plants in that they have no energy storage capabilities and are completely dependent on real-time weather conditions. These also include distribution level resources and flexible load programs that may introduce additional volatility into energy forecasts.

Layered into operational uncertainty is that some areas natural gas fueled resources may, depending on the contract for fuel acquisition,[3] be subject to fuel curtailment or interruption during peak fuel demands. Additionally, natural gas pipeline design and how generators interconnect with the pipeline can vary; this can result in significantly different impacts to the generator and the BPS under pipeline disruption scenarios. Furthermore, in some areas, variable energy resources require that there are sufficient flexible energy resources available to quickly respond to off-set ramping requirements. In addition, the impacts can be mitigated with the supply and geographical diversity from renewable and smaller distributed resources. However, these uncertainties are already causing many system operators to consider scheduling as well as optimization and commitment of resources over a multi-day timeframe. Replacing the existing generation fleet with energy limited resources require industry to consider both capacity requirements and energy adequacy, and by extension, fuel availability. Even if sufficient capacity is available, a level of certainty in the delivery of fuel is required to ensure that energy is available to support demand.

Furthermore, as demonstrated in California, when solar becomes a significant resource, the flexibility of the natural gas system (generating plant ramping capability plus pipeline flexibility to support needed ramp rates) also becomes a key planning consideration. This issue came into focus with the limitations placed on the Aliso Canyon natural gas storage facility that caused operational challenges to ensure adequate pipeline pressure was available to support the late afternoon ramp. Provision of fuel flexibility will remain a concern as solar generation grows, at least until large scale electric storage or other solutions are available to attenuate the fuel draw requirements to support steep ramp rates.

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[3] Contracts here should be considered in the broadest sense. Namely, beyond just firm/interruptible natural gas, there is the need for logistics of natural gas and fuel oil acquisition, transportation, and delivery in a timely fashion to address emerging and projected energy requirements.

Understanding Energy Adequacy

Understanding energy adequacy, and by extension, fuel availability compared to capacity requires advanced consideration of multiple technologies and concepts; see the following examples:

1. What flexibility is required to balance volatility in resource and load uncertainty through multiple operating horizons and seasons of the year?
2. Should emergency procedures be revised to reflect current fleet structure and operating needs?
3. When and how should demand response be considered when assessing fuel availability and energy adequacy?
4. How should the fuel availability/energy adequacy of battery or long-duration storage be evaluated?
5. Does there need to be common practices on how effective load carrying capability[4] or other useful metrics are determined?
6. Does there need to be common planning practices for how forced outages are incorporated into resource adequacy analysis?
7. How does the availability of the interconnection's import transfer capability factor into the resource adequacy analysis?
8. Are there new tools needed to address not only the traditional capacity adequacy but energy adequacy and meeting reliable operational requirements?
9. Could strategically overbuilding a similar technology (i.e. solar) augmented by either storage or some portion of the firm capacity fleet (albeit operating at low capacity factors only when needed) could provide for a resilient and reliable transition?
10. How should fuel availability through long-term fuel contracts (commodity plus transportation capacity) and on-site storage (e.g. oil, coal, and reservoir-based hydro) be incorporated as part of the analysis, looking at a simultaneous demand on transportation capabilities over an extended period?
11. How should natural gas pipeline disruption scenarios be modeled, realizing that individual pipeline design and generators interconnections vary that result in different impacts to the generator and the BPS?

Three Timeframes

Faced with transformation, planners and system operators should consider energy adequacy requirements that need to be planned and available over three timeframes:

1. **Mid- to Long-Term Planning:** When undertaking mid- to long-term planning for resources to support the system in the 1–5 year timeframe, planners should ensure that sufficient amounts of energy are planned such that sufficient options are available to acquire needed energy to meet demand and

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[4] Effective load carrying capability results in a derating factor that is applied to a facility's maximum output (Pmax) towards its expected capacity value.

flexibility requirements for reliably operating the BPS throughout all seasons of the year. Review of traditional approaches and metrics is required to put forward advances needed to support energy sufficiency; this includes considering fuel contract types, dual-fuel requirements, hybrid resource requirements, projected emission limitations, early unit retirements, forced outage uncertainty, and scenario analysis of wind, solar, and water droughts, etc. under normal and N-1 scenarios.

2. **Operational Planning:** When evaluating the operational planning timeframe (1 day to 1 year), system operators should ensure that sufficient units are available with the ability to provide the needed energy both to meet demand and off-set potential ramping requirements. Electrical energy production measurements need to reflect contracts in place, dual-fuel available, unit maintenance, and fuel (e.g. liquefied natural gas) levels as well as barge and other transportation requirements for short-term turnaround to re-supply. Fuel assurance should insure that energy is available for defined scenarios. The operational planning timeframe includes forecasting of variable renewable resources, the forward scheduling, optimization, and commitment of power system resources to produce the needed energy to meet forecasted demand, which in turn leads to the scheduling, optimization, and commitment of the required fuel availability.
3. **Operations:** When evaluating the operations timeframe (0–1 day), system operators should provide situational awareness of energy adequacy to ensure sufficient amounts of energy and ramp flexibility are available from existing resources given contract status, start-up time, unit maintenance, dual fuel availability, etc. and are scheduled to be on-line to cover potential system contingencies, including ramping requirements while meeting real-time demand.

Standard Requirement

One common underlying risk is the increased use of just-in-time delivery of fuel. More specifically, challenges are mounting from the single points of failure caused by the penetration of wind, solar, and natural gas with increased uncertainties due to unexpected interruptions of fuel delivery. This could be a result of the sun not shining or blocked by snow and ice, the wind not blowing (or blowing too much, or extremely cold or hot), and natural gas becoming unavailable (due to contract type, equipment failure, or pipeline maintenance or failure). A NERC reliability guideline[5] was recently drafted on fuel assurance and fuel-related reliability risk analysis. The philosophy set forth in this white paper is to begin considering design basis and potentially strengthening the Reliability Standards.

Energy security, and by extension fuel security, risks are increasingly becoming more apparent as extreme weather has resulted in deficits in energy (rather than capacity); for example, in January 2019, temperature dipped below design basis for wind turbines, resulting in the need for quick action by the Reliability Coordinators, Transmission Operator, and Balancing Authorities. Similarly, a 2019 report[6] by FERC and NERC staff on the event of January 17, 2019, when cold weather resulted in a number of natural-gas-fired units to become unavailable that resulted again in energy deficits and the requirement of quick action to meet energy needs. As recommended in the FERC and NERC Staff report, a Standard Authorization Request that recommended writing a standard that is being reviewed with industry, and is expected to be in effect prior

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[5] reliability guideline
[6] 2019 report

to the winter of 2021-2022, that sets out to improve the ability to provide energy is communicated by Generator Operators to the Reliability Coordinator, Transmission Operator, and Balancing Authority during winter timeframes when local forecasted cold weather conditions are expected to limit BPS generator unit performance or availability.

High impact points of failure require study by industry towards understanding impacts and putting in place plans to address them. Namely, enhancement to existing NERC Reliability Standards (i.e., Transmission System Planning Performance Requirements – TPL-001-4[7]) is needed to require the relevant entities to address the critical risks to reliability for planned and extreme events design basis; for example, study of the loss of a large natural gas pipeline is already called for extreme event(s) in the transmission planning Reliability Standard TPL-001-4, but more scenarios for planning and extreme events are needed to represent common modes of failure, such as the loss of solar, wind, water, and natural gas (e.g. not just the total loss of a pipeline but partial loss of natural gas availability) resources for suitable periods of time (e.g. energy deficiency scenarios), towards understanding their impacts on the reliable operation of the BPS. This would be demonstrated by entities performing assessments ensuring that they understand the risks. Furthermore, corrective action plans should be in place to mitigate impacts from agreed upon planned event design basis and an evaluation of possible actions designed to reduce the likelihood or mitigate the consequences and adverse impacts from agreed upon extreme event(s).

The scenarios belonging in planned events versus extreme events require the development of an agreed upon design basis identifying what risks/impacts are acceptable and which are not and require mitigation. The resulting Reliability Standard should provide certainty of risk mitigation and expected reliability performance across industry when the system is planned and would be a companion to the operational Reliability Standard mentioned above that is currently being considered by industry. Rather than a burden, these enhancements would provide certainty of risk mitigation between organizations and throughout the interconnections, thereby, ensuring that an Adequate Level of Reliability[8] for the BPS is maintained.

Analysis Requirements[9]

The ability to model and address fuel limitations or shortages in BPS planning is a critical part of system planning and operations. Therefore, there is a need for improved models as well as required data and information to support this planning to ensure the continued reliable operation of the BPS. The following considerations may be taken in the performance of analysis:

- **Identify Energy Limitations and Constraints:**

  Every generator has some level of energy limitation:
  - Solar resources are limited by the availability of the sun's irradiance.

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[7] TPL-001-4

[8] Adequate Level of Reliability

[9] NERC currently has an in-house project to complete a composite reliability study (assessment) of two Planning Coordinator footprints that aims to incorporate the requirements detailed in this section. This pilot project will use NERC staff and existing tools to achieve a probabilistic, rather than a deterministic, assessment to assess adequacy of deliverable resource energy. The pilot should identify specific input data needed for similar industry studies.

  - Hydro-resources are limited by the amount of water stored behind dams or run-of-river capacity.
  - Natural gas resources are limited by the transport capability of the pipeline system under normal and outage conditions as well as response capability.
  - Dual fuel resources are limited by the amount of on-site back-up fuel plus replenishment capability.
  - Coal resources are limited by frozen or wet coal.

  All resources are limited by forced outages (and partial outages) due to thermal stresses, equipment failure, and, in some cases, emission allowances and discharge water temperature values. For example, all fossil-fire resources may experience energy limitations due to emission limitations which are expected to increase over time. In addition, energy limitations can also be caused by transmission maintenance that limits energy delivery. To further complicate analyses, market rules are in place to reserve limited-energy resources for a later time, optimizing the overall solution.

- **Identify the Tools and Methods Needed**: For the planning, operational planning, and operations time horizons, tools and methods are needed that can identify the right mix of resources to ensure that sufficient amounts of energy are available to serve demand and meet ramping requirements at all times as well as ensure that the required energy can be delivered from the source to the end user. In addition, in organized markets, market-based incentives or rules, tariff changes, and other market tools need to be investigated; for example, some jurisdictions have evolved to performing 8,760 stochastic simulations to assess hourly levels risk. In addition, some jurisdictions also have established locational, flexible, capability, and performance requirements into their resource adequacy programs. Reviewing existing tools and methods already developed, identifying any gaps, and providing guidance in these will support creation of systems that will have sufficient amounts of energy for the reliable operation of the BPS.

- **Conduct Loss-of-Load Assessment:** The system must be planned (in both the Mid-to Long-Term and Operations Planning timeframes) to provide a set of options to the operator so sufficient amounts of energy are available for the reliable operation of the BPS throughout all seasons of the year. Energy limitations need to be incorporated into the electric power resource adequacy models to more accurately estimate the key adequacy metrics, such as loss-of-load expectation, loss-of-load hours, and expected unserved energy. As the applications of electricity grows in North America, the value of lost load will further increase and, as result, the value of energy assurance to serve load will also grow in importance. Furthermore, as micro-grid developments increase, assessment of contributions to reliability and consequences on energy adequacy need to be more fully understood. An important feature of integrating these suggested analyses with existing tools is the ability to incorporate operational solutions into the planning models. For example incorporation of demand response, voltage reduction, and public appeals would be valuable. By recognizing cross-energy sector study results from the energy limitations, such as fuel or pipeline infrastructure limitations into probability-based resource adequacy models, an accurate representation of risk can be quantified and then translated into risk-based planning solutions. Cross-energy sector studies should include agreed upon study criteria between the sectors on what it means to be reliable and what are the implications on resilience.[10] This is important as one sector may have a view of reliability that does not translate into other dependent sectors; for example, should sustaining the loss of a large natural gas storage field be considered a credible event impacting reliability that should be addressed by both the natural gas and electric sectors? Additionally, agreed upon contingencies impacting fuel transportation or severe weather event scenarios that impact multiple energy sectors require agreement. This analysis can be used for all time frames, incorporating more granular information as the system approaches the operations timeframe.

Appropriate reliability metrics and criteria for the **Three Timeframes** must be developed as the degree of uncertainty in the assumptions varies across each of them. Study is needed to determine if the same or different metrics are needed when the three timeframe assumptions have varying risk profiles.

Next Steps

Advancing these concepts with industry requires discussions with appropriate NERC technical committees. This document should be forwarded to these committees for their consideration and incorporation into their work plans. In addition, the following actions should be initiated:

- Coordinate developments of energy assurance activities with industry working groups
- Subject matter experts should be assembled (e.g. task forces, working groups) to develop the following:
  - The technical foundation for the three timeframes
  - Ways to identify the levels of energy that are required to meet the operational needs
  - The tool and data specifications needed to incorporate energy considerations into planning, operational planning, and operations assessments
- Engage industry research and development organizations (e.g., The Electric Power Research Institute, The United States Department of Energy, Natural Resources Canada, national laboratories) to validate the technical foundation(s) and development of the tool(s) and methods
- Coordinate studies and plans with adjacent Balancing Authorities to identify enhanced collaborative regional support
- Evaluate the need for a Standard Authorization Request to enhance existing or create new Reliability Standards to address fuel assurance and resulting energy limitations for the planning timeframe

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[10] See the Reliability Issues Steering Committee's Report on Resilience.