Natural gas fuel starvation at large power plants in the U.S. and the effect of gas transportation arrangements on reliability

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Overview

In 2018, Murphy et al. [1] showed that the long-time assumption of resource adequacy planners that power plants fail independently has been historically violated. But, their paper does not investigate the causes of these violations of independence. In this paper, we examine one reason for the violation of independence: the natural gas pipeline network that moves fuel to a large portion of the U.S. power plant fleet.

Across the North American Electric Reliability Corporation (NERC) footprint, on-peak generation by natural gas units has increased from 360 GW in 2009 to 432 GW today. NERC projects further additions of natural gas generating capacity of 45 GW over the next decade [2]. The number of outages at these gas units due to lack-of-fuel from gas pipelines increased from 419 in 2012/13 to over 1,700 in 2014/15 and remained above 1,000 for the following two years before falling to 622 in 2017/18. The number of hours per year with at least one lack-of-fuel outage at a gas power plant similarly increased from 1,900 in 2012 to almost 8,000 in 2016 before falling to 4,200 in 2017.

Here, we examine the statistics of these lack-of-fuel failures at gas-fired power plants to further our understanding of the operational interdependence of the gas and electricity grids. Our primary goal is to identify how many of these "fuel-starvation" failures at gas power plants were caused by physical interruptions of the gas flow on pipelines as opposed to operational procedures on the pipeline network, such as gas service curtailment priority.

We observe that failures on a single pipeline serving multiple generating units have affected even those with firm pipeline contracts. But, pipeline incident data only explain a small fraction of these power plant failures and have been observed throughout the whole year.

The research for Murphy et al. [3] shows that temperature can drive failures at natural gas power plants – offering another potential explanation of independence violations. In the data used for our research, more than 70% of lack-of-fuel failures at gas-fired power plants occurred between October and March. This paper extends previous work by determining how much of the temperature-failure relationship is due to cold weather performance issues of gas generating equipment at plants versus pipeline curtailment priority created by increased demand for gas from pipelines.

The overarching, policy-motivated research question for this paper is: "Does increased firm pipeline service increase generator availability/performance? And if so, does it make sense for every generator to hold a firm pipeline contract?"

Methods

We simultaneously analyze power plant failure information collected as part of the North American Electric Reliability Corporation (NERC) Generating Availability Data System (GADS), power generator characteristics from the U.S. Energy Information Administration (EIA) and fuel receipt and contract information from both the EIA and the Federal Energy Regulatory Commission for the period January 2012 to December 2017. We use a matching process with the NERC and EIA data to identify the pipeline that fuelled the power plants and the plants' fuel supply contract statuses at the times of their reported lack-of-fuel failures.

Next, we use publicly-available pipeline failure data to investigate whether there is evidence that pipeline incidents resulting in gas flow interruptions caused any of the fuel-starvation failures at natural gas power plants. As we find that pipeline incidents only account for a small fraction of power plant failure events, we examine whether pipeline curtailment priority processes drive these fuel unavailability events.

Following [3], which found increased unavailability on gas power plants using logistic regression on power plant failure data, we next determine the magnitude of this relationship that may be attributed to fuel unavailability events. Finally, we define each generating unit's mean time between lack-of-fuel failures and use statistical tests to explore whether pipeline transportation contract status significantly affected gas power plant reliability.

Results

We find that lack-of-fuel failures occurred at approximately 27% of U.S. natural gas power plants with generating units of nameplate capacity of 20 MW or more between January 2012 and the end of December 2017. The maximum, simultaneous capacity affected by fuel interruption of plants served by a single pipeline network exceeded 1,000 MW in six of the eight NERC regions.

We find that events that shut down gas flow on the pipeline network only explained approximately 3% of these fuel-starvation failures at gas power plants. We are currently underway with the analysis of how much fuel-related power plant unavailability in a sample eastern RTO is due to service interruption to pipeline shippers as a part of curtailment procedures when cold weather increases the demand for gas.

Firm gas transportation contracts significantly increased the mean times between fuel-related failures of gas generating units but did not prevent fuel-related failures.

Conclusions/policy implications

These results provide an important insight into whether policy measures designed to promote the adoption of firm pipeline contracts can be a successful measure to increase electric grid reliability. The ability of firm pipeline contracts to increase reliability at gas power plants will likely depend on the makeup of the customers on the pipeline network in the region. If the pipeline network's capacity surrounding the plant is heavily owned by gas utilities with residential customers, it may not make sense to pay for a firm contract because it would not buy a spot much later in the curtailment order. On the other hand, if the pipeline capacity near the plant does not mostly belong to gas utilities, it may be worthwhile for RTOs to promote firm pipeline contract adoption in those areas. Identifying areas of the pipeline network where firm contracts should be promoted is an area for future research.

References

[1] S. Murphy, J. Apt, J. Moura and F. Sowell, Resource adequacy risks to the bulk power system in North America. Applied Energy, vol. 212, 2018.
[2] North American Electric Reliability Corporation, 2017 Long-Term Reliability Assessment.
[3] S. Murphy, J. Apt, and F. Sowell, A model of correlated power plant failures and recoveries. (Working paper)