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Enhancing electric reliability with storage-field generators[☆]

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ABSTRACT

The U.S. natural gas industry has experienced two significant changes recently. First, consumption has increased since 1995, as electric utilities substitute gas for coal. Since electricity use is summer peaking, this new consumption smooths demand over the year. Second, the shale gas revolution has increased production and storage since 2005. This decreased prices, encouraging the coal-to-gas substitution. Frictions between the gas and electricity industries have, however, decreased electric reliability. Just as locating generators at coal mines decreases the cost of transporting coal, locating gas generators at storage sites increases reliability by decreasing these frictions. But because the increased reliability is external, and thus ignored by generators and infrastructure providers, FERC must provide incentives to coordinate investment in generation and storage to realize these gains.

1. Introduction

The Federal Energy Regulatory Commission (FERC) regulates the interstate transmission of natural gas in the U.S. It introduced important restructuring with Order Nos. 436 (FERC, 1985) and 500 (FERC, 1987), which decoupled storage from pipeline transportation, and with Order No. 636 (FERC, 1992), which instituted open access for pipelines. Joskow (2013) reviews problems caused by regulation that spurred these regulatory developments. This restructuring set the stage for significant industry changes.

Historically, natural gas production was fairly stable over time, with storage injections and withdrawals accommodating seasonal demand swings. This allowed for smaller scale production and distribution with higher utilization rates than are possible without storage. Two recent developments, however, are disrupting this seasonal pattern: the electric utility substitution of natural gas for coal and the growth of shale gas production.

Increasingly stringent EPA emissions rules are leading electric utilities to substitute natural gas for coal, which have cleaner emissions than coal units. The EPA mandated decreases in various emissions with its Clean Air Act (EPA, 1970). The Clean Air Interstate Rule (EPA, 2005) decreased in SO_2 and NO_X emissions for large fossil fuel generators in eastern states (EIA, 2014b). This rule was replaced with the more stringent Cross-State Air Pollution Rule (EPA, 2015). The Mercury and Air Toxics Standards (EPA, 2011) decreased mercury and other emissions of large coal generators.

These rules increase fixed and marginal costs, as the required scrubbers and other hardware reduce efficiency. This pressures utilities to retire coal generators (American Public Power Association (APPA), 2010).[1] While nuclear generators are not affected by these rules, they too are pressured into early retirement but for different reasons. Between 2006 and 2016, fifty nuclear power operating licenses have expired. Many licenses are not extended for political and environmental reasons (for example, see Rothwell, 2000; Lacey, 2015; Overton, 2015; Follett, 2016). Most of the coal and nuclear generators are being replaced with gas-fired generators and renewables (EIA, 2014a).

The shale gas revolution, almost symbiotically, has dramatically increased production and storage since 2005. This decreased natural gas prices, further encouraging coal-to-gas conversions. It has had an additional effect by impacting the price of the marginal fuel. The coal-to-gas conversion was not initially disruptive of the electricity market, as the high marginal cost gas units set peak prices based on high gas prices (*Id.*). But the subsequent drop in natural gas prices led to a drop in electricity prices. Hence, utilities that had been facing increasing costs were also then facing decreasing revenues, encouraging additional retirements (*Id.*).

Growing electric utility dependence on natural gas decreases reliability. Operational problems arise from trading day differences for

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[1] For a contrary opinion regarding the importance of EPA rules, see Culver and Hong (2016).

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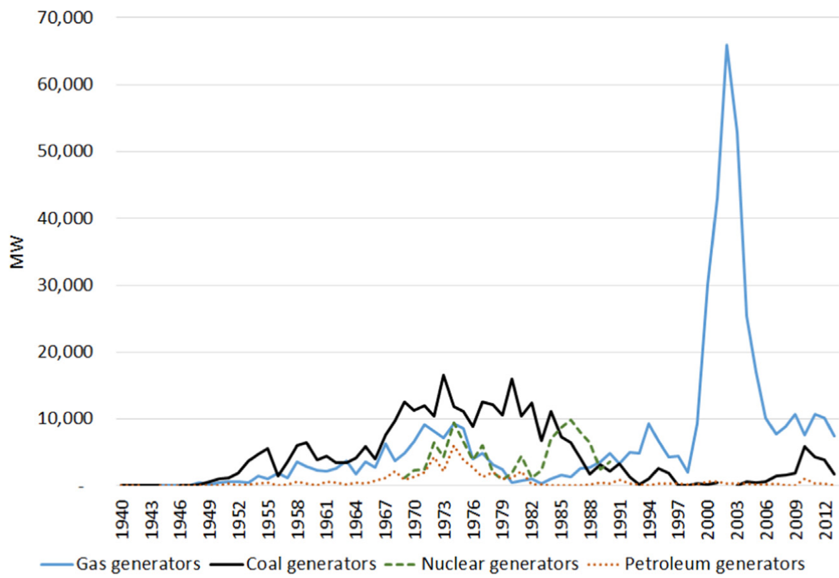

Fig. 1. Electric Generation Capacity Additions, by Fuel: 1940–2013.
Source: EIA, Annual Generator Report 2013 (http://www.eia.gov/electricity/data/eia860/index.html).

electricity and natural gas, use of non-firm gas transportation to support firm electricity sales, and increased reliance on non-dispatchable renewables. Structural problems arise from the timing of the new electric utility demand versus Local Distribution Company (LDC) demand for natural gas, when the new demand competes with LDC demand during peak periods.

We explore how natural gas storage can enhance reliability if gas generators locate so that they have direct access to storage, an updated version of Joskow's (1985) and Kerkvliet's (1991) mine-mouth generators. Much of the friction between the industries that decreases reliability is then eliminated. This coordination requires FERC's involvement, however, as the cost to be economized on is an external reliability cost, and thus ignored by generators and other infrastructure providers. The analysis results in a policy recommendation for FERC to enhance reliability through coordinated investment in generation at storage sites, and in supporting infrastructure.

Sections 2 and 3 discuss the significant changes affecting the natural gas industry and the resulting reliability problems. Section 4 proposes that FERC encourage gas generators to locate at storage facilities to enhance reliability. Section 5 concludes.

2. The changing natural gas industry

2.1. The coal-to-gas conversion

Tightening EPA emission rules are creating turnover in the electric utility industry. Fig. 1 shows annual investment in generator capacity by fuel. Investment in coal capacity increased from the 1940s until the mid-1970s, decreased in the 1980s, and virtually disappeared by the early 2000s as the EPA's rules took effect. It subsequently recovered somewhat with higher gas prices. Investment in nuclear capacity spiked in the mid-1970s and mid-1980s, with little investment otherwise. Investment in petroleum capacity also spiked in the mid-1970s, also with little investment otherwise. Investment in natural gas capacity, in contrast, increased dramatically in the early 2000s, exceeding 60,000 MW in 2002. This greatly exceeds the annual investment for any other type of fuel over this period.

Fig. 1 implies that roughly half of the coal and nuclear capacity was built before 1980. Older generators tend to be smaller, and thus less economic to retrofit: only eight of over three hundred plants retired in 2015 were over 500 MW (EIA, 2016a). If all coal-fired generators built before 1980 and under 500 MW are retired by 2040, capacity would fall by about 215 GW. Similarly, if all nuclear generators built before 1980 are also retired by 2040, capacity would fall by about 46 GW. The potential conversion to gas-based generation over the next two decades is thus significant. If most of these old coal and nuclear generators are retired and replaced with natural gas generators, as seems likely, natural gas might account for 50% of electricity generation by 2040. This exceeds the 31% share suggested in the reference case of the Annual Energy Outlook 2015 (EIA, 2015a).

Fig. 2 shows the impact of the growing electric utility demand for natural gas on the industry. Consumption by residential and commercial customers grew rapidly in the 1950s and 1960s, and then leveled off. Industrial use decreased during the mid-1990s until the mid-2000s, after which it steadily increased.[2] Electric utility use began its dramatic increase in 1995, and now approximately equals residential plus commercial use.

One important feature of electric utility consumption of natural gas is its timing. Unlike gas used for winter heating, gas used for generation is summer peaking, with air conditioning demand. Fig. 3 shows natural gas use for electricity, total use, and production, for 2001–15. In general, peak demand has been increasing, from about 700 to 1,000 Bcf. Minimum demand has also been increasing, from about 300 to 600 Bcf.

A second important feature of electric utility consumption of natural gas is its relative size. Natural gas demand peaks in the winter, with heating demand. The seasonal minimum and maximum values exhibit a modest upward trend, with fairly stable differences. Gas production, in contrast, is fairly stable during the year. Since 2005, production increased from approximately the minimum to the average consumption over the year. This is due to the shale gas boom, which is displacing other domestic sources and imports. While the growing summer peaks of electric utility gas consumption offset the traditional winter peaks, and so help smooth consumption, the winter peaks dominate. The average peak-trough differential for electricity use, though, is about 400 Bcf/month, about 30% of the total consumption differential.

2.2. The shale gas revolution

The second significant event impacting the industry is the shale gas

[2] Prior to 1996, agricultural use was classified as commercial. Subsequently, it is classified as industrial. See http://www.eia.gov/dnav/ng/ng_cons_acct_dcu_nus_a.htm.