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The economics of distributed power: A Marcellus Shale case study

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ABSTRACT

We study the economics of a small natural gas powered electricity generation unit that is part of a distributed power system and is also located near a gas well, while supplying electricity to local dedicated customers. Beyond the environmental and social benefits from localizing production and usage, economic benefits accrue to (1) the gas producer, from selling close to the source and saving costs associated with gas transportation, (2) the electricity producer, from cheaper fuel and higher margins in the electricity they sell behind the meter, and (3) to the final consumer, in the form of electricity prices that are lower than the retail grid price, with little or no distribution costs. We study this arrangement using an actual distributed power generation unit along with demand and cost data from an actual potential customer, in order to estimate overall supply chain savings that could be shared between the various entities.

1. Introduction

This study evaluates the potential benefits of distributed power generation, fueled by natural gas extracted from deposits such as the Marcellus Shale. With this approach an electricity generating company in the midstream portion of the natural gas supply chain would use a series of small, natural gas based power generation units to profitably supply electric power (up to 20 MW, say) to satisfy demand from one or more dedicated local customers, with any excess production being put back into the traditional electric grid. In contrast to a centralized power generation scheme where one large generator provides power to many geographically dispersed customers over the grid, our system is similar to a microgrid, and we look in particular at one that is fueled by locally available natural gas and has dedicated full-time local customers.

1.1. Motivation

Our study is motivated by several factors related to the rapidly evolving energy sector within the United States. First, there has been a strong push in the last few years towards a reduction in the power generated from traditional coal-fired plants because of their negative impact on the environment. Second, while there has been a concerted effort to increase the development of renewable energy sources like solar and wind as alternatives, along with a focus on energy storage, the consensus is that we are still several decades removed from the point where these can effectively replace fossil fuels. Third, there has been a boom in natural gas production due to the large-scale commercialization of new methodologies such as horizontal drilling and hydro-fracturing, and natural gas, while not a renewable source, nevertheless produces pollutants at a far lower scale than coal when used as a source of electric power. Finally, with deregulation there has been a renewed emphasis on distributed energy production where a single large source is replaced with multiple smaller sources that can meet local needs much more cost-effectively.

Motivated by the above factors this study examines the economic feasibility of using a small power generation unit that can be set up very quickly and is powered by locally available natural gas to deliver distributed power locally. Such distributed systems have the potential to reduce dependence on environmentally unfriendly coal based power, reduce transportation costs and losses associated with natural gas, reduce the cost of electricity for local customers, and improve the resilience of the grid. We develop an economic model for evaluating costs and benefits over a twenty year lifespan for a small gas-powered plant and also study the sensitivity of the results to variations in costs. The study makes use of electricity consumption data from an actual potential customer and generation data from an actual distributed producer.

1.2. Description of the ecosystem considered

Some defining characteristics of the distributed power generation scheme we study are: (1) a small, gas-fueled power generation facility that is close to the natural gas source and that can be built rapidly with standardized components at relatively low cost; (2) dedicated end user

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(s) or customer(s) with relatively large electricity requirements (e.g., airports, malls, hospitals, industrial parks) that are located close to the power generation facility, and whose electricity needs can be met by the facility; (3) distribution of electricity generated by the facility through a small-scale transmission/distribution system that is independent of (but connected to) the main electricity distribution grid (i.e., electricity is sold behind the meter, or possibly distributed to the purchasing customer through the existing grid, typically though a power purchase agreement (PPA) or other contractual mechanism); and (4) any additional electricity produced beyond the amount demanded by the dedicated customer(s) being supplied directly into the main distribution grid. These characteristics represent significant differences in the value chain of a *distributed power producer* (DPP) from that of a traditional power producer, and could result in significant economic benefits for all three parties in the chain: the gas supplier, the electricity generator, and the end customer. Gas companies could receive a higher profit for gas extracted and sold to the DPP because of reduced transportation costs and pipeline losses. The DPP could benefit from lower gas (fuel) prices and higher revenues from electricity that is priced higher than the wholesale prices charged when selling to the grid. Power customers could potentially purchase power at off-grid prices that are lower than retail and pay nothing (or substantially reduced amounts) for distribution. In addition, there are potential benefits to other parties as well. Communities where the gas source and power generation company are co-located could see benefits such as local use of natural gas, job creation, reduced regional electricity prices and the concurrent economic advantages, as well as other benefits like a reduced carbon footprint from electricity consumed, lower emissions, and more energy security.

1.3. Contributions

The feasibility of the business case for the solution described earlier hinges on several key challenges. The main one is identifying the efficiencies along the distributed power supply chain and the benefits to the community. Economic models and forecasts based on these efficiencies are critical for a DPP to choose suppliers and customers and to develop appropriate pricing structures and contracts that would result in the net increase in the power supply chain value being shared among the three parties in this value chain (the shale gas producer, the DPP, and the electricity customer). The overall value proposition has to be one where all three parties realize economic benefits; otherwise this model would be infeasible. To our knowledge this issue has never been studied before in the research literature. This paper provides a methodology to quantify the benefits of the business case while using real-world data from an actual distributed power producer and a real potential customer. In addition to providing an economic basis for decision making, using our approach will allow companies to better articulate the benefits to local or state governments and to their customers, and develop strategies for the future of the natural gas industry.

2. Literature review

While there is nothing in the research literature that addresses the exact problem that we study, we present here an overview of the literature relevant to the items discussed in Section 1.1.

The Marcellus Shale formation is a 95,000 square mile geologic formation running roughly southwest to northeast from West Virginia and Eastern Ohio through most of Pennsylvania and into New York. Due to the somewhat porous nature of the formation, a significant amount of natural gas is trapped within it. Hydraulic fracturing is required to encourage flow of the gas toward the surface because of the depth at which the shale formation is located. Average natural gas production in the Marcellus Shale region has increased rapidly from under 2 billion cubic feet per day in 2009 to over 18 billion per day in 2016 (EIA, 2016a), although recently, there has been a slow-down because of the glut in gas and the concurrent lower market prices. The impact of Marcellus Shale production has been tremendous. Studies have documented its positive economic effect on employment, wages, and local business activity (e.g., Cosgrove, 2015; Kelsey & Hardy, 2015; Kinnaman, 2011; Ladlee & Jacquet, 2011; Paredes, Komarek, & Loveridge, 2015), and also its other indirect economic and social impacts on regions experiencing natural gas extraction from the Marcellus Shale (Ramsaran & Rousu, 2016; Schafft & Biddle, 2014; Wang & Stares, 2015).

In addition to the economic impact, natural gas is also a significant "bridge" fuel source. It has a big environmental advantage when compared to different fossils when it comes to electricity generation. Natural gas produces only about half of the Carbon Dioxide, less than 30% of the Nitrogen Oxides and under 1% of the Sulfur Dioxides compared to coal (EPA, 2012). While gas is of course, not comparable to renewable sources like wind, solar and hydro based power in this regard, it should be kept in mind that the latter technologies are not at the point where they can effectively replace fossil fuels. Moreover these renewables also come with their own set of problems. For example, studies have shown that wind turbines create a significant amount of noise emissions, have a significant surface footprint and visual impact and can threaten migration routes for birds (Chourpouliadisa, Ioannoua, Korasb, & Kalfasa, 2012; Kaldellis, Garakis, & Kapsali, 2012). Hydroelectric power station could potentially cause extensive loss of land and geodiversity (Rodrigues & Silva, 2012), serious impact on the ecosystem (Sá-Oliveira, Hawes, Isaac-Nahum, & Peres, 2015) and water siltation and downstream flow shortage (Poleto, 2012). Large scale solar power requires large land areas to produce sufficient electricity, and both solar, wind and hydroelectric power are highly location and climate dependent. Similarly, nuclear power plants have high capital costs and still lack a sustainable and efficient solution to waste disposal (Babu, 2017; Dawson & Darst, 2006; Schaffer, 2011).

In contrast to conventional power systems where a large generation unit is typically centralized and requires transmission of electricity over long distances to end users through a transmission grid, a distributed power grid is a more flexible, decentralized system. The generation unit is located close to the demand it services, and normally processes a relatively small capacity (say, 20 megawatts (MW) or even less). Several studies have noted that such a system has the potential to be a significant player in the energy market of the future, as it can greatly reduce transmission costs and waste, while increasing grid resilience and helping restore the transmission system rapidly in the event of disruption (Blaabjerg, Yang, Yang, & Wang, 2017; Hirase, Sugimoto, Sakimoto, & Ise, 2016; Liu et al., 2017; Panteli & Mancarella, 2015).

3. Natural gas and its distribution chain

In this section we overview typical usage of natural gas in the U.S. and the components of its distribution chain

3.1. Current typical use

In 2015, a total of 1,068,687 MMcf of natural gas were delivered to consumers in Pennsylvania. Major customers and the corresponding gas usage may be classified as follows:

(1) Electric Power: Gas used as fuel in the electric power sector
(2) Residential: Gas used in private dwellings for household uses such as heating, air-conditioning, cooking, etc
(3) Industrial: Gas used directly by the industrial sector, and by generators that produce electricity and/or useful thermal output to support industrial activities
(4) Commercial: Gas used by the nonmanufacturing sector engaged in the sale of goods or services, e.g., hotels/restaurants, wholesale/retail stores, etc., as well as gas used by local, state, and federal