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Distributed generation: An empirical analysis of primary motivators

Sanya Carley *

Department of Public Policy and Center for Sustainable Energy, Environment, and Economic Development, University of North Carolina at Chapel Hill, CB#3435, Chapel Hill, NC 27599, USA

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ABSTRACT

What was once an industry dominated by centralized fossil-fuel power plants, the electricity industry in the United States is now evolving into a more decentralized and deregulated entity. While the future scope and scale of the industry is not yet apparent, recent trends indicate that distributed generation electricity applications may play an important role in this transformation. This paper examines which types of utilities are more likely to adopt distributed generation systems and, additionally, which factors motivate decisions of adoption and system capacity size. Results of a standard two-part model reveal that private utilities are significantly more inclined to adopt distributed generation than cooperatives and other types of public utilities. We also find evidence that interconnection standards and renewable portfolio standards effectively encourage consumer-owned distributed generation, while market forces associated with greater market competition encourage utility-owned distributed generation. Net metering programs are also found to have a significant marginal effect on distributed generation adoption and deployment.

1. Introduction

Dating back to Edison and his close successors, the scale of electricity operations in the United States over the past century has steadily risen. Whereas the US first deployed dispersed generation units in the late 19th century, it eventually built larger, centralized generation units in conjunction with AC generation and a more dynamic and extensive transmission and distribution infrastructure (Patterson, 1999). Exploiting economies of scale, these developments enabled power producers to spread higher voltages across great distances. By the 1920s and 1930s, centralized electricity operations became the predominant scale of electricity production; electricity became the biggest industry in the US economy, while federal support for the deployment of electricity operations grew at an unprecedented level.

While centralized electricity and large-scale transmission and distribution networks still dominate the industry, this model of electricity generation has been challenged in recent decades. Critics of large-scale electricity operations question their costs, security vulnerabilities, environmental impacts, and waste in generation and transmission, and advocate instead for a more decentralized industry composed of a greater number of smaller-scale and more localized generating facilities. In view of these concerns, some industry leaders have begun to modify the scale of their electricity operations. Federal and state policymakers have concurrently enacted legislation that specifically focuses on size and alternative forms of power generation.

The present study aims to empirically identify the motivating factors behind the trend toward a more decentralized electricity industry. Specifically, this analysis considers which factors lead an electric utility or a utility's customer to deploy distributed generation (DG) systems. Consistent with this objective, the following research question guides this analysis: do some ownership models demonstrate a greater proclivity toward DG deployment than others and, if so, which factors motivate these trends?

2. Distributed generation: moving beyond a definition

Distributed generation is the subject of a rapidly evolving body of research. Over the past decade much attention has been devoted to the definition (Ackermann et al., 2001; El-Khattam and Salama, 2004; King, 2006; Pepermans et al., 2005) and classification (Gumerman et al., 2003; Lopes et al., 2007; Pepermans et al., 2005) of DG systems. The following is the author's own working definition of distributed generation systems, classified according to defining characteristics that include size, location, and application.

2.1. Location

DG systems are frequently built close to the power load to minimize electricity losses and inefficiencies. DG units are either

* 919 265 4651.
E-mail address: scarley@email.unc.edu

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connected to the electricity network (hereafter referred to as the "grid") on the customer side of the meter or at the distribution network. Traditionally, either utilities own and operate their own DG systems or their customers own the systems and "borrow" or "lend" power to the electricity grid when needed. Net metering policies and programs – the former is mandated by the state or federal government and the latter is self-initiated by specific utilities – allow commercial, industrial, and residential customers to "hook" their DG units or other micro-generation units to the grid. Under a traditional net metering framework, customers are able to buy (or "sell") electricity from (to) the grid when the DG capacity is short (in excess) of the customers' electricity needs.

2.2. Size

DG systems generally produce between 1 kW and 5 MW of power. Medium to large DG systems can produce over 5 MW and up to 300 MW of power, though there is some dispute over whether these larger systems can truly be classified as DG units (Ackermann et al., 2001).

The majority of studies that consider the role of DG power in the electricity, industrial, or building sectors, with the exception of those that specifically focus on the broader definition or classification of DG systems, tend to identify DG power only by location or size attributes. Some additionally classify DG power according to type of technology, as is typical of EIA studies and other studies that aim to model the deployment of DG power over time (see, for instance, EIA, 2005a or Boedecker et al., 2002). Yet a definition based solely on these attributes does not provide information about the application or specific use of DG systems, or about how these attributes vary according to different types of DG applications. A definition based on application, as well as size and location can help us identify the motivating factors that lead to DG deployment in different circumstances.

2.3. Applications

There are a variety of DG system applications, all of which are designed to serve different functions and use different, yet overlapping, technology and fuel types. We conceptually divide these applications into six different classification categories: peaking plants, standby power, combined heat and power units, micro-generation systems, remote applications, and localized conventional plants.

Peak load shaving (or "sharing") plants provide supply security during times of peak electricity usage. These plants generally deploy natural gas, diesel, petroleum, battery, or flywheel power. Peaking DG plants are typically owned by either a utility or a major industrial or commercial electricity consumer. DG technologies have the ability to shave peak electricity demand and concurrently reduce grid operator costs through the provision of ancillary services and interruptible load operations (King, 2006).

Standby power systems are designed to provide power in times of outages or failures. Standby power systems are able to serve the needs of both utilities and industrial or commercial facilities. Utilities use standby systems for grid support to help meet short-term power needs during scheduled shutdowns or during power feed failures. Industrial or commercial users deploy standby systems when facility outage costs are high or when outages may potentially compromise human lives or have other severe effects. For instance, hospitals are likely to own standby DG systems when power is critical to life support. Diesel fuel is the most typical fuel source for standby power systems (EPA, 2007).

Combined heat and power (CHP) systems, also known as co-generation systems, are DG applications that generate electricity and also capture the thermal energy from the process' waste heat. The thermal energy can then be used for cooling, heating, or other power applications, and helps increase fuel efficiencies by 80% or more. Internal combustion engines ("reciprocating engines"), external combustion engines ("Stirling engines"), and micro-turbines are the most common CHP units. Anaerobic digesters and industrial biomass operations can also be used with CHP technologies. CHP systems are often owned and operated by commercial or institutional organizations, metal industries, paper or chemical industries, or electricity providers.

Micro-generation units are small-scale systems that are primarily powered by renewable or alternative sources, such as fuel cells, solar photovoltaic, micro-wind, or micro-hydro. These units are best catered to meet residential electricity needs and constraints. These units have positive environmental benefits but typically have high start-up and equipment costs.

The fifth type of DG technology, a remote power system, is the most general classification. Anaerobic digesters or other biomass operations, micro-hydro, wind or solar power, or a variety of natural gas systems are capable of providing power to homes, communities, or other facilities that are beyond a utility's service territory or isolated from the grid. When isolated from the grid, remote power systems are classified as dispersed power units; when connected to the grid, they are distributed generation units.

The final type of DG technology resembles a conventional power plant in purpose – it functions as a standard utility investment in generation capacity – but differs in size and location. These plants tend to be smaller and more localized than conventional, centralized power plants. Localized conventional plants tend to burn relatively efficient fossil fuels, such as natural gas, and some alternatively deploy renewable fuel sources.

2.4. Barriers to adoption

A number of economic and institutional barriers currently prevent DG technologies from playing a more prominent role in the US electricity sector (Alderfer et al., 2000; Budhraja et al., 1999; Dondi et al., 2002; Johnston et al., 2005; Johnson, 2003; King, 2006; Morgan and Zerriffi, 2002; Strachan and Dowlatabadi, 2002; Van Werven and Scheepers, 2005). The following is a list of the most frequently cited barriers that may, depending on political and economic circumstances within each state, hinder the adoption and deployment rate of all DG types.

- There are no national procedures for standard interconnection of DG systems, insurance policies, technical standards for the necessary connecting equipment, standard tariff payment schemes, and power quality characteristics;
- DG system operators must get an approval of various technical parts from either the local serving utility or their state's regulatory commission, which requires considerable time, financial resources, and effort;
- Utilities have inexperience dealing with DG operators and thereby rarely have standard interconnection procedures of their own;
- The approval process for DG systems can be long and require significant effort;
- The associated fees for interconnection to the central grid may be very high;
- Regulatory appeals may be prohibitively expensive; and
- DG systems may not recover appropriate payback due to a lack of standard tariff schemes.