ELSEVIER

Energy Policy 33 (2005) 787–798

ENERGY POLICY

www.elsevier.com/locate/enpol

Distributed generation: definition, benefits and issues ☆

G. Pepermans[a,*], J. Driesen[b], D. Haeseldonckx[c], R. Belmans[c], W. D'haeseleer[c]

[a] K.U. Leuven Energy Institute, Naamsestraat 69, B-3000 Leuven, Belgium
[b] K.U. Leuven Energy Institute, Kasteelpark Arenberg 10, B-3001 Leuven, Belgium
[c] K.U. Leuven Energy Institute, Celestijnenlaan 300A, B-3001 Leuven, Belgium

Abstract

This paper starts from the observation that there is a renewed interest in small-scale electricity generation. The authors start with a survey of existing small-scale generation technologies and then move on with a discussion of the major benefits and issues of small-scale electricity generation. Different technologies are evaluated in terms of their possible contribution to the listed benefits and issues. Small-scale generation is also commonly called distributed generation, embedded generation or decentralised generation. In a final section, an attempt is made to define the latter concepts more precisely. It appears that there is no consensus on a precise definition as the concept encompasses many technologies and applications.

Keywords: Distributed generation; Embedded generation; Electricity

1. Introduction

Distributed generation, for the moment loosely defined as small-scale electricity generation, is a fairly new concept in the economics literature about electricity markets, but the idea behind it is not new at all. In the early days of electricity generation, distributed generation was the rule, not the exception. The first power plants only supplied electricity to customers in the close neighbourhood of the generation plant. The first grids were DC based, and therefore, the supply voltage was limited, as was the distance that could be used between generator and consumer. Balancing demand and supply was partially done using local storage, i.e. batteries, which could be directly coupled to the DC grid. Along with small-scale generation, local storage is also returning to the scene.

Later, technological evolutions, such as the emergence of AC grids, allowed for electricity to be transported over longer distances, and economies of scale in electricity generation lead to an increase in the power output of the generation units. All this resulted in increased convenience and lower per unit costs. Massive electricity systems were constructed, consisting of huge transmission and distribution grids and large generation plants. Balancing demand and supply was done by the averaging effect of the combination of large amounts of instantaneously varying loads. Security of supply was increased as the failure of one power plant was compensated by the other power plants in the interconnected system. In fact this interconnected high voltage system made the economy of scale in generation possible.

In the last decade, technological innovations and a changing economic and regulatory environment have resulted in a renewed interest for distributed generation. This is confirmed by the IEA (2002), who lists five major factors that contribute to this evolution, i.e. developments in distributed generation technologies, constraints on the construction of new transmission lines, increased customer demand for highly reliable electricity, the electricity market liberalisation and concerns about climate change.

This paper presents a rather general discussion of distributed generation. The second section deals with the technologies that allow small-scale generation of electricity. The main characteristics of each technology are summarised in a table. Section 3 then discusses the major potential benefits that are linked to the use of

☆ All authors are affiliated to the K.U. Leuven Energy Institute. Comments by Bert Willems were appreciated. The authors take full responsibility for any remaining errors.

*Corresponding author. Tel.: +32-16-32-68-26; fax: +32-16-32-67-96.

E-mail address: guido.pepermans@econ.kuleuven.ac.be (G. Pepermans).

0301-4215/$ - see front matter © 2003 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enpol.2003.10.004

distributed generation. Section 4 focuses on the major issues that are raised in the distributed generation literature. In both sections, we present a table that links the technologies discussed in Section 2 to the different benefits and issues discussed. This will illustrate that many of the benefits and issues depend on the distributed generation technology used. Section 5 then tries to define distributed generation. This appears to be difficult, as the answer depends on the problem being looked at. Finally, Section 6 concludes.

2. Distributed generation technologies

This section presents a table listing the different technologies that can be used for small-scale electricity generation. The different technologies are not discussed in great detail.[1] For a discussion of the advantages and disadvantages of distributed generation, we refer to the Sections 2 and 3.

3. Why use distributed generation?

In the introduction, it was mentioned that the IEA identifies 5 major factors that contribute to the renewed interest in distributed generation. We feel that these five factors can be further reduced to two major driving forces, i.e. electricity market liberalisation and environmental concerns. This section discusses these major driving forces. The developments in small-scale generation technologies have been around for a long time, but were as such not capable of pushing the "economy of scale" out of the system. We doubt that distributed generation is capable of postponing, and certainly not of avoiding, the development of new transmission lines, as, at the minimum, the grid has to be available as backup supply.

3.1. The liberalisation of electricity markets

There is the increased interest by electricity suppliers in distributed generation because they see it as a tool that can help them to fill in niches in a liberalised market. In such a market, customers will look for the electricity service best suited for them. Different customers attach different weights to features of electricity supply, and distributed generation technologies can help electricity suppliers to supply the type of electricity service they prefer. In short, distributed generation allows players in the electricity sector to respond in a flexible way to changing market conditions. Some major examples are discussed below.

[1] See for example Jenkins et al. (2000) for a more in depth discussion of the technical features of the different technologies.

In liberalised markets, it is important to adapt to the changing economic environment in the most flexible way. Distributed generation technologies in many cases provide this flexibility because of their small sizes and the short construction lead times compared to most types of larger central power plants. According to the IEA (2002), the value of their flexibility is probably understated when economic assessments of distributed generation are made.[2] However, it should be stated that the lead time reduction is not always that evident. For example, public resistance to for instance wind energy and use of landfill gasses may be very high.

3.1.1. Standby capacity or peak use capacity (peak shaving)

Many distributed generation technologies are indeed flexible in several respects: operation, size and expandability. For example, making use of distributed generation allows a flexible reaction to electricity price evolutions. Distributed generation then serves as a hedge against these price fluctuations. Apparently, this is the major driver for the US demand for distributed generation, i.e. using distributed generation for continuous use or for peaking use (peak shaving). In Europe, market demand for distributed generation is, for the moment, driven by heat applications, the introduction of renewables and by potential efficiency improvements. These will be discussed below.

3.1.2. Reliability and power quality

The second major driver of US demand for distributed generation is quality of supply or reliability considerations. Reliability problems refer to sustained interruptions, which are voltage drops to near zero (usually called outages), in electricity supply. The liberalisation of energy markets makes customers more aware of the value of reliable electricity supply. In many European countries, the reliability level has been very high, mainly because of high engineering standards. Customers do not really care about supply interruptions because they do not feel it as a great risk. This can change in liberalised markets, because a high reliability level implies high investment and maintenance costs for the network and generation infrastructure. Because of the incentives for cost-effectiveness that come from the introduction of competition in generation and from the re-regulation of the network companies, it might be that reliability levels will decrease. However, having a reliable power supply is very important for industry (chemicals, petroleum, refining, paper, metal,

[2] Recent work based on option value theory suggests that flexible power plants operating during peak periods may be much more profitable than conventional evaluations suggest. See Feinstein et al. (1997) and Frayer and Uludere (2001) for some literature on this subject.