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UNCERTAINTIES AND RISK FACTORS OF DISTRIBUTED GENERATION

Abstract. These study starts from the observation that there is a renewed interest in small-scale electricity generation. The author 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 decentralized generation. It appears that there is no consensus on a precise definition as the concept encompasses many technologies and applications.
Keywords: Distributed Generation, electricity production.

NIEPEWNOŚCI I CZYNNIKI RYZYKA GENERACJI ROZPROSZONEJ

Streszczenie. Niniejsza analiza bierze swój początek od obserwacji, że istnieje ponowne zainteresowanie produkcją energii elektrycznej na małą skalę. W pracy przedstawiono analizę istniejących technologii, a następnie omówiono główne korzyści i problemy związane z wytwarzaniem energii elektrycznej w małej skali. Technologie te są oceniane pod względem potencjalnego udziału wymienionych korzyści i problemów. Wytwarzanie energii na małą skalę jest powszechnie nazywane generacją rozproszoną lub zdecentralizowanym wytwarzaniem. Nie ma precyzyjnej definicji generacji rozproszonej, ponieważ jako pojęcie obejmuje ona wiele technologii i zastosowań.
Słowa kluczowe: generacja rozproszona, produkcja energii elektrycznej.

Introduction

Distributed generation, the small scale production of electricity at or near customers' homes and businesses, has the potential to improve the reliability of the power supply, reduce the cost of electricity, and lower emissions of air pollutants [1]. Distributed generation can come from conventional technologies, such as motors powered by natural gas or diesel fuel, or from renewable technologies, such as solar photovoltaic cells. Over the past two decades, declines in the costs of small scale electricity generation, increases in the reliability needs of many customers, and the partial deregulation of electricity markets have made distributed generation more attractive to businesses and households as a supplement to utility supplied power.

Three basic characteristics differentiate most distributed generation from traditional electricity supply: location, capacity, and grid connection [2]. Distributed generators are located at or near the point at which the power is used. They are typically on site generators, owned and operated by retail customers that are used to meet a portion of the customers' demand or to provide backup service for customers that need highly reliable power. Applications of distributed generation could include combined heat and power operations. The second defining characteristic of most distributed generation is its size. Generation capacities of customer owned units, used primarily to meet on site requirements, typically range from a few kilowatts to several hundred kilowatts. The level of their connection with the local or regional electric grid is the third characteristic that distinguishes distributed generators from traditional suppliers.

Distributed generation is an important, although small, component of the nation's electricity supply. The principal source of electricity today continues to be large central facilities that generate electricity from steam plants (coal, natural gas, or nuclear power) and hydroelectric power. Among distributed generation technologies, the most important in terms of their capacity to generate electricity are customer owned generators that produce both electricity and steam for on site use (called combined heat and power, or cogeneration [7, 9]) and emergency backup generators. For the most part, the cogeneration plants that have been built to date are large facilities that sell the majority of their output to utilities. Natural gas fuels most of those plants, but coal and biomass also power a significant percentage of the total capacity. Most backup generators are internal combustion engines fuelled by diesel oil or gasoline. Diesel fired backup generators are commonly used in high rise buildings for safety reasons (as required by local building codes), in hospitals, and in manufacturing facilities that depend on a highly reliable supply of power.

Renewable technologies that are currently used to generate electricity at homes and businesses include wind turbines and solar photovoltaic systems.

Those technologies produce electricity intermittently and generally are not available to operate continuously [5, 8]. Fuel cells and small turbines (called micro-turbines) are frequently mentioned, newly emerging high efficiency technologies. Although they account for very little of the nation's existing electricity supply, proponents believe they will contribute significantly in the future. There are different types of DGs from the constructional and technological points of view as shown in Fig. 1.

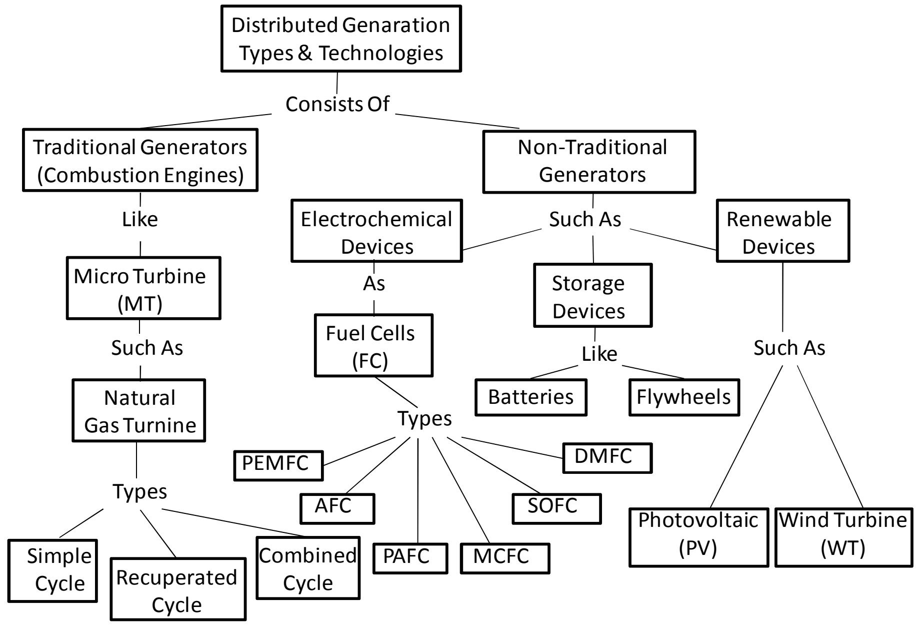

Fig. 1. Distributed generation types and technologies [3]

A classification can be concluded by relating most candidates of DG types and also the traditional centralized generation stations to different wide range applications as shown in Table 1.

Uncertainties and risks of Distributed Generation

The prospects for widespread adoption of distributed generation technologies are not at all certain. Nor is it clear that those technologies will be used in ways that achieve their full potential economic benefits. Moreover, this new source of electricity poses a distinct risk of negative impacts that may be difficult to anticipate or expensive to avoid. Those effects include potential degradation in the performance of the electricity distribution network, inequitable and possibly inefficient redistribution of the costs of electricity service among customers, and a decline in environmental quality. Measures to mitigate those adverse impacts could significantly limit the adoption of distributed generation or increase costs to the point at which most applications would no longer be financially viable.

Tab. 1. Comparison between common energy types

Energy type	Application
Micro-turbines	Co-generation, help for peak load shaving, commercially available in small units with sizes 30-75kW [1]
Fuel cells	Suitable for providing CHP for air-conditioning, cooling and heating purposes, commercialy available in small units with sizes 3-250kW as modular to serve large loads [1]
Photovoltaic	Stand alone and base load in some rural applications if combined with batteries.
Wind turbines	Remote homes and farms and process industry applications.
Traditional internal combustion engines (diesel engines)	Already in use for several years, but they have high emissions and operation and maintenance costs in addition to diesel's hazardous during transportation to remote consumers [1]. Most of them are used for peak load shaving and backup operation not for continuous operation.
Central power generation (fossil fuel)	Main electricity generation as the main base load. Used for peak load shaving and backup operation.

The reliability of power to all customers might be diminished rather than bolstered if the operators of electric systems found it difficult to manage a much greater number of power sources – suppliers that were adding electricity to or drawing electricity from the grid at will. Equivalently, the retail price of electricity could rise if ratepayer funded investments were necessary to maintain power quality.

Increased competition in wholesale electricity markets and reforms in retail electricity pricing could significantly reduce the number of situations in which distributed generation was profitable to owners. Competition in wholesale markets could lower electricity prices to the point at which many investments in distributed generation would no longer be attractive. Widespread application of real time pricing, which could provide incentives for the operation of distributed generators, could also end up making many of them unprofitable. Real time pricing and other tariffs (rate schedules) that encouraged retail customers to vary their demand for electricity in response to price changes could significantly lessen price volatility as well as average prices. That result would reduce the number of hours per year that many distributed generators could operate profitably.

Uncertainty related to market restructuring. If competitive wholesale markets for electricity develop with nondiscriminatory access and hourly prices determined by supply and demand, those markets will give operators of distributed generators an incentive to run their units when such operation will reduce the overall cost of supplying electricity. But if wholesale markets do not develop efficiently – for example, because of restricted access or regulated prices – the benefits of distributed generation may not be fully realized.

Uncertainty about market potential. Besides uncertainty related to market restructuring, other types of uncertainty will affect the potential growth of distributed generation applications. Such uncertainty includes the actual costs of installing and operating distributed generation technologies relative to central power technologies, the actual value to individual customers of improvements in reliability of service, and variations in the financial benefits for individual customers, which are difficult to capture in an overall analysis such as this one.

The costs of the various distributed technologies themselves are uncertain. The two most widely mentioned high efficiency technologies – microturbines and fuel cells – either are not yet commercially available or are in the early stages of commercialization. Although their proponents predict that installed equipment costs will decline substantially in the future as commercial production increases, such an outcome cannot be known in advance. Other technologies – such as photovoltaic systems – have been in commercial production for some time, but proponents still forecast that their costs will fall considerably as manufacturing processes continue to improve and production increases. A second uncertainty surrounding the market potential of distributed generation concerns the benefits from improved reliability of service, which are often difficult to value.

The financial benefits that customers will weigh to decide whether to invest in and operate distributed generators are much more diverse that those summarized here. Conditions will vary widely from customer to customer-depending on such factors as the customer's economic activity, size, location, and load profile – and many technologies will not prove suitable.

Threats to the performance of electric system. Without adequate upgrades to the electricity supply network, widespread adoption of distributed generation could adversely affect regional electricity distribution systems. For example, with many customers switching their generators on and off, the quality of the power and the reliability of the systems could be degraded.

Risks to air quality and national security. The distributed generation technologies with the greatest market potential are probably those fueled by fossil energy (backup generators powered by diesel fuel and cogenerators powered by natural gas), not renewable energy. The potential for customer owned wind and solar power will probably continue to be realized only in limited circumstances, unless the capital costs of those technologies fall considerably. High efficiency micro-turbine and fuel cell technologies are still at the earliest stages of commercialization, so their potential is largely unknown. Thus, the immediate promise of improved air quality from wider adoption of distributed generation may be limited, and improvements would probably come primarily from substituting natural gas and diesel fired generators for coal fired generators. On the down side, those new generators might end up displacing power from units that were already fired by natural gas. And if some generators switched from relatively clean burning natural gas to diesel, local air quality could worsen.

Another risk is that widespread adoption of gas fired distributed generators could necessitate construction of additional pipeline capacity. The EIA's Reference Case Mid-Term Energy Forecast projects that electricity generated from natural gas will climb from 17 percent in 2001 to 29 percent in 2025. If that increase largely takes the form of distributed generation near growing population centres, additional pipeline capacity will be needed to supply those generators. Any savings in investments in electricity transmission and distribution networks would be partially offset by the need for investments in new natural gas pipelines. Other adverse (or at least costly to control) effects also could result. They might include damage from unconventional forms of pollution such as waste heat and noise problems that have been associated with diesel powered backup generators and cogeneration plants sited in urban settings. Even windmills have environmental drawbacks, including detracting from the aesthetics of the landscape. Such impacts might not be easy to anticipate or be readily apparent for a small number of units, but the cumulative effect of many dispersed generators could be significant. In geographic areas with strict emissions standards, it would be necessary to inspect distributed generators regularly to monitor their compliance with those standards. Under the scenario of widespread use of small scale generators envisioned by proponents, the cost of that monitoring could be steep.

Barriers for development of Distributed Generation

Proponents of distributed generation argue that significant barriers impede the widespread adoption of distributed generation technologies. Most, if not all, of those barriers are related to the risks cited earlier. They include utilities' pricing and operational practices and local governments' rules about reliability and safety, cost, or environmental quality [4]. A common theme of the complaints against those practices or rules is that they result in restricted access to the grid and protect the utilities' current investment in central generation capacity and transmission lines. Four types of barriers are frequently cited.

Protecting the grid: Interconnection requirements and costs. The first type is contractual and technical interconnection requirements for the installation of protective equipment and safety devices to protect the grid and ensure power quality; distributed generation proponents argue that those requirements are often duplicative, excessive, and time consuming.

The stated purpose of the technical interconnection restrictions and requirements is to ensure the safety and quality of the electric power system and to avoid possible damage to equipment. Those restrictions often prohibit small generators from connecting to the grid at the distribution level of the network. For example, under existing rules in some utilities' service territories, customers with on site generation must disconnect completely from the grid before starting their generators, to protect against accidental transmission of power onto the grid or possible voltage and frequency disturbances from the new power.

In the absence of outright prohibitions, however, operators of distributed generation units may want to remain connected to the grid while producing power (termed parallel operation) whether to draw supplemental power from the grid or to transmit excess power onto it. In that case, utilities generally require operators to install additional controls and equipment in order to protect the network from feedbacks or disturbances. That additional site specific equipment may include voltage regulators, frequency synchronizers, isolation devices, monitoring devices, and network protectors. Because the number and types of devices that utilities require vary widely and depend on many factors, utilities often demand specialized studies typically paid for by the operator to determine the equipment necessary in each case. Utilities may also require upgrades to the distribution system itself to support the power supplied by the distributed generators and to protect neighbouring customers from disruptions or variations in power quality. Operators typically bear the cost of such site specific equipment and any system upgrades, too.

In general, utilities require that operators of distributed generators execute contracts governing the interconnection of their equipment with the distribution and transmission network. Distributed generation proponents complain that provisions in those contracts are often one sided or overly burdensome. They include insurance requirements that may boost operators' costs significantly and indemnification and dispute resolution provisions that proponents say unfairly favor the utilities.

Many observers argue that those technical and contractual interconnection requirements are often excessive. For example, the electronic control equipment built into most small generators effectively protects against electricity feedbacks and other technical problems, so industry requirements for additional equipment are often redundant.

Utility surcharges: paying for stranded costs and standby service. The second type is surcharges imposed by utilities on operators of distributed generators (who are still utility customers) for standby service; proponents contend that those surcharges often do not reflect the actual cost of the service and do not give credit for the ways in which distributed generation benefits the grid.

Compensating for avoided costs: prices for power sold to utilities. The third type is pricing of electricity that is based on the utilities' average cost rather than their marginal cost (the cost of supplying an additional unit of electricity). Proponents contend that average cost pricing does not give owners an incentive to operate their distributed generators during periods when doing so will lower the overall cost of electricity.

For operators who do qualify to sell their excess power to the utilities, the prices they receive may not offer sufficient incentives to install and operate their distributed generators in a cost effective manner. That is because the prices in those markets generally do not reflect the costs of the additional utility supplied power that would have been produced in the absence of power from the distributed generators. At the wholesale level, the costs of producing and delivering electricity vary continuously by time and location, as consumption fluctuates in real time. During periods of peak demand, the cost of electricity typically rises as less efficient generators are placed in service. The costs also vary by location because of constraints in the capacity of the transmission and distribution system that affect deliveries during periods of peak demand.

But at the retail level, prices generally do not vary by time or location. Similarly, administratively set „avoided cost" payments to qualifying operators of distributed generators are often fixed, with predetermined prices in defined periods. Whether the cost of power is high or low during a given period, retail customers typically pay the same price per kilowatt hour.

That disparity between the wholesale cost of electricity and the prices that operators of distributed generators receive may raise the overall cost of electricity by limiting operators' incentives to run their units most efficiently. Distributed generators may operate during periods when it is less expensive to supply additional power from the grid.

Environmental concerns: sitting restrictions and permitting requirements. Air quality issues are one component of the permitting process for installing distributed generators. The other components are land use approvals and building codes. Local governments require land use approvals to ensure that a project conforms to zoning ordinances governing allowable uses for a property. Typically, ordinances do not identify electricity generating plants as a permissible land use, so jurisdictions usually require a review to weigh benefits and drawbacks and determine whether a permit should be granted. The building permit process a separate requirement ensures that a project conforms to certain safety standards. Those standards are described in building codes governing such characteristics as fire protection, plumbing, electric power, and mechanical equipment. Building permits are required for all new construction and most substantial building improvements and equipment additions.

Many building codes include specific regulations for on site generators. Codes often require that certain building classifications be equipped with an emergency power supply to generate electricity when normal service is interrupted. Those generators must typically be powered by a fuel supply that is on the premises, such as diesel fuel or gasoline. That requirement can preclude the use of distributed generation technologies fueled by natural gas (which must be piped in), even though they can be less costly to operate and are associated with fewer harmful emissions than diesel fuel or gasoline. For buildings that are required to have an emergency power supply, natural gas could be used only if the operator installed a dual fuel generator burning natural gas for non emergency power needs (and sales to utilities) and burning diesel or gasoline for backup power.

Achieving the potential cost and reliability benefits from widespread adoption of distributed generation technologies may depend on retail competition and unrestricted customer choice. The competitive positions of many utilities are already weakening with the restructuring of wholesale electricity markets and increased use of the most wide spread form of distributed generation (cogeneration for customers' own use and for sale to the utilities). Broader adoption of distributed generation by customers could be an important part of what many analysts believe will be the next level of market restructuring the introduction of retail competition. Such competition would give customers the ability not only to choose their electricity suppliers but also to elect to generate electricity on their own.

Conclusions

This work started from the observed renewed interest in small-scale electricity generation. Existing small-scale generation technologies are described and the major benefits and issues of using small-scale distributed generation are discussed. The different technologies are evaluated in terms of their contribution to the listed benefits and issues. Small-scale generation is commonly called distributed generation and we try to derive a consensus definition for this latter concept. It appears that there is no agreement on a precise definition as the concept encompasses many technologies and many applications in different environments. In our view, the best definition of distributed generation that generally applies seems to be 'an electric power generation source that is connected directly to the distribution network or on the customer side of the meter [6].

Depending on the interest or background of the one confronted with this technology, additional limiting aspects might be considered. A further narrowing of this 'common divider' dentition might be necessary depending on the research questions that are looked at. However, the general and broadly understandable description as proposed here, is required to allow communicating on this concept.

Bibliography

[1] Ackermann T., Andersson G., Soder L., Distributed generation: a definition, Electric Power Systems Research, Vol 57, 2001, p. 195-204, DOI: http://dx.doi.org/10.1016/S0378-7796(01)00101-8
[2] Brown M., Casten T.R., Guide to Decentralized Energy Technologie, World Alliance for Decentralized Energy (WADE), 2003, p. 1-49,
[3] El-Khattam W., Salama M.M.A., Distributed generation technologies, definitions and benefits, Electric Power Systems Research, Vol. 71, 2004, p. 119-128, DOI: http://dx.doi.org/10.1016/j.epsr.2004.01.006
[4] Gnatowska R., Pietrzak P., Socio-Economic Development District in the Context of Rational Use of Energy and Environment, Turbomachinery, No 143. 2013, p. 33-38.
[5] Lewandowski W.M., Proekologiczne źródła energii odnawialnej. WNT, Warszawa 2001.
[6] Pepermans G., Driesen J., Haeseldonckx D., Belmans R., D'haeseleer W., Distributed Generation: definition, benefits and issues. Energy Policy, No 33, 2005, p. 787-798, DOI: http://dx.doi.org/10.1016/j.enpol.2003.10.004
[7] Sawin, J., Mainstreaming Renewable Energy in the 21st Century. Worldwatch Paper 169. Washington 2004.
[8] Smolec W., Fototermiczna konwersja energii słonecznej. PWN, Warszawa 2000.
[9] Voorspools, K., D'haeseleer, W., The impact of the implementation of cogeneration in a given energetic context. IEEE Transactions on Energy Conversion, No 18, 2003, p. 135-141, DOI: http://dx.doi.org/10.1109/TEC.2002.808332