

Distributed power generation in the United States

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A B S T R A C T

With electricity consumption increasing within the United States, new paradigms of delivering electricity are required in order to meet demand. One promising option is the increased use of distributed power generation. Already a growing percentage of electricity generation, distributed generation locates the power plant physically close to the consumer, avoiding transmission and distribution losses as well as providing the possibility of combined heat and power. Despite the efficiency gains possible, regulators and utilities have been reluctant to implement distributed generation, creating numerous technical, regulatory, and business barriers. Certain governments, most notable California, are making concerted efforts to overcome these barriers in order to ensure distributed generation plays a part as the country meets demand while shifting to cleaner sources of energy.

Keywords:

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Barriers

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1. Introduction

1.1. Traditional electrical grid

In the late 1800s as the newly industrialized United States was beginning to generate electric power in order to accomplish significant work, power plants were located geographically near to the demand as electricity was transmitted over high-loss direct current (DC) power lines. However, as transmission techniques evolved to rely upon safer and lower-loss alternating current (AC), power plants began to move further away from the point of demand. With this evolution developed the modern electric grid with massive central power plants. These power plants typically generate thousands of megawatts of power, transmitting electricity at around 100 kV over country-wide distribution networks, which helps reduce losses accumulated in transmitting electricity over long distances. Upon reaching the consumer, the voltage is stepped down through the distribution network to safer levels.

1.2. The state of the electrical grid

For most of the electrical grid's history, it has been in the hands of vertically integrated, investor-owned utilities that operated as monopolies within a region. These utilities owned the generators, transmission lines, and distribution networks, but were strictly regulated by the local and federal governments (Federal Energy Regulatory Commission, or FERC). Traditionally, the local governments had to approve the rates set by utility companies to ensure that they were covering investment costs and making a fair profit without overcharging the customers.

Beginning in the second half of the twentieth century, the structure of the grid began to change into wholesale markets, where utilities started choosing the generation source based on current prices. A variety of sources were controlled by computers to balance supply and demand perfectly. Then, in the 1970s, the Public Utilities Regulatory Policies Act (PURPA) was passed, allowing utilities to buy power from independent power producers. This created a wholesale market for electricity, where price was fluctuating hourly from constant negotiations between the utilities and independent producers.

At the turn of the century, the wholesale markets opened up even more. FERC proposed the forming of independent transmission organizations throughout the US, essentially dividing the power industry into generation, transmission, and distribution. Generators would bid hourly to sell power to regional markets. This discrete time size opened the prospect for allowing hourly pricing of electricity, directly affecting the consumer. In this way, the price of consumer electricity could be higher during times of peak usage and lower during the levels of low usage, called dynamic pricing [1]. Dynamic pricing is most commonly available to industrial consumers; however, it is becoming increasingly available to residential consumers.

As the electric grid becomes more market-driven, it also becomes more physically interconnected at the same time. While divided into numerous regulatory regions, all systems are

connected, creating what is often described as the largest machine in the world. By interconnecting systems in California with those in New York, power could theoretically be generated on one side of the country and consumed thousands of miles away. Within the market-driven model, this helps to ensure competition.

Despite the market advantages of an ever expanding grid using centralized power plants, there are numerous drawbacks. Of the many, some include the lack of incentive for utilities to support energy efficiency, as the profit of utilities is most commonly tied to the amount of power that is sold. In addition, as seen in the power outage of 2003 in the northeast US, an interconnected grid can propagate problems causing cascading failures. The blackout was a result of poor management of power coming in from hundreds of different sources over thousands of miles of transmission lines. The liberalization of markets and the drawbacks of central power plans create opportunities for implementation of distributed generation (DG) within the United States.

1.3. Distributed generation

There are differing perspectives on the definition of DG. For the purpose of this paper, "distributed generation is an electric power source connected directly to the distribution network or on the consumer side of the meter [2]." Connection to the distribution network is a key component of the definition, as power generation units not connected to the distribution network is known as "dispersed generation," according to the US Energy Information Administration (EIA)[3].

According to the EIA, in 2007, there were 7103 commercial and industrial DG units installed with a total electric capacity of 12.7 GW-electric [4]. There are no statistics available on the residential sector; however, it can be assumed that it is currently a negligible, albeit growing, part of the DG picture. DG capacity represented 1.27% of the 995 GW-electric capacity in 2007 [5], an increase from 0.5% in 2000 [1].

The technology and applications of distributed generation, as well as its benefits and drawbacks of the economic, environmental and technical aspects will be discussed in this paper. Lastly, the barriers to further implementation as well as suggestions for improvement and further research will conclude.

2. Technology

2.1. Internal combustion engine

With 4614 MW installed capacity as of 2007 [4], the DG technology with the largest installed capacity is the internal combustion engine. Internal combustion engines achieved this position through low cost and a relatively high operating efficiency of up to 43%, and the ability to use various inputs. Gas-powered engines usually take natural gas, but can also use biogas or landfill gas. Diesel engines naturally take diesel fuel, but with the rise of environmental awareness, they are more commonly taking biodiesel [6].

2.2. Combustion turbine

Combustion, or gas, turbine technology is installed with a capacity of 1964 MW as of 2007 [4]. While combustion turbines are often used in new combined cycle central plants, they are generally the generator of choice for large industrial sites looking to install on-site power. They can be used in a variety of ways; however, it is most common for them to be used in combined heat and power (CHP) systems, where excess heat is captured and put to use as steam or hot water [7]. General efficiency is usually 21–40%, while with CHP, efficiencies can reach 70–80% [1]. Sizes can range from 500 kW to 250 MW, and operate on fuels such as natural gas, synthetic gas, landfill gas, and fuel oils [7]. The main advantage of gas turbines, as previously mentioned, is their extremely high efficiencies when used in CHP applications. These systems are very environmentally friendly and cost effective. The main disadvantage, however, is that gas turbines are generally too big for smaller consumers.

2.2.1. Microturbine

Microturbines are a subset of combustion turbines. As the name implies, they are basically gas turbines that have been scaled down in size. The power output of a microturbine ranges from 20 kW to 500 kW, and the size typically ranges from 0.4 to 1 m³. They run on natural gas, propane, fuel oil, and, more recently, biogas. They also, run at very high rotational speeds of up to 100,000 rpm [8]. General electrical conversion efficiency is about 20–30%. With heat recovery from cogeneration, the overall efficiency can be raised to 60–85% [9].

Microturbines have many advantages, most of all is the small size and light weight compared to the power output, which is useful when there are space limitations. Additionally, they can start-up and shut-down relatively easily. With the help of power electronics, they can be controlled very efficiently. Because of a small number of moving parts and a simple design, they have low maintenance costs [8]. However, as a relatively new technology, microturbines are still quite expensive compared to traditional gas turbines. Also, the cost-effectiveness of micro-turbines is very sensitive to the price of fuel [6]. Microturbines burn fossil fuels to generate power, which releases CO₂ and NO_x into the atmosphere.

2.3. Steam turbine

Steam turbines have a total installed capacity of 3595 MW as of 2007, ranking second among DG technology types within the US. The reason for this high capacity could be that steam turbines can be used with a wide variety of applications, accepting steam generated from geothermal, solar thermal, and biomass installations, for example.

2.4. Small-scale hydroelectric

Hydroelectric is most commonly seen as a large-scale, centralized power plant of the style of the Hoover Dam (capacity of roughly 2 GW). In contrast, small-scale, distributed hydroelectricity has an installed capacity of 1053 MW as of 2007 [4]. Small-scale hydroelectric is typically defined as 5–10 MW installations [10], and is typically considered an economic and environmental manner of generating electricity. Costs are limited to relatively low (compared to other renewable technologies) up-front investment costs and maintenance, as the fuel is free. In addition, hydroelectric is a desirable solution for providing peak power and spinning reserves considering the quick start-up time of the generators.

2.5. Other

Despite the highest aspirations, other technology types, particularly renewable, do not yet form a large part of the installed capacity, having 1427 MW as of 2007 [4]. This total includes fuel cells, photovoltaics, and wind turbines.

2.5.1. Fuel cell

Fuel cells are generators that use hydrogen and oxygen to create electricity and heat. They output power like a battery, but are different in that they do not need to be charged electrically. Instead, they are fueled with hydrogen rich substances, such as natural gas, gasoline, biogas, propane, as well as pure hydrogen [11]. Fuel cells come in a variety of sizes, depending upon the application, with a maximum power output of the order of 1 MW. They operate with an electrical conversion efficiency of between 35 and 80%, using pure hydrogen as the fuel. Efficiency goes down when using other fuel types. Typical operating temperature is between 20 and 200 °C [12].

Fuel cells have a variety of advantages. They are considered as one of the most environmentally friendly generators, as the only byproduct is water (when using pure hydrogen as the input). There are little or no moving parts within a fuel cell, so they are extremely quiet. Because they output energy in the form of electricity and heat, fuel cells can be used for combined heat and electricity applications. They can be easily stacked to accommodate larger power demands. Many fuel cells have also exhibited high reliability, operating for over 99% of the time [11]. Unfortunately, a cost-effective method for extracting hydrogen has yet to be found. Also, there is not the same, well-built infrastructure for hydrogen as there is for fossil fuels like oil and natural gas.

2.5.2. Photovoltaic

A photovoltaic (PV) cell is a silicon crystal that has been designed to capture photons from the light and convert them into electrical energy. Cells are connected together to form PV panels of varying sizes and shapes, generally with the bigger panels generating more power. Photovoltaic cells have been created with efficiencies of near 50%; however, these high-efficiency models are too expensive for standard electricity generation. The average efficiency of the best commercial PV panels is about 15%, although this is rapidly improving [13]. Power output can range from a few watts to megawatts, depending almost only on size of the PV array.

The main advantage of PV systems is that the fuel, sunlight, is completely free. Because of this, PVs can be used in a variety of applications, like space travel, where fuel is not an option. Since no fossil fuels are used to generate power, PV cells are emission-free. However, as the sun shines only during the day, storage mechanisms are required. Additionally, the up-front cost of PV installation is very high compared to other types of power generation. However, as investment increases, the costs of PV are rapidly decreasing.

2.5.3. Wind turbine

It is debatable whether wind turbines can even be considered distributed power. Currently, most wind turbines are installed in giant, hundreds-of-megawatts “wind farms” that function more as centralized power plants than distributed generators. Wind turbines used for centralized wind farms have a capacity up to 4 MW [10].

The advantage of wind power, like PV cells, is that the fuel is free; in this case, wind. Wind blows both day and night, allowing for the continuous, albeit unpredictable, generation of power. Wind turbines are one of the most developed “alternative” energy technology. However, cost is still an issue, as well as energy storage for when the wind is not blowing.

3. Applications

3.1. Emergency backup

The main use of on-site generators has been as backup power generation in case of a power outage. There are many services, such as hospitals, brokerages, telecommunications, and data centers, in which a power outage cannot be tolerated. These services and industries are willing to pay a premium to maintain constant power.

Traditionally, diesel internal combustion engines have been used in combination with batteries to provide backup power. These diesel generators lay dormant while monitoring the incoming power from the grid. If there is a disruption, the backup power turns on. Uninterruptible Power Supplies (UPS) have also been used in order to achieve backup power. However, since these are generally battery based, they can only run for a finite amount of time (generally less than an hour) and are not optimal for extended power outages.

With environmental concerns growing, diesel generators have begun to fall out of favor because of the large amount of CO₂ and NO_x emissions that they produce. Hydrogen fuel cells have begun selling commercially as backup power supplies. They have no or low emissions, making them cleaner than diesel generators. They also are cheaper than battery backups of the same capacity [12].

3.2. Peak/load shaving

Because utilities generally charge industrial clients more during peak demand periods, it is sometimes economical to install DG for this purpose. Using set price points, the generators are turned on only when they are cheaper to run than buying electricity from the grid.

The installation of on-site generation also benefits the utility. In many cases where capacity is near the maximum level, utilities generally need to add more generation units into the power scheme, which can often be quite expensive for incremental increases. However, if the user installs on-site power, this burden is lifted off the utility and shared by the user.

3.3. Base load generation

In some cases, companies decide to use DG for base-load power needs. That is, they use on-site generation 100% of the time, and buy any extra needed power from the grid. Many times, this is the case when a company wants to install on-site wind or solar power generators. Because the output of these generators is variable, they need to be supplemented by the grid. Google, the Internet search engine company, recently completed a project to install 1.6 MW of solar panels on its Mountain View, California headquarters. This is only enough to power less than half of the Google campus, but still a substantial amount nonetheless. Base load generation can be often most economical in scenarios with high electricity rates, such as Southern California. Using combined heating and power, the efficiency gains often create an even greater economic advantage over buying from the grid.

4. Economics

When considering power supply options, the choice usually comes down to the bottom line: Is this project cost-effective? While DG may not be a universal answer to solve the country's power supply problems, there are certain situations in which DG offers distinct economic advantages over the traditional grid power.

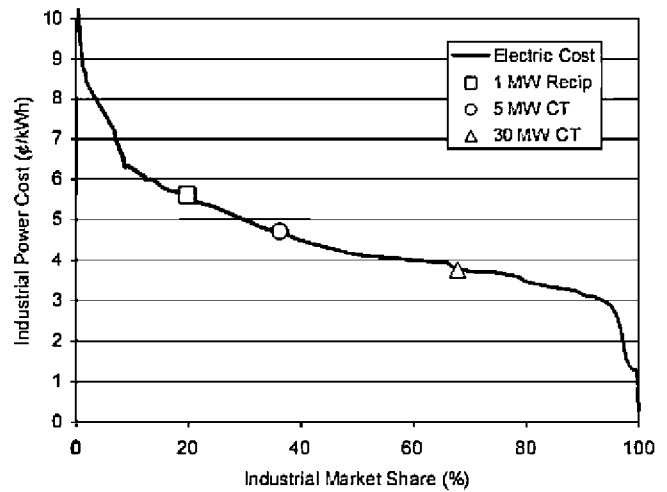


Fig. 1. Percent of industrial market share that is economical using CHP of various sizes vs. industrial power costs. Recip is reciprocating engine; CT is combustion turbine. [15].

4.1. Combined heat and power

Combined heat and power is one of the best, if not the best, advantages of distributed generation. By locating the power generator physically close to the end-user, excess heat that usually is wasted can be utilized, many times boosting total efficiencies to up to 70–80%. The most common technology employed now is simple-cycle gas turbine, which can then transmit extra heat in the form of hot water or steam. As of 2003, 8%, or 46 GW, of US energy generation capacity came from CHP [14]. Note that this capacity may include dispersed generation as well as distributed.

CHP is the most economically viable DG technique available today, mainly because it increases the process efficiency so drastically. As seen in Fig. 1, larger CHP plants are more economical than smaller ones, mostly because of economies of scale.

CHP is sensitive to prices of natural gas. As natural gas prices increase but electricity price stays the same, the value of CHP decreases, as seen in Fig. 2. The natural gas price within the United States is currently \$4.55/MMBtu [16]. Considering the recent discoveries of natural gas deposits (shale gas) within the United States, gas prices are not expected to increase in the near future.

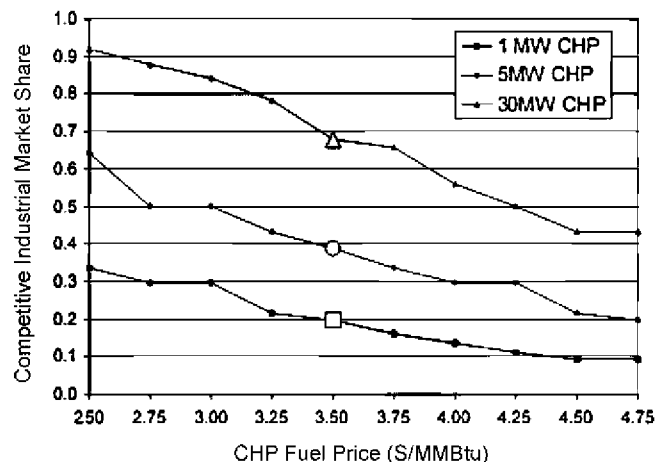


Fig. 2. Effect of CHP fuel price on market share [15].

Table 1
Economic DG implementation for reliability costs [18].

Outage cost (per hour)	Reliability needed (based on outage cost)	Economical DG backup power	Type of power
<\$10,000	99.9% – 8.76 h/year	None	Grid – 1000 kW
\$10,000–\$50,000	99.99% – 52.6 min/year	1000 kW	Grid – 1000 kW IC and/or GT – 2 × 500 kW
\$50,000–\$700,000	99.999% – 5.2 min/year	1500 kW	Grid – 1000 kW IC and/or GT – 3 × 500 kW
\$700,000–\$10,000,000	99.9999% – 31.5 s/year	2000 kW	Grid – 1000 kW IC and/or GT – 4 × 500 kW

4.2. Reliability

In many industries, the cost of a power outage is staggering. It is estimated that 1.5–3% of manufacturing sales dollars are spent solving power quality problems [17]. The hourly cost of blackouts for the cellular communications industry is \$41,000 per hour; for the airline reservation industry, \$90,000 per hour; and brokerage firms, \$6480,000 per hour [18]. Because these numbers are so high, about \$1 billion is spent on Uninterruptible Power Supplies (UPS) and around \$5 billion on power quality equipment and services [17]. The US grid is about 99.9% reliable, but that still leaves 8.76 h/year of down time [18].

One way to analyze the value of distributed power generation for reliability purposes is to measure the break-even point of on-site power. That is, the point at which the added cost of having backup power on-site equals the cost of having less reliability without backup power. One study analyzed the value of DG for reliability in situations where extra power was not sold back to the grid [18]. The included technologies were internal combustion engines (IC), gas turbines (GT), microturbines (MT), and fuel cells (FC), all fueled by natural gas. The goal of the study was to minimize total system cost while at the same time minimizing outage costs incurred over a ten-year span for a 1000 kW load. See Table 1 for the results.

As the table shows, the most economically viable solutions involve internal combustion engines or gas turbines, not microturbines or fuel cells. However, this changes when environmental legislation is taken into account. For example, California’s permitting standard for small-scale standby generation is 0.5 lb/MWh of NO_x [18]. When this limitation is applied to the previous cost analysis, the results change, as seen in Table 2.

The reason microturbines are more useful in the case of limited emissions is because they emit about 0.44 lb/MWh of NO_x, while average emissions from traditional generating units is 2.541 lb/MWh (Virginia) [18].

4.3. Interaction with the grid

With the decrease in utility regulations, it is now possible for DG owners to sell excess energy back to the grid in certain regions. With the combination of combined heating/cooling and power generation from on-site generators, DG becomes an even more valuable option. Using computer algorithms, DG can be balanced with grid electricity to provide the most economical mix of power.

Table 2
Economic DG implementation for reliability costs with NO_x limitations [18].

Outage cost (per hour)	Reliability needed (based on outage cost)	Economical DG backup power	Type of power
<\$475,000	99.99%	1000 kW	Grid – 1000 kW MT – 2 × 500 kW
\$475,000–\$10,000,000	99.9999%	1500 kW	Grid – 1000 kW MT – 2 × 500 kW IC – 1 × 500 kW

Recently, individual DG systems have started interacting with each other in systems called microgrids. In these microgrids, usually a few different DG options, such as PV and natural gas, work together to provide an energy solution to a small area, such as a college campus. With this combination of technology and grid interaction, the best balance between fuels can be found to create a cost effective and efficient system. The following results were extracted from a study using microgrids of natural gas generators [17].

The most important factor in determining economic viability of DG (using natural gas powered generators) of a facility is customer mix. That is, how a facility uses heat and electric power, varying based on time. This result actually goes against the conventional wisdom that cold climates were the optimal sites for DG because they have a higher heat demand. The heat demand in cold climates does not necessarily increase with electricity demand. More important is the heat-electric coincidence, which is a way of measuring how heat demand increases compared to electricity demand for a facility. Examples can be seen in Fig. 3. Sites with a high heat-electric coincidence take more advantage of combined heating and power generation. Naturally, as the generator produces more electricity, it produces more heat as well. Results comparing the sensitivity of climate versus customer mix can be seen in Fig. 4. Bubble area represents total lifetime energy costs [17].

DG in certain liberalized markets is also cost-effective when used as a peak-shaving mechanism. This result appears in markets where DG operators are rewarded extra for supplying energy during times of peak consumption. For example, systems in Little Rock, Miami, and Richmond yielded internal rates of return above 10%, while only generating 1–2% of their own power needs. This is because they sold excess power to the utility in times of peak demand.

Because the generators in this scenario are natural gas based, the viability of these systems is very sensitive to the price of gas. If gas and electricity prices rise together, then DG becomes even more valuable because it can produce heat as well as electricity. If gas prices increase while electricity prices rise 60% as much, the value of DG remains constant. However, if electricity prices rise less than 60% as much, then on-site generation begins to decrease in value. Due to the recent discovery of vast natural gas resources, prices have dropped significantly relative to electricity, and are expected to remain stable in the near future.

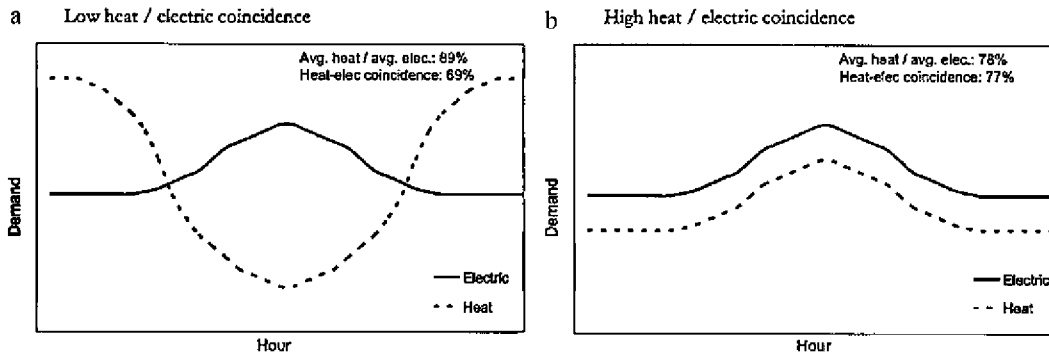


Fig. 3. Example of heat-electric coincidence [17].

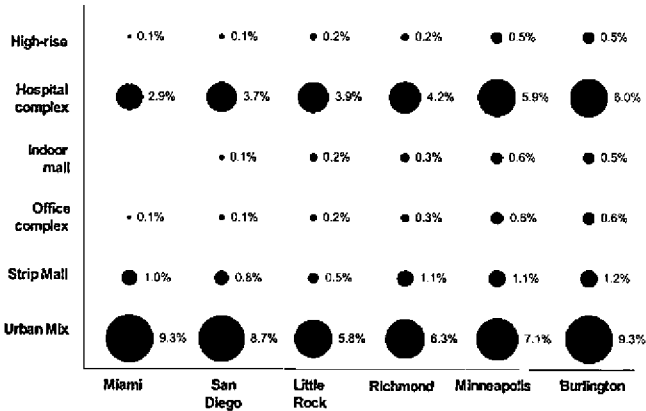


Fig. 4. Sensitivity analysis comparing climate (x -axis) and customer mix (y -axis). Bubble area represents total lifetime energy costs [17].

5. Environmental impact

One of the main hopes for DG is that it will help usher in an age of clean, economical power that has a smaller environmental impact than traditional central plants. At the current state of the technology, there are both positive and negative environmental impacts to be considered.

5.1. Positive impacts

One strong advantage of DG is that it brings the power directly to the end-consumer. This eliminates the hundreds, if not thousands, of miles that the electricity must travel, practically eliminating transmission losses. In 1995, losses from transmission systems were 7.2%, with transmission lines accounting for 60% of the losses, and transformers the other 40% [14].

DG also encourages the installation of renewable, variable output generators such as wind turbines and photovoltaics. While these technologies cannot serve as a primary energy source, they can substitute for a fair amount of grid power, as in the case of the Google headquarters. These technologies are completely clean and emission free, although there are some concerns about the disposal of PV cells.

Lastly, CHP drastically increases the efficiency of manufacturing processes. This increased efficiency not only decreases the amount of energy consumed from the grid, but it also prevents some of the output of hot emissions into the atmosphere. If the estimated full potential of CHP was realized (130 GW installed capacity), 285 million tons of CO₂ emissions would be prevented [15].

5.2. Negative impacts

While DG is often times cleaner than central generation, it still has some emissions. Without considering CHP applications, large, modern, combined-cycle gas plants are generally more efficient than smaller scale generators [19]. However, CHP vastly improves the process efficiency to the point where emissions per kWh are below those of centralized power plants.

Because DG brings the power generation directly to the user, where people work and live, there are concerns that DG will adversely affect air quality. Centrally located plants traditionally have been placed far from population centers, and often include tall smoke stacks to keep emissions from people. In places already having major pollution problems, such as southern California, adding fossil fuel burning DG may exacerbate the already present smog problem. In particular, it has been found that emissions introduced by DG implementation have a highly non-linear response in time and space on pollutant concentrations. This means that planners need to choose not only the type of DG that is installed, but also the spacing of DG within an urban area [20].

6. Barriers

At the time, there are numerous technical, business practice, and regulatory barriers preventing the implementation of DG on a wide level. In a study of 65 cases in which DG was attempting to be installed, only 7 related no major utility-related barriers. 52% of all projects encountered technical barriers; 52% encountered regulatory barriers; and 66% encountered business practice barriers [21].

Note that this section on barriers to entry is based off of a comprehensive study conducted in 2000 by the National Renewable Energy Lab [21]. Already, many progressive states such as New York, Texas, and California have passed legislation supporting the integration of DG, and utilities have begun recognizing the value of DG within the grid. However, these barriers remain prevalent, as stated in the 2007 DOE report required by the Energy Policy Act of 2005 [22].

6.1. Technical

Despite the acceptance of the IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems in 2003 [23], technical barriers encountered usually involve the interconnection issues related to connecting on-site DG to the grid. In these cases, utilities often have unnecessary requirements to ensure safety, reliability, and power quality. Some of the technical requirements asked for include protective relays and transfer switches, power quality requirements, and power flow studies and other engineering analyses.

The main goal of the utilities' safety requirements is to prevent islanding, or continuing to supply power to a portion of the grid that has been de-energized. This is a safety concern for two reasons: islanding may be powering a short-circuit, which could cause a fire; also, a worker may come into contact with what is thought to be a de-energized line. Protection from islanding has traditionally been solved with mechanical switches installed by the generator. However, over the past 20 years, anti-islanding power electronics have been developed that are much cheaper than traditional methods. This circuitry often comes pre-installed in DG systems and has been functioning with good results for the past 20 years.

Unfortunately, utilities are unfamiliar with these types of anti-islanding circuits, and often require the DG operator to install utility approved circuitry at a high cost, or require a lengthy period of time to examine and test the component in question. This substantially reduces or negates the cost savings of many DG projects. For example, an operator of a 0.9 kW PV system was required to pay \$600 for extra anti-islanding protection, as well as an annual \$125 calibrating fee, which offset 65% of the yearly cost savings of the system.

Utilities are also concerned with power quality standards because as much as DG can improve power quality of a system, it can also disrupt it. Utilities require the installation of items like over/under voltage and frequency protection, which is becoming commonly installed in newer DG systems. However, just with the safety requirements, utilities are not familiar with the new technology, and instead rely on traditional, more expensive methods that raise the cost of DG installation.

Another technical barrier being faced by DG operators is that utilities often require an extensive study into the effects of adding the DG capacity to the grid, the cost of which gets passed to the DG operator. Because the operator is paying for these studies, the utilities often will abuse this and go more in depth than need be, incurring extraneous costs and taking extra time. For example, an operator of a 0.9 kW PV system had to pay \$600 for an interconnection study (\$667/kW). However, legislation in states such as New York and Texas is beginning to address these problems, setting output requirements for such a study (for example, only DG operators exporting over 10 kW), time limits, written findings requirements, and providing an estimate of the cost to the operator prior to conducting the study.

It should be noted that most of the items required by utilities are to ensure a safe and reliable grid, which is extremely important. However, the utilities are failing to adapt to and adopt new technology, which is retarding the progress of DG implementation. The technology exists that can make DG cost effective for operators and beneficial to the safety and reliability of the grid.

6.2. Business practice

Business practice barriers constitute the majority of all barriers to DG entry. Business practice barriers include all the contractual and procedural requirements imposed by the utilities prior to interconnection. The barriers often arise from initial contact and requests for interconnection, application and interconnection fees, insurance and indemnification requirements, utility operational requirements, and final interconnection requirements and procedures. The results of cases show a range from outright prohibition of DG interconnection to only needing to notify the utility that DG is being installed.

One of the main problems for smaller DG projects was during the initial contact to the utility. Because interconnection procedures are rarely defined and standardized, it was difficult for DG operators to receive consistent answers from different people within the utility. The length of time required to negotiate and get a

concrete answer from the utility added an artificial and completely unnecessary barrier for the DG operator.

Another major problem facing smaller DG operators are application and interconnection fees, which are typically the same price regardless of the size of the installation. These fees can represent several months, or even years, of anticipated energy savings due to on-site installation.

Utilities often require excessive insurance and indemnification requirements be charged to the DG operator, to pay for damages in the event of problems. Small DG generators argue that installation of IEEE certified DG systems pose a similar risk as normal electric loads attached to the grid, and should be treated similarly. However, utilities disagree with this, and moreover believe that in the event of an accident, the utilities will be the ones forced to pay for damages because they have "deep pockets." As a result, extraordinarily high insurance requirements are sometimes required. For example, one utility required that \$1 million in workers compensation insurance and \$5 million in general liability insurance be paid for by the DG operator. Legislation in some states, such as New York, is beginning to limit the liability requirements imposed by utilities.

In many cases, the utility requires control over the operation of the DG system. This is sometimes used to ensure system reliability, and other times abused to ensure competitive advantage over the DG operator. Some control restrictions required by the utility include full operational control over an installed DG system, denial of use during power outage situations (rendering the on-site installation useless as an emergency backup), and denial of use as a peak-shaver. In the instances in which the DG could be used as a peak-shaver, the DG system would actually be helping the grid by reducing energy demand during peak times.

After all the initial negotiations and fees were worked out, utilities often caused final interconnection delays, waiting until installation was convenient for them. One example is waiting until after the end of the summer, during which there is high demand and stress on the energy grid, to approve a customer's DG installation.

6.3. Regulatory

Regulatory barriers, or regulations imposed by both the utilities and governments in the area of DG, also create barriers. Some regulatory barriers include direct utility prohibition, tariff barriers, selective discounting, and environmental permitting.

Direct utility prohibition can come as a result of either the utility or legislative body. As DG is often seen as direct competition for the utility, in many cases it will stop at nothing to prevent a project from becoming a reality. Utilities will often deny DG operators the right to install on-site power, and, in extreme cases, lobby the local government to enact legislation that prohibits the installation of DG. As a result of lobbying by utilities, local governments will either outright prohibit DG installation, or subtly change zoning regulations in the area in which the project is proposed.

In most cases, the utilities offered unfavorable tariffs to DG operators. These tariffs include demand charges and backup tariffs, buy-back rates, uplift tariffs, and regional transmission procedures and costs. Demand charges and backup tariffs are charged when a DG operator wants to remain connected to the grid for backup purposes. Often times, these charges are prohibitively high and do not reflect the actual cost of the utility to keep the DG generator connected. Buy-back rates are, in many cases, quite low at only 1.5–2 cents/kWh, and usually do not fluctuate with the peak power rates, which DG is most useful for. Uplift tariffs are meant to reflect the cost associated with sending the power to the transmission network. However, because of the localization of DG, transmission networks are rarely used. Along the same lines, DG operators are usually charged for the expected losses (7–10%) associated with

transmitting power over long distances, despite that fact that the power is often used locally within the distribution network.

When a large DG project is proposed to the utility, it is not uncommon for the utility to offer discounts in pricing in order to negate the cost savings of DG installed. The result is often a rate reduction if the operator opts not to install DG. DG system vendors and utilities are sometimes forced to negotiate against each other, so that the potential DG operator can get the best price possible. While this is advantageous to the customer, it retards the progress of the industry, and fails to take into account all the non-economic benefits that DG has to offer, such as higher efficiency and reduced environmental impact. Also, these rate reductions are often only temporary, and within a few years the potential DG operator's rates rise back to the normal level.

Environmental permitting is often a costly and lengthy process, which is prohibitive to smaller DG projects. For example, a 60-kW natural gas installation was required to pay \$2500 for initial permitting, and then \$200 each month after for inspection. This is despite the fact that new, efficient DG is often replacing older, inefficient, and more highly polluting sources, such as central coal plants. Additionally, environmental permitting usually only takes into account combustion efficiency, not overall energy efficiency that could be found in CHP applications.

6.4. Ways to reduce barriers

The problems associated with many of the technical and business practice barriers seen come as the result of lack of standards. Developing and implementing technical standards, such as those by the IEEE, will ease some of the worries that utilities have about connecting DG with their grid. Along the same lines, standardized business practices will reduce much of the confusion faced with DG operators when proposing a DG project to a utility. Implementing these standards can be beneficial to both utilities and DG operators.

Additionally, legislation needs to be passed to protect free market rights of DG operators. Because utilities currently have all the negotiation power, they are able to charge ludicrous fees and charges that discourage or prohibit the installation of DG. As the electricity market becomes more liberalized, legislation needs to be enacted to allow DG operators to compete. Again, this can benefit both DG operators and utilities, as DG can help solve a lot of demand problems that many utilities face around the country. The Energy Policy Act of 2005 was a step in the right direction to support DG, and particularly CHP; however, more action must be done in order to ensure that DG achieves greater penetration.

6.4.1. California

After discussing all the barriers that DG has to overcome, it is important to provide a role model for solving these problems. That role model is California, which has transformed itself from a state known for brown-outs due to electricity mismanagement to a state modernizing its grid and leading the fight against climate change. As of 2004, California had 3500 MW of installed DG, which represents 20% of all DG installed in the US [24]. According to the vision of the California Energy Commission, "distributed generation will be an integral part of the California energy system, providing consumers and energy providers with safe, affordable, clean, reliable, and readily accessible energy services." Clearly, California sees DG as the power generation method of the future [25].

Using the NREL's report on DG barriers, the California Energy Commission created its own DG Strategic Plan [25]. This document directly addresses all of the barriers discussed by the NREL. The report suggests which government agency is best suited to solve these problems, at the local, state, or federal level. It describes what work was being done by the state to address these issues (as of 2002), as can be seen in Fig. 5. The report also lays out a series

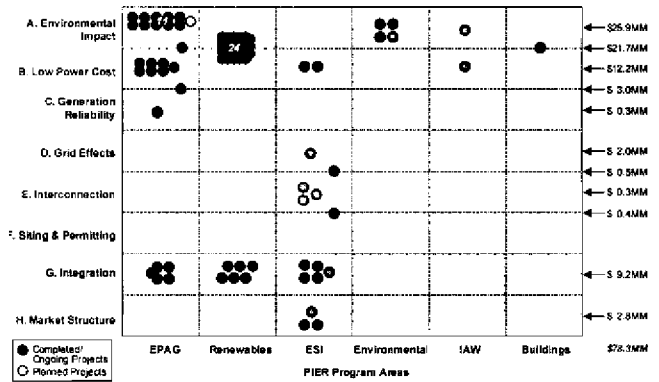


Fig. 5. Portfolio of PIER Projects Addressing Distributed Generation Issues [25].

of short-term, mid-term, and long-term strategic goals to achieve in the area of DG. This report is a great resource for lawmakers and potential DG operators, as well as a model for other state energy commissions.

Another resource that California offers is an online Distributed Energy Resource Guide (<http://www.energy.ca.gov/distgen/index.html>). On this website, potential DG operators can find information on everything related to DG in California, including technology, research, example installations, economics analysis, state incentives, interconnection standards, permitting requirements, regulatory activity, and strategic planning. This website shows that California has addressed many of the technical, business practice, and regulatory barriers of DG.

7. Future research

Experts in the field agree that the future of the power generation will be distributed. This change will be accompanied by many growing pains, but in the end will result in more reliable and cheaper electricity.

The traditional electric grid has been one-way in terms of power flow. Electricity is generated in central stations, and then sent to the customer via thousands of miles of transmission lines. With the rise of DG, power will begin traveling in two directions: to and from the end-user. The grid needs to be improved in order to accept this added complexity and fully take advantage of the benefits that DG has to offer.

The grid needs to be upgraded to a "smart" grid, which not only transmits power but also communicates with every spot on the grid. The smart grid could function like a communications network, in which utility computers could communicate with distributed generators. In times of high demand, the utility could buy power from the distributed generators in order to supplement grid power. Utility companies gain increased reliability and lower operating costs, while distributed generator owners receive money at peak prices. Also, to improve reliability, the grid should constantly be monitoring a variety of parameters, such as voltage, current, real and reactive power, power quality, and connection/fault status [26].

Speaking in more theoretical and futuristic terms, DG would be instrumental if electric cars were ever to replace combustion engine powered vehicles. Studies have been done on vehicle-to-grid (V2G) technology, in which electric vehicles function as part of the grid, selling and buying power when it is most economical for the customer. Not only would this assist the US in reducing dependence on oil, but it would also stabilize grid fluctuations. In times of peak demand, vehicles could sell stored energy to the grid to meet demand. Then, during low demand periods, the vehicles could buy power to recharge their batteries. The demand curve would be flattened by essentially having millions of generators and energy

storage devices on the roads. With the advent of plug-in hybrid-electric and pure electric vehicles such as the Chevrolet Volt and Nissan Leaf, an electric car future may be closer than previously thought.

8. Conclusions

This paper presented an overview distributed generation within the context of the United States. Despite barriers constructed by utilities and regulators, distributed generation is a key to meeting future demand with cleaner and more efficient methods than currently used in central power plants. The technology is already in place and improving, particularly in the areas of wind, solar, and fuel cells. The environmental improvements are undeniable, though not perfect due to the proximity of emissions to the population. Given the proper regulatory structure, distributed generation, particularly when implemented as cogeneration, presents a highly attractive economic investment that could benefit both the user and the utility.

Distributed generation received a great push with the Energy Policy Act of 2005. With the act came an extensive study of the potential of distributed generation in the United States. Despite this, more work needs to be done in order to convert potential into reality. Federal policy needs to trickle down into regional and state regulatory policy. Transmission and distribution system operators must focus on the barriers presented and consider ways not only to remove them, but also encourage the implementation of highly efficient, clean distributed generation.

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