GSGF>>REPORT

GRID_CONNECTIVITY_OF_DISTRIBUTED_GENERATION

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Electricity systems worldwide are changing rapidly. During the last decade, technological advances and (inter)national objectives related to sustainability, security of supply and competitiveness have been driving both the physical outlook of the power grid, as well as the policy and regulatory frameworks. Because of the continuing electrification of energy demand (e.g. transport, heating,..) these developments also have a profound economic impact. Common international trends include the integration of vast amounts of distributed and renewable energy sources into distribution grids, the empowerment of consumers and the encouragement of active demand side participation, the increased load on distribution grids, the development and roll-out of new metering infrastructure, the introduction of distributed energy storage and the establishment of competitive electricity markets.

Historically, power systems were characterized by centralized generation, largely based on fossil fuel, nuclear and large hydropower. The current value chain is undergoing a paradigm shift towards a more dynamic and distributed system, with significant renewable generation. However, limited storage possibilities still require grid operators to maintain a balance between supply and demand, and, in addition, market participants are subject to high reliability standards. Furthermore, competition and regulation typically drive cost efficiency, but they put a strain on the investment in grid extensions, the replacement of ageing infrastructure and the development of smart grids. Because of these conditions, many distribution systems are being operated closer to their design capacity. Additionally, the connection of distributed generation to the existing grid creates challenges related to power quality, voltage and frequency management, congestion, balancing and reliability.

This report outlines the worldwide developments of the distributed and renewable generation connection to the distribution grids. It provides a detailed and accessible overview of the primary global trends, as well as country-specific aspects of distributed generation integration, based on the results of a survey carried-out with various GSGF member countries, including Denmark, Ireland, Japan, Canada, Korea, Australia and the USA. In particular, this work deals with technological, economic, policy and regulatory aspects of distributed generation. For each of these categories, national trends, problems, proposed solutions, and success stories are examined. It is found that, although different countries are typically characterized by a different generation mix and distribution system structure, most nations worldwide experience a significant increase in integration of distributed generation in general, and renewables generation in particular. Regarding the latter, many countries have committed to ambitious targets of renewable integration. However, this survey confirms that the traditional design of power systems and market regulation often does not adequately support them.

From a technological perspective, it is found that maintaining power quality, managing voltage and frequency levels, increasing consumption, standardization and interoperability issues are major challenges related to distributed generation. Many countries address these problems by funding smart grid R&D projects and by exploring the potential of active demand and distributed storage in mitigating the cost related to grid expansion and replacement.

Challenges related to policy and regulations include regulatory instability and complexity, a lack of standardization and interoperability, unclear definition of roles and responsibilities, and a strong emphasis on cost-efficiency and competitiveness restraining innovation. To incentivize smart grid investments and "green" solutions, countries often resort to mechanisms such as feed-in tariffs, tax benefits, subsidies, accelerated depreciation.

Integration of distributed generation is also found to have profound economic consequences, because of the stimulation of economic progress and employment through manufacturing and construction of new facilities and infrastructure. The incentive schemes associated with distributed generation also have a significant impact on governmental revenues and expenses. Typically, incentive mechanisms are adapted or lifted when technology matures and becomes more cost-efficient, allowing competition with traditional sources. In some countries, distributed generation has a positive impact on system reliability, especially when consumers are geographically dispersed and in the context of microgrids. Lastly, it is believed that distributed generation can decrease a nation's energy dependence on other countries, and thus increase its national security of supply.

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1 INTRODUCTION

During the last decade, electricity markets have experienced substantial changes. From a structural perspective, there has been a fundamental overhaul in the way this sector is organized. In Europe, for instance, energy policy has made a significant push towards unbundling and increasing market competition. At the same time, technological progress colors the energy landscape. Nations worldwide expressed interest in the development of renewable and distributed energy sources. Whereas the historical power system was characterized by centralized generation, largely based on fossil fuel, nuclear and large hydropower, the current value chain is undergoing a paradigm shift towards a more dynamic and distributed electricity system. On the other hand, some aspects of electricity markets remained fairly unchanged. Limited storage possibilities generally require system operators to maintain a balance between supply and demand, and market participants are typically subject to very high reliability standards.

In this report, distributed generation (DG) is considered conventional as well as renewable. Conventional DG is based on fossil fuels, for instance natural gas or diesel, which is either coupled to the grid synchronously, or coupled by inverters which convert direct current (DC) sources to alternating current (AC). Renewable DG comprises many renewable technologies, such as wind, solar, biomass, biogas. It may also encompass combined heat and power (CHP). In principle, CHP can be based both on fossil fuels and traditional "brown" technologies, and on clean, low-emission fuel cell technologies.

DG has been a power supply option for as long as the electric power industry has existed. In many parts of the world, it is not economically feasible to extend the power grid and supply electric energy from centrally-generated sources. Therefore, options such as photovoltaic solar, diesel or gas-fueled small generators, and sometimes combines with battery storage technology can fulfill short-term electric needs as a primary or back-up source. On a larger scale, combined heat and power (CHP) systems, with the right fuel pricing and grid interconnection incentives, can provide both electric power and process heating needs for commercial and industrial establishments. However, integrating a vast amount of distributed generation units has a considerable impact on system operation complexity, especially on the distribution level, where the greatest challenges can be observed.

This report provides an accessible overview of the primary global trends, challenges and solutions with respect to grid connectivity of DG. In particular, this work looks at three different subjects: technology, policy and regulation, and economics. The reason is that all these aspects have a considerable impact on the outlook of the electricity market in general, and the development of DG systems in particular. In order to obtain a clear view of what challenges are being faced across different network geographies and which solutions are being put forward, GSGF carried-out a survey across its member countries. This document is largely based on the information provided by Denmark, Ireland, Japan, Canada, Korea, Australia and the USA.

In most typical power systems, power is generated at a number of large centralized power stations using fossil fuel (coal, gas and oil), nuclear or large hydropower with the transmission and distribution (T&D) system used to transport this centrally generated power to the industrial or residential consumer.

Many T&D system operators are charged with the primary goal of delivering energy at 99.9% or better availability rates to consumers, in a ready to use form, on a continuous basis. The requirement of high availability naturally leads to very high standards of reliability. As a result, the electric power system has been developed into an extremely complex network that can be essentially viewed as one machine, reaching across national borders, consisting of mixed interacting components.

Running such a power system is technically complex. Add the growth of distributed generation (DG) within national systems, particularly on the distribution side of the network, and this complexity increases considerably.

As part of our survey across member countries of the GSGF, this study group posed the following questions in order to gather a clear view of what challenges were being faced across different network geographies and what solutions were being put to work to address those same challenges.

1. What key technological trends and/or barriers exist that delay or prevent the connection of DG systems to the distribution network?

2. How are these trends being addressed in specific countries or regions of our review?

3. What existing or emerging technologies (e.g., hardware, software) are being developed or tested that are most prevalent to resolving these identified issues or barriers?

4. How are specific regions or countries supporting R&D to prove out some of these new technologies?

2.1 Overview of technical challenges

Traditionally, distribution systems and the power system as a whole have been highly developed with a considerable level of redundancy built into it. With liberalization of the electricity industry and the introduction of electricity markets, these principles are being influenced by the need for cost effectiveness. The connection of DG has pushed the operation of the distribution system closer to its design capacity. This pressure to get more out of the existing assets can pose problems in terms of security of supply and reliability. Operating a system closer to its limits is not inherently detrimental, but it does inevitably lead to a number of network issues or constraints that should be considered.

The introduction of DG will change the characteristics of the power system. A number of technical constraints and factors arise which are impacted by the amount of DG connected: equipment ratings, system short circuit considerations, voltage and frequency changes, power quality, protection systems, losses and system reliability and safety. These issues are discussed below.

Equipment Ratings

Ratings of existing lines, transformers, buses, etc. cannot be exceeded. Much of this equipment has been designed for the traditional power systems that are now being asked to handle the newly introduced generation. Curtailment of generation output is being implemented by operators to ensure ratings are not exceeded.

Short Circuit considerations

Short Circuit Level (SCL) and Short Circuit Ratio (SCR) need to be respected as SCL gives an indication of the strength of the electrical system and SCR, if exceeded can lead to voltage instability.

Voltage Rise and frequency

Active and reactive flows are altered with the connection of DG, which in turn has influence on the voltage along the power lines. Non-urban areas present a bigger challenge due to low demand and a growing level of generation being connected. Voltage levels on the distribution network are controlled by adjusting transformer taps or by voltage regulators – equipment that has discrete steps for adjustment, and can electromechanically change tap settings within a number of tens of seconds. With DG such as solar, the power change is in the order of seconds or even less. In the case of large amounts of PV generation, rapid voltage fluctuations can force transformer tap regulation and line voltage regulators to continually change tap levels and hunt for the best voltage level. Persistent tap changing of voltage regulators to manage constant voltage fluctuations can reduce the useful life of this equipment and can contribute to instability of the distribution network. Voltage from a distributed system that is not connected to the grid will generally have a higher voltage harmonic distortion, which can result in malfunction of sensitive consumer end-use devices.

Power Quality

Variability of the energy source, e.g. wind, solar and the introduction of technology such as power electronic converters to allow interface to the power system have contributed to the severity of voltage flicker and harmonics. This leads to greater care needed during the planning and design stage; however it is worth noting that DG also has the potential to improve the power quality, through its contribution to the short circuit level.

Protection

Most distribution networks systems are operated on unidirectional power flows from the higher voltage transmission system down through the lower voltage systems. DG is now altering the flows on the distribution and transmission systems, which can lead to unwanted protection detection and tripping. New methods of protection detection and new protection philosophies will need to be implemented to cater to the new DG paradigm within the distribution system.

Reliability and Safety

Measures of SAIFI (System Average Interruption Frequency Index) and SAIDI (System Average Interruption Duration Index) are used to measure frequency of supply interruption and duration respectively. With the introduction of DG, the use of islanding can be enabled through the sharing, exchanging and recycling locally produced and locally power-matched energy within an island cluster, thus contributing to greater reliability of supply to customers. The concern with islanding is where the DG unit continues to energize a feeder even though the electric utility is no longer supplying power due to an outage or other cause. This creates a very high safety risk to utility workers who might not realize that a circuit is still energized.

Another remote consequence of very high DG penetration levels could be a system-wide blackout. If an area or region had a very high number of DG installations – on the order of 10,000 100-kW generators – and a bulk system event occurred that caused these DG systems to trip, it could have the same impact as losing a nuclear plant.

In addition to reliability, the grid enables such things as compressors and air conditioners that require a strong flow of current to start up without severe voltage fluctuation. Therefore, in the case of DG, it is the customer's grid connection that supplies the majority of this required starting power.

Losses

With the introduction of DG, traditional networks are now expected to operate in a new manner. Electrical losses are inherent in electrical networks and with the wider inclusion of DG bi-directional and more variable power flows become the new norm. As losses are related to current flows i.e. losses will quadruple with a doubling of current, DG, being located closer to the distribution loads, will present a significant opportunity for improving network losses. It is worth noting that rotating-engine-based distributed resources, such as micro-turbines or CHP systems are most efficient when operating steadily near full output. Without grid connectivity, the output of a distributed generation resource must match changing load demand, which could reduce efficiency by 10% to 20%.

2.2 General trends

Network operators in many mature markets will face the above technical challenges within their system. Each system operator has addressed the challenges faced in differing ways with no one solution being the right one. Introducing a greater level of DG will require using the most practical approach and an understanding by the new generating entities of the importance of a grid that can eventually be more flexible to allow more participants.

As a sample, the following is what is being implemented to help the introduction and further growth of Distributed Generation in the countries discussed.

- Var Voltage management
- Self-healing grids
- Dynamic line rating
- Greater interconnectivity between system operators
- Active network management
- Demand response mechanisms
- Microgridding
- Advanced metering solutions
- Energy efficiency
- Improved data analytics of the above area

2.3 Country-specific aspects

2.3.1 Denmark

Denmark is European leader in the development of smart grids. 22% of all demonstration and development projects relating to intelligent power grids in the EU take place in Denmark. Germany is in second place with 11%.

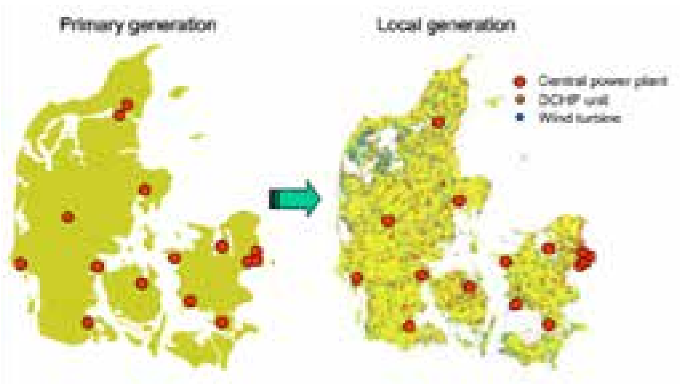


Figure 1: The Development in Denmark from Centralised to Decentralised Generation Systems. Source: Cell Controller Pilot Project, 2011, Energynet.dk

The Danish government established a goal that the entire energy needs of Denmark will be met by renewable energy by 2050. The government's goal assumes the phasing in of renewable energy on a massive scale, and by 2020 half of the traditional electricity consumption must come from wind power[1].

There are over 90 DSOs where the seven largest grid companies distribute electricity to more than 100,000 consumers each, which together account for 60% of all consumers in the country. The next smaller 50 companies with less than 10,000 consumers each account for fewer than 5%[2].

Denmark's DG is mostly represented by wind energy and industry cogeneration (with a small share of hydro) and was developed between the early 1980s up to present by a mix of compulsory targets and subsidies for renewable energy[3].

The Danes have one of the world's most energy efficient systems due to an extensive expansion of district heating that utilizes renewable energy and heat from combined heat and power (CHP) units.

[1] Smart Grid in Denmark 2.0, 2012, Danish Energy Association
[2] RES-INTEGRATION – Country Report Denmark, December 2011, Eclareon
[3] Perspectives for Distributed, October 2011, Americas Competitiveness Forum

In order to transform the energy system intelligently and cost-effectively, continuous research, development and testing of new technological solutions has been identified as required. Initiatives include:

- DKK 60 million has been committed to funding the development and use of new renewable energy technologies for electricity production (solar, wave power, etc.)
- DKK 35 million has been committed to funding the development and use of new renewable energy technologies in district heating (large heat pumps, geothermal energy, etc.)
- DKK 9.5 million has been committed to the project to make the island of Samsø independent of fossil fuels[4]

Considering the barriers to adoption, converting to a Smart Grid requires considerable investments. The present regulation of the grid companies assumes that all costs and investments are driven by traditional grid components. Companies wanting to use a Smart Grid are automatically put at an economic disadvantage, which discourages them from converting their distribution grids to a smart grids.[5] Additionally, grid companies do not have a real option of using price signals as a means of activating customers' flexibility. Today there are 3.2 million electricity customers who are not subject to hourly settlement and therefore do not have a financial incentive to respond to price signals.

For Energinet.dk (the TSO), the main challenges include balancing consumption and production and maintaining voltage stability to ensure the stability of the power system. For the DSOs, the main challenges consist of handling increased loads in the distribution grid due to higher electricity consumption and increased local production capacity, while at the same time maintaining high-quality deliveries to consumers.[6]

In order to address some of the barriers, Denmark has put in place a joint Smart Grid concept. The electricity sector through Energinet.dk and the grid companies invite suppliers and other stakeholders to develop new solutions and products to support the approach. The concept is based on the mobilization of currently unused and potentially cheaper resources, i.e. flexible electricity consumption and production, leading to socioeconomic benefits. Mobilization involves using the properties of electricity-consuming and electricityproducing resources to control active power output, as well as activating their potential voltage control properties. The concept also creates a framework that will allow all the players involved to create additional value by activating what is today an unused resource (i.e. the flexibility of the electricity consumption and production of even smaller customers).[7]

In order to facilitate the establishment of new technologies in the network, grid companies are taking additional measurements, at strategic points in the distribution grid, and setting up operations support systems which, based on the measurements, can facilitate greater capacity utilisation in the existing grid. The measurements must be used by future planning and dimensioning tools. At the same time, increased awareness of load levels can be used to define new specifications for components and protective equipment.

To operate the power grid closer to its capacity limit while electricity consumption and production become more unpredictable, a higher degree of monitoring and estimation is required. Operations support systems must, in the long term, perform state estimations, operational simulations, shortterm prognoses and the activation of regulating services. The individual grid companies have different needs and requirements regarding their operations support systems; for example, data availability will differ.[8]

Denmark has been active in facilitating R&D support to prove some of these new technologies. Over the last few years, public funding for research in Denmark has increased, and in 2011, approximately EUR 135 million was allocated for research. In addition to this, European funding is contributing further to the development of smart grid technology in Denmark. One of Europe's most ambitious smart grid projects is currently taking place on the island of Bornholm in Denmark. The full-scale EcoGrid project is aiming to lead the way in establishing the energy system of the future. Over the next few years, the largest intelligent power supply system in the world will be set up on Bornholm, and the project will test and demonstrate how a region can become fully self-sufficient with renewable energy.

Denmark has a number of world class universities and a highly educated work force. In Denmark, the production of scientific articles on climate technology per million inhabitants is 70. This is four times as many as in the US and EU, being 16 and 17 respectively.[9]

[4] Smart Grid in Denmark 2.0, 2012, Danish Energy Association
[5] Smart Grid in Denmark 2.0, 2012, Danish Energy Association
[6] Smart Grid in Denmark 2.0, 2012, Danish Energy Association
[7] Smart Grid in Denmark 2.0, 2012, Danish Energy Association
[8] Smart Grid in Denmark 2.0, 2012, Danish Energy Association
[9] Denmark: A European Smart Grid Hub, 2013, Clean Tech

2.3.2 Ireland

Source: Eirgrid Annual Report (www.erigrid.com)

Ireland's transmission and distribution system is a small synchronous system in comparison to continental Europe, with limited connectivity to the Great Britain network through two HVDC links. The introduction of distributed generation (predominantly Wind in the case of Ireland) onto such a grid presents many technological challenges for System Operators and has been well documented through the current "delivering a Secure Sustainable Electricity System" (DS3) programme[10] by the local TSO, Eirgrid/ SONI.

The immediate issues are frequency response, voltage control/ regulation, inertia monitoring capability with high levels of renewable generation. Additionally, protection coordination becomes more challenging. With increasing short circuit levels with the increase of DG on the local grid, maintaining power quality in islanding situations becomes a concern. System security, if not readdressed, can create nuisance tripping of DG on the grid. Low power factor scenarios require review of allowed operational settings and long cable connections can lead to upgraded or differing earthing requirements in the grid.

Barriers to faster connection of DG without introduction of constraints in generating output comes from the network capacity available to transport the new generation in remote areas of the grid, which tends to be designed for low load delivery rather than high capacity generation delivery. With increasing amounts of embedded generation connected, the Irish distribution system can no longer be considered to be a truly passive radial system.

Irish TSOs (EirGrid and SONI) have carried out studies and analysis of the all-island system through the facilitation of renewables programme[11] and the key messages from these studies are that the 2020 renewable targets set by governments in Ireland and Northern Ireland are achievable; however, significant challenges to the operation of the system will have to be overcome.

To manage the achievement of these targets over the coming years, EirGrid and SONI have established the (DS3) programme. This work programme includes enhancing generation portfolio performance, developing new operational policies and system tools to efficiently use the generation portfolio to the best of its capabilities, and regularly reviewing the needs of the system as the portfolio capability evolves.

Both Distribution and Transmission Network Operators on the island of Ireland are currently focused on a major Smart Grid project titled the North Atlantic Green Zone (NAGZ)[12]. The focus of the project is to reduce customer outage minutes experienced in a given year, reduce the impact of curtailment by implementing smart changes in the zoned area of the electrical gird and to implement other energy services to allow more power to flow out of the area. One of the hard criteria of the operators is to move beyond pilot or trial stage and implement proven technologies into the live system. Once implemented, the solutions that will evolve in the NAGZ have the potential to be implemented across the Irish system to push Ireland into a fully implemented Smart Grid system.

Being a synchronous island system, the stability of the electrical system has always been the key focus of the operators. However, both TSOs and DNOs have nurtured pilot programmes in their networks to allow identification of greater flexibility, greater participation and greater intelligence in the system.

2.3.3 Japan

Japan's electric infrastructure comprises two main power grids. The western part of the country operates a 60-Hz system, while the eastern section, including Tokyo and Fukushima, runs on 50 Hz.

Ordinarily, this isn't a problem — there are enough power plants in each of the grids to allow electricity to be shifted around if there are spikes in power demand or outages at a plant. There are also ways to pass some power across the 50/60 Hz divide for a limited amount of power (1200MW through 3 frequency conversion stations).

[10] Eirgrid: Delivering a Secure Sustainable Electricity System (DS3)
[11] Eirgrid: Facilitation of Renewables Workgroup
[12] ESB Networks: North Atlantic Green Zone Project

Source: Institute of Energy Economics, Japan; USGS
Credit: NPR

Distributed generation in Japan is recognized not only as efficient, but also as emergency power source for citizens after the great East Japan Earthquake in 2011. Installed capacity of distributed generation in Japan is accelerated by Feed in Tariff policy in 2012-2013. Hokkaido and Tohoku regions have enough places to install wind and solar power systems; however the transmission capacity of Hokkaido, Tohoku and Tokyo has become a bottleneck. Therefore, the focus of DG development is being shifted into the quality and stability of voltage and frequency output.

The trouble comes when there is a big, unplanned shortage of power, such as what happened with the destruction of the Fukushima Dai-ichi nuclear power plant in 2011. Many of the Japanese reactors that have shutdown for routine maintenance since Fukushima have no firm date in sight for reopening. Japan has changed from an energy system that counted on 30% of its electricity[13] from nuclear power plants to one where nuclear is slowly being removed. Creating new links between the 50 and 60 Hz systems is hugely expensive and will take years to deliver. Replacing such a large generating source in such a short space of time requires more than distributed generation and smart grid initiatives; therefore an appreciation of some of the Japanese systems complexities is worth highlighting.

Since the natural disaster, the installed capacity of renewable energy exceeded the upper limit due to lack of the capacity of power transfer. Under such circumstances, the expansion of transmission capacity (especially between Hokkaido and the main island) and the installation of grid-connected power storage are generating a great amount of interest in Japan. The number of independent power producers generating from distributed sources has tripled, due mainly to the new feed in tariff mechanism for renewables. Distributed generation now accounts for 10% of the energy mix; however to replace the high percentage of energy that nuclear once held, remains a considerable challenge.

Hokkaido and Tohoku regions are best suited for installing wind and solar power, as the conditions are good and there is enough land to allow development. Currently a HVDC interconnection line between Hokkaido island and the main island is being reinforced (600MW+300MW) by Hokkaido Electric Power Company (HEPCO) & J-Power. It addresses the transmission capacity between the regions, as renewable energy installation has increased considerably on Hokkaido Island. The transmission system to export the power further South will also need reinforcement. Additionally, as these sources of power are variable, development of backup power supplies (e.g. CCGT) and power storage in substations is planned within the electricity system[14]. The demonstration of grid-connected power storage (Redox flow: with a capacity of approximately 60 MWh) consists of storage batteries and is expected to increase HEPCO's interconnection capacity by 10% and contribute to control the load frequency and reverse power flow. Another project that demonstrates grid connected power storage (lithium-ion battery with a capacity of approximately 20 MWh) has been started by Tohoku Electric Power Company and METI (Ministry of Economy, Trade and Industry) for a similar purpose.

R&D activities of distributed generation in Japan are mainly supported by METI and NEDO (New Energy and Industrial Technology Development Organization). METI has been supporting "Next-Generation Energy and Social Systems Demonstration" since 2010 with 4 cities (Yokohama, Toyota, Keihanna and Kitakyushu) being selected. From this demonstration, regional energy (electricity and heat) management system was established and the regional energy such as biogas, waste heat, solar power and co-generations were integrated. It is for these experiments to demonstrate complementarities between a regional nano-grid and the national grid.

NEDO has been supporting R&D in smart grid technologies for the past several years, such as, the mega-solar power demonstrations in Wakkanai and Hokuto. The objective is to develop the PCS and storage (NAS: sodium(Na)-sulfur(S) battery) suitable for large scale PV for voltage and frequency stabilization. The system is combined with a weather forecasting system and can be operated based on the output plan supported by NAS storage.

[13] The Economist - Electricity in Japan - Power Struggle; Sept 21st 2013
[14] METI Press release - METI Selected Successful Applicants that will Introduce Large-scale Storage Batteries into Electricity Grid Substations and Commit to Expanding the Introduction of Renewable Energy; July 2013

2.3.4 Canada[15,16]

Source: Centre for Energy

The Canadian grid is part of a North American transmission system which is comprised of three major interconnected grids: (1) the Eastern Interconnect, which spans the entire eastern and central states, (2) the Western Interconnect, which spans the Pacific Rocky Mountains and southwestern states in the U.S., and (3) the Electric Reliability Council of Texas interconnect which includes most of the State of Texas. In Canada, only the Provinces of Ontario and Alberta have independent grid managers: the Ontario Independent Electricity System Operator and the Power Pool of Alberta, respectively.

As the world's third largest hydropower[17,18] producer, generating 372 TWh/year, hydro accounts for aproximately 63% of Canada's electricity production. Provinces such as British Columbia, Manitoba, Ontario, Quebec and Newfoundland and Labrador are rich in water resources. As an example, in the Quebec[19] region there are 65 power plants totaling more than 350 MW connected at medium voltage and a few connected at low voltage. As an indicator of the growth in DG in the area, since 2012, two new hydraulic plants (15 MW), 3 new biogas and biomass plants (26 MW) have been integrated, all connected at medium voltage. In the next two years, another 125 MW of wind power plants will be added.

While it is important to weigh the costs and benefits of DG within a sustainable energy framework as a whole, Canadian utilities are more specifically concerned with the technical feasibility of integrating large amounts of intermittent power into the existing grid infrastructure. Without storage, which is an expensive addition to any distributed generation project, the power output from DG installments is typically highly variable, both hourly and seasonally. Changes in protection schemes, voltage stability, standardization of interconnectivity and access to real-time data from DG to facilitate better decision making or automation on the grid are some of the principal concerns. Furthermore, many parts of Canada's electricity system are ageing, which means Canada needs to invest significantly in refurbished or new electricity infrastructure by 2030.

Smart Grid is very much the solution and aim of Canadian utilities to achieve desired customer priorities, interoperability with legacy infrastructure, and be appropriate for use with respect to geographical location and other needs such as demand response, facilitation of distributed generation, facilitation of electric vehicles, optimization of asset use, and problem detection and mitigation.

Many of Canada's power utilities have smart grid strategies in progress to address the issues in their systems. Hydro One in Ontario is one of the first jurisdictions in North America to equip every home and small business with a smart meter. It also continues its Advanced Distribution System trial, modernizing its distribution system and realizing its vision of a smarter grid. The first deployment stage of its Smart Grid for advanced distribution will include a subset of its service area in Southern Ontario known as the Living Lab. Figure 2 illustrates part of Hydro One's service area near Owen Sound, Ontario. Those areas offering representative insights for the technology and processes to assist with future rollout, will go first in the Living Lab area, followed by other areas in the province in order of priority.

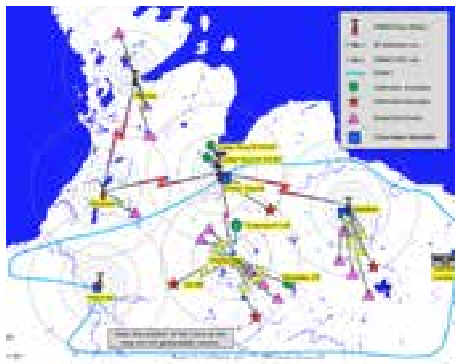


Figure 2: Hydro One Living Lab area

The largest North American initiative for the reduction in carbon emissions has been the closing of coal-fired generation by 2014 in Ontario, as mandated by the provincial government. To fill the resource gap, the province has required that 10,700 MW of renewable energy (wind, solar and biofuel) will be added to the grid by 2018. It is expected that nearly 5,000 MW of this renewable energy will be connected to the distribution system. The Feed-in Tariff program established by the government has provided generous payout. Although the rates payed by the government have come down in the last years, there are high enough to encourage producers to launch renewable energy projects and connect them to the grid.

[13] The Global Smart Grid Federation 2012 REPORT
[16] Distributed Generation in Toronto: A Stakeholder Survey of Barriers and Benefits, April 2009, World Wildlife Fund Canada
[17] Canada's Electricity Supply, 2014, Power for the future
[18] Hydro Power, 2014, Power for the future
[19] Distributed Generation at Hydro-Quebec, September 2013, Smart Grid Canada

New Brunswick Power (NB Power) has entered into a multi-year agreement with a smart grid multinational solutions provider to integrate smart grid technology into the province's electrical system and to create a Centre of Competence, with an estimated staff of 40, based in Fredericton, New Brunswick. As part of the initiative, the two companies will work together to accelerate the benefits of NB Power's Reduce and Shift Demand strategy. The new technology will help NB Power to understand customer usage in real time and by collaborating with customers to reshape electricity demand on the electricity system.

Toronto Hydro captures and processes interval data for transformer smart meters, bi-directional meters used for solar panel electricity generation (energy used and energy generated) and electric vehicle charging stations. They are currently rolling out a community energy storage project focused on improving power quality, energy flow and reliability; reducing peak demand and offering temporary relief in neighborhoods at risk; removing the need for diesel generators; facilitating the integration of renewable technologies like solar panels and electric vehicles; helping to keep voltage levels constant for commercial and industrial customers; and actively monitoring grid conditions and responding dynamically.

In terms of research, the NSERC CREATE Program[20] in Distributed Generation for Remote Communities (DGRC) is the first program in Canada to train personnel to integrate clean energy technologies into distributed generation systems that work in the remote settings of Canada. Through partnerships with community, institutional, and industry stakeholders, the aim is to provide trainees with a diverse research and training program that is internationally unique and launch them into successful careers in the energy sector. EPCOR has partnered in the past with University of Alberta[21] in sponsorship of a distributed generation research project to look at reducing anti-islanding costs to enable small independent power producers to tie small generators onto distribution systems more cost-effectively.

2.3.5 Korea[22, 23, 24, 25]

Source: Korean Power Exchange

South Korea has pushed the introduction of distributed generation technology into the electrical system since the early 2000s through programs such as NRE (New and Renewable Energy). It has continued to develop the strategy through a very clear roadmap for smart grid development, which sets as its target the implementation of a nationwide smart grid by 2030.

Much of the large generation capacity of South Korea is located in the South, with a relatively large quantity of energy flowing North. DG connected to the transmission system is considerable and consists of wind. DG connected to the distribution network totals approximately 2000 MW. The mix of the distributed installed base is represented in Table 1.

The growth in power demand in Korea has been one of the highest globally for some years. This drives the requirement for power capacity, with which come the issues of an expanding system needing greater interconnectivity, rising fault levels, rising capacity levels in equipment and a requirement to introduce higher voltage levels in the system. The key barrier for the introduction of significant DG onto the Korean electrical system has been the voltage management problem that tends to manifest as overvoltage. Connecting numerous DGs to the system creates changes in the topology of the distribution network. Additionally, the network operators have had little control on the DGs and their outputs.

	PV	Wind	Waste to energy	Small hydro	Land fill gas	Fuel Cell	LNG	Other	Total
Num. of sites	54,488	91	25	96	15	298	57	44	**55,114**
Capacity (MW)	1,036	70	67	127	26	38	473	133	**1,970**

Table 1: DG capacity connected to the distribution system

[20] Distributed Generation For Remote Communities, 2014, DGRC
[21] Distributed Generation, 2011, EPCOR
[22] South Korea: Jeju Island Smart Grid Test-Bed, 2012, GSMA
[23] Renewable Energy and Distributed Generation Task Force, Asia-Pacific Partnership
[24] Korea's smart grid policy and deployments, December 2012, Ministry of Knowledge Economy
[25] The current status and prospect of distributed generation in Korea, 2007, Korea Institute of Energy Research

In order to address the technical issues, the South Korean operator has implemented shunt reactors into the HV network. Static condensors have also been implemeted to compensate for voltage drops during heavy load periods and to assist in the regulation of the distribution voltages, automatic onload tap changer operation has been required to maintain a constant voltage level. The Korean smart distribution management system (KSDMS) project was started in 2009 to achieve advanced distribution operation. The prototype system of KSDMS was tested in the distribution system of Je-Ju Island in Korea – a National Smart Grid Project.

The South Korean government announced in August 15, 2008, Korea's new national vision "Green Growth, Low Carbon." To implement this vision the Korean Smart Grid Institute (KSGI) was established, with the mandate to manage comprehensively the government's Smart Grid roadmap operate a Smart Grid test-bed, pilot city and extend other policy support for Smart Grid related issues which in essence mainly targets the modernization of electric power systems.

In the public and the private sectors, many research institutes such as the Korea Institute of Energy Research (KIER), Korea Institute of Science and Technology (KIST), Korea Energy Economics Institute (KEEI), and Korea Electric Research Institute (KERI) are working together to ensure that technological opportunities are commercialized and exploited as soon as possible. In addition, business entities are encouraged to actively participate to expand the market and to foster the relevant industry.

In order to test and evaluate Korea's future green growth infrastructure and services, government bodies and private companies have teamed up to set up the national smart grid project on Jeju Island. Approximately 240 billion Won (USD 208 million) is set to be invested in the project, of which 64 billion Won (USD 56 million) is committed by the government and the rest by private companies, on the basis of plans to transpose the resulting innovation to a wider commercial base, and internationally. The project was set up with the objective of being the world's largest smart grid test-bed to eventually commercialize technologies from the project and facilitate their export.

Additional R&D in a field test project for a distribution management system (DMS) was launched in 2012 funded by the government and KEPCO in the Jun-Nam province located in south-west of Korea. The DMS is targeted to be developed for operating distribution network actively and hosting large capacity of DG.

2.3.6 Australia

Source: http://www.gridaustralia.com.au/

Most electricity in Australia, whether on the National Electricity Market (NEM), or the stand alone markets in Western Australia and the Northern Territory, is generated by large-scale centralized generating units. The electricity networks are large and complex with long transmission lines connecting these big, centralized generators to widely dispersed consumers. Currently, there are three primary drivers for the capital expenditure on network infrastructure: replacement of ageing infrastructure increased reliability standards imposed by governments on electricity utilities and growth in peak electricity demand. The final driver of peak demand growth is the key area of interest in the context of potentially avoidable costs through the large-scale deployment of decentralized generation. DG in Australia grew by 20% in absolute terms between 2006 and 2010, but this has not kept pace with the national average increase in installed capacity. This translates to approximately 3 GW of dispatchable DG in the NEM at present, an estimated 5.4% of total electricity generation.

By far the most commonly used DG technology in Australia is solar PV, which is now a common sight in most Australian cities. The growth in local rooftop solar PV is also the main cause of localized voltage increases[26]. Coupled with a change in the low voltage system in 2000 to become a 230 V nation, the average voltage across the country is now in the mid 240 V, and often in the low 250 V, which has an impact energy efficiency. This has led to a growth in the offering of voltage optimization or stabilization solutions as a service in the broader market.

Utilities such as Western Power Smart Grid projects[27] have run a demand side management project and trialed a solar city in Perth that has shown benefit to the grid. CityPower and PowerCor distributors are currently developing a demand management process. Jemena[28] and United Energy[29] encourage the uptake of embedded generation particularly where these generators can defer or avoid network augmentation. As the increased investment in the broader system has

[26] The Australian: Rooftop solar panels overloading electricity grid
[27] Western Power Smart Grid projects
[28] Jemena Distributed Generation information
[29] UE embedded generation information

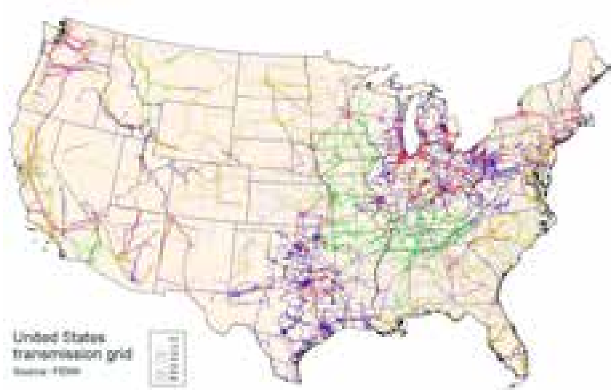
impacted the price to the consumer quite considerably and the wider use of air-conditioning, encouraging embedded generations makes sense for utilities.

BGC (Australia) Pty Ltd, a diversified construction and contracting organization based in Western Australia, coordinates shut downs across eight diverse manufacturing sites removing up to 5 MW of energy demand from the grid. During dispatch, these facilities can curtail their load by shutting down equipment such as crushers, mills, a packing plant, and lighting. Curtailment is quick and efficient. In all, it takes as little as half an hour—delivering the much needed capacity during periods of peak usage representing around 90 % of BGC's overall electricity use.

The Energy research from CSIRO[30], the Commonwealth Scientific and Industrial Research Organisation, aims to improve the affordability, reliability and grid integration of renewable energy technologies including solar, wind and biofuels. Its National Solar Energy Centre is a focal point for solar research in Australia, bringing together state-of-the-test facilities for solar thermal, photovoltaic and cooling. Researchers at the Renewable Energy Integration Facility are examining new grid design and operation techniques that can significantly transform electricity networks. The CSIRO Energy Centre in Newcastle is a state-of-the-art facility that showcases a unique combination of energy efficient building design and small-scale generation units. As an example of successful development, CSIRO has been behind the development of gas fuel cells by Ceramic Fuel Cells Ltd, which are now being retailed under the marketing name BlueGen in Australia and globally.

2.3.7 United States[31, 32, 33, 34, 35]

The amount of DG, particularly solar PV[36], has risen sharply in the United States over the past few years. As of 2013 U.S. PV installations had grown to nearly 10 GW, which represents less than 2% of total installed U.S. generation capacity. The amount of distributed capacity is expected to increase to as much as 20 GW by 2020. California is the nation's leading market for distributed generation. California has set a goal of developing 12 GW of distributed renewable energy by 2020. In the first three months of 2013, close to 3,000 residential solar installations were completed in California with no state incentives. Many businesses are seeing an opportunity to save money by installing solar panels. Walmart plans to install solar PV on 1,000 of its retail stores (approximately one-quarter of its US locations) by 2020. Other businesses have similar plans, though on a smaller scale. Even the partial loss of the load of such large customers would lead to a significant reduction in utility revenues.



Source: FEMA

Utilities are increasingly committing to DG in their grids. The role of DG and microgrids to reduce the effects of grid outages is now being recognized by States impacted by extended grid outages due to storms or fires. In July, 2013, utilities in Georgia, New York, and Colorado announced plans to bring a total of 840 MW of solar energy online by 2016. In a similar move, California-based Edison International actually acquired a solar developer – SoCore Energy – to expand the utility company's ability to install and operate rooftop solar installations for commercial and industry customers.

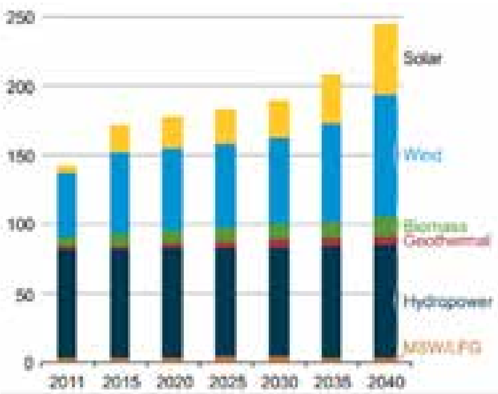
Solar is not the only technology being applied at the distribution level. Small wind, biomass, geothermal and digester/landfill gas facilities have also seen success in deployment throughout the country, each with different, important grid benefits. Distributed wind currently tops over 800 MW, from more than 69,000 turbines across all 50 states.

The growth in DG has led to technical and integration challenges for utilities that are now converting into key barriers to a much faster adoption. First, variability of DG output is causing voltage challenges on distribution systems. Second, poor forecasting capabilities makes renewables output hard to predict. As a third impact, the lack of monitoring and control capabilities limits visibility into output when running in parallel and notification when running independently. This lack of transparency of the condition of the DG unit has implications as to the safety of the wider system in that no DG unit is back energizing the grid.

[30] CSIRO Intelligent Grid report
[31] Distributed Generation System Characteristics and Costs in the Buildings Sector, August 2013, US Energy Information Administration
[32] Biennial Report on Impacts of Distributed Generation, May 2013, California Public Utilities Commission
[33] Distributed Generation: An Overview of Recent Policy and Market Developments, November 2013, Public Power
[34] Forecasting Distributed Generation Resources in New England, June 2013, Synapse Energy Economics
[35] 2012 Market Report on U.S. Wind Technologies in Distributed Applications, August 2013, U.S. Department of Energy
[36] Distributed generation: Facts, 2013, Energy Fact Check

Yet despite the number of Smart Grid projects in the distribution grids across the U.S., the investment gap between now and 2020 is estimated by the ASCE to be $57.4 billion[37]. In a distribution grid that already experiences the most service disruptions; the U.S. appears to be underinvesting in its distribution grids while in contrast, investment in transmission infrastructure has been increasing at a respectable 7% since 2001.

Regulatory investigation into grid modernization, as well an analysis of the barriers to implementing smart grids is underway. Approaches being considered to address the technical issues include fast response voltage regulators, short-term demand response to offset variability of output, micro EMS to monitor and control delivery system and loads. Also under consideration is grid based storage to improve power quality, reliability and voltage stability, use of AMI meters/sensors with disconnects to separate home from utility after the power supply is interrupted, use of micro EMS to monitor output of distributed resources and report status. Storage coupled with the customer-owned renewable energy would make it a small microgrid in conjunction with a load and generation balance (microgrid) controller.



Renewable electricity generation capacity by energy source, including end-use capacity, 2011-2040 (gigawatts). Source US EIA – Annual Energy Outlook 2013.

Smart Grid research in the U.S. initially began through the Bush administration by investing resources and time to improve grid reliability, security and economics. During this period, the Department of Energy (DOE) acknowledged that the U.S. economy lost several billions of dollars through power outages. Several collaborative research programs have been established looking at areas such as Smart Grid communication, architectures, standards, simulations, new regulations and market frameworks. Other efforts in the U.S. are undertaken by the Electric Power Research Institute (EPRI) through intelligent grid initiative projects. EPRI deals with the technical frameworks and architectures of Smart Grid.

As an example EPRIs Smart Grid Demonstration Initiative[38] is a seven-year collaborative research effort that will conduct several regional demonstrations and supporting research focusing on smart grid activities related to integration of Distributed Energy Resources. These are to include distributed generation, storage, renewables, and demand response technology into a "virtual power plant" to:

- Help to define roles for distributed resources and integration requirements in different market environments
- Determine requirements for demand-side technology integration with system operation
- Provide the basis for standards development that will facilitate widespread deployment and integration of distributed resources

EPRI leverages multi-million dollar investments in the smart grid by the electric utility industry, with the goal of sharing information and research results on a wide range of smart grid technologies and applications. Not only are Utilities in the US collaborating in the work but also utilities from Australia, Canada, France, Ireland and Japan.

[37] ASCE's Infrastructure Report
[38] EPRI: Smart Grid Demonstration

This section explores a number of countries and their relevant policy and regulatory issues related to DG interconnection. Some of the key questions that the Grid-Connected Distributed Generation work group sought to address included the following:

- Which key policy or regulatory trends and/or barriers exist that delay or prevent the connection of distributed generation systems to the distribution network?
- Which successes have been observed in changing relevant policy issues?
- What are major policy issues?
- How are these trends being addressed in specific countries or regions of our review?
- What environmental, social benefits are being developed in support of distributed generation?
- What are regulatory positions on distributed generation systems and uses?
- Which new policies appear to be emerging or imminent based on recent changes in country or regional government representatives or leaders?

This paper explores these questions across several countries, including Australia, Canada, Denmark, Ireland, Japan, Korea, Norway, Taiwan, and the United States. The responses from these countries provide a greater understanding of the impact that policy makers and regulators can have relative to the further development and installation of DG technology.

Regardless of the definition of DG, when policy is made to be applied to all DG, conflicts will emerge as some type of application is deterred. One example is fossil fuel, traditional technology, base-loaded CHP – which will deter clean technology like large-scale solar or wind.

3.1 General trends

Which key policy or regulatory trends and/or barriers exist that delay or support the connection of distributed generated systems to the distribution network?

The electricity market of eastern and southern Australia – the National Electricity Market (NEM) – is separate from that of the remote areas of Western Australia and the Northern Territory. Western Australia has a stand-alone market arrangement known as the Wholesale Electricity Market (WEM) operating in the South-West Interconnected System (SWIS). In the Northern Territory, because of its relatively small population and remoteness, there is an integrated electric utility, which can procure additional electricity from independent power producers and remote generators.

The National Electricity Market (NEM) began operating as a wholesale market for the supply of electricity to retailers and end-users in December 1998. Operations today are based in five interconnected regions that largely follow state boundaries. The NEM operates one of the world's longest interconnected power systems – a distance of around 5,000 km.

Some assets that comprise the NEM's infrastructure are owned and operated by state governments, and some under private business arrangements. Some states have integrated power companies and others separate generation, transmission, distribution and retail business. Victoria is the only state in Australia whose retail electricity market is fully deregulated as of 2009, and is also leading the way in the introduction of smart meters.

Key policies/trends/barriers in Australia include:

- The process for connection is being reviewed to streamline it and provide greater clarity in obligations on the parties.
- The lack of technical standards / regulation for small generators leaves networks having to assess impacts for each connection request. Consistent guidance is not available for proponents to do this. Connection delays result and proponents perceive networks hindering connection.

- The assignment of network augmentation costs required to accommodate the generator is disputed, whether the generator should pay any cost, shallow cost or the full cost of works required.
- Providing certainty to proponents on time requirements to make an offer to connect. This is most problematic where proponents do not have a high degree of certainty regarding the plant specification to be connected and intended operating modes.

In countries such as the **Republic of Korea**, there are fewer policy, but greater technical barriers, particularly where there are standards for connecting distributed generation to the network. The maximum hosting capacity of DG has been limited to 20 MW with respect to the main transformer at substations. Nowadays, this limitation is the key barrier that prevents the connection of DG to the network.

In **Denmark**, there is an enhanced level of policy support for DG systems. There are more than 86,000 small PV systems (<6 kW) connected to the distribution network[39], challenged due to expected load increases from new electricity demand and decentralized production. It can be handled by traditional grid expansion or by taking advantage of new technologies coupled with flexible electricity consumption. Generation can help to increase capacity utilization in the grid.

The first step is to increase the utilization of existing network capacity through the use of new technology. By improving the condition monitoring, Denmark believes it can reduce safety margins and thus allow higher loads. Therefore, policies are being established to encourage a coherent system of measurement, forecasting, and communication systems to map network loads and increase utilization. The second step is to increase the utilization of existing capacity in the distribution network further by taking advantage of flexible electricity consumption and production. This gives grid operators the ability to reduce peak demand by load shedding in congested operating conditions.

In both **Northern Ireland (NI)** and the **Republic of Ireland (ROI)**, energy policy is driven by security, sustainability, and competitiveness of energy supply, which are the main drivers of EU energy policy in addition to the Kyoto Protocol. The governments' all-island renewable energy policy is presented in the document entitled "All-Island Energy Market-Renewable Electricity: A 2020 Vision". Both have set a target of 40% electricity consumption from renewable sources by 2020, one of the highest renewables targets globally. Significant growth in onshore wind resources is keeping them on track.

The electricity regulators in NI and ROI are involved in a joint initiative called "The All-Island Project" to better harmonize their respective energy sectors. There is a single wholesale electricity market for the entire Island in which participation is mandatory. All electricity generated, imported, or consumed on the Island must be purchased or sold in the Single Electricity Market, with the exception of micro-generation. 50% of all renewable generation (mainly wind) is connected to the distribution system.

Micro-generation covers small scale generators where customers produce their own electricity and feed the surplus onto distribution LV system. This is subject to a rated maximum output of 6kW when the connection is single and 11kW three phase. They must install import / export meters and have an agreement with an electricity supplier to purchase their excess power. All other embedded generators must sell their output to the all- Island electricity pool.

All installed micro-generators must comply with EN 50438 and the specific Irish protection settings. Each micro-generator must have interface protection, as specified, which will include the following elements: over voltage, under voltage, over frequency, under frequency, loss of mains [LOM].

Each government has already introduced premium pricing for renewable generation – the "Renewables Obligation" in Northern Ireland and the "Renewable Energy Feed in Tariff" in the Republic of Ireland. The costs associated with these incentives are recovered from the final consumer through supply tariffs in NI and through a Public Service Obligation in ROI.

In NI, subsidies are based on Renewable Obligation Certificates (ROCS) which are sold to suppliers. Different technologies have a different number of ROCS.

In some countries, such as **Japan**, policy in combination with market necessity can act as a powerful incentive to encourage increased use of DG systems. Since the great East Japan earthquake in 2011, the cost of electricity in Japan has

[39] http://energinet.dk/DA/El/Engrosmarked/Udtraek-af-markedsdata/Sider/Statistik.aspx

been increasing due to the use of fossil-fired power stations as an alternative to nuclear power production. This situation, combined with the government's feed in tariff (FIT) strategy, has encouraged the increased use of DG in the form of solar PV, biomass, and small hydroelectric systems.

In **Norway**, DG is dominated by small hydro power plants of up to a few MW. Generation connected to the low voltage (LV) distribution system is rare, but a few PV installations exist. In some regions, the lack of sufficient transmission capacity has led to a halt in all developments of new generation. There has been a perception among DG developers that distribution network companies have been reluctant or too conservative when considering new DG connections, putting high grid reinforcement costs on the DG developers. This will require further review as the Norwegian water and energy directorate which hands out the concessions to build hydro power plants. It has significantly slowed down the application queue for building new power plants, in some cases up to several years, while the construction of new transmission lines has met increasing public opposition.

The **Taiwan** Power Company (TPC) system operates the generation, transmission and distribution of electricity in that country. Taiwan energy policy, regulations, and rate regulatory matters are developed and administered through the Bureau of Energy (BOE), and with TPC's input, promulgates a 20-year, $4 billion smart grid investment program. The program's objectives are: 1) ensure continued high reliability; 2) encourage energy conservation and emissions reduction; 3) enhance the use of green energy by improving interconnection capacity to 30% by 2030; and 4) develop a low-carbon smart grid industry. The key policy goal is to encourage the connection of distributed generated systems to the distribution network. One of the key barriers is to educate people regarding the knowledge of PV systems. The development of wind turbines is blocked by the infrastructure, i.e. is the investment of grid connection.

In **Canada**, the main policy barrier is the mandate to keep electricity rates low, as provincial governments own most of the large utilities. Another obstacle is the abundance of hydro electricity, which precludes a positive business case for renewable generation, unless the provincial governments have enacted strong policy incentives (i.e. Ontario).

Finally, within the **United States**, there are many different DG sources being deployed, as their installation costs approach grid parity. Natural gas fueled DG – micro-turbines and reciprocating engines, for example - benefit from currently low gas prices and can be installed at around $400 per kW in some cases. Wind and solar photovoltaic systems run, respectively from $900/kW to $5,000/kW, with the savings found in low operating costs. Other kinds of DG technologies range from CHP plants and fuel cells to run-of-river hydro generators.

The policies and laws that govern connection of DG systems are regulated by each state and is some cases local permitting requirements with the resulting inconsistency across the U.S. States and even among utilities in the same State, which creates complexity in several key areas.

- **Net Metering** – Not all U.S. States or utilities have policies in place to permit net metering, such that individual DG investments will gain economic benefit from "selling" excess energy supply to the load serving entity (utility, retail energy provider). Net metering also requires a special electric meter that can either measure net flow (i.e., energy flow is measured in both directions, but subtracted in display or billing) or both delivered and received energy flow (kWh). In some States, there is a limit (MW size) to the size of the interconnected system, which again varies considerably[40].

- **Safety & Protection** – Utility interconnection standards vary considerably, but many require that DG connections must be equipped with (1) protective functions designed to prevent the generator from being connected to a de-energized utility circuit and (2) necessary protective functions designed to prevent connection or parallel operation if the distribution service voltage and frequency are not of normal magnitude.

- **Incentives** - Many state and federal incentives (e.g., grants, rebates, loan guarantees, purchase power agreements, sales/property tax credits, accelerated depreciation) are being re-examined and could be eliminated entirely in the coming few years. Emerging schemes that address this gap include energy project "bundling", whereby DG is included in a portfolio of energy efficiency investments that provide an attractive ROI. In other cases, Real Estate Investment Trusts, where companies that own and often operate real estate enable multiple investors to pool their resources and own real-estate holdings without the risk of owning individual properties, now including DG systems. Also, a third-party broker market (e.g., Mosaic) is emerging in some locations, where private funding is again pooled for the sake of making green or energy efficiency investments, managed by the broker.

[40] http://www.dsireusa.org/summarymaps/index.cfm?ee=0&RE=0.

Since renewable energy portfolio standards exist in only 29 States (+ Washington D.C.), there are few legislative incentives in some parts of the U.S. to encourage renewable investments at the consumer level. Clean Air Act restrictions on running fossil-based, small scale generation, especially in large metro areas that have reached "non-attainment" status under the U.S. Environmental Protection Agency, also impact deployment.

Overall, the lack of a consistent national U.S. energy policy relative to renewable energy and the inconsistent nature of interconnection, net metering, and renewable energy incentive schemes across the U.S. States (+ D.C.) present the greatest challenges. In some locations (e.g., North Carolina), there have even been due diligence reviews of existing renewables energy standards for potential repeal, as DG cost comparisons with low-cost and plentiful natural gas shale deposits.

Other major issues are arising as the federal production tax credit for wind expired at the end of 2013 and the solar renewable investment tax credit is expiring in 2016. There are expectations that the U.S. Congress may not be as amenable to extending these credits further, which can have considerable impact to future deployment and advancement of large-scale systems.

Finally, one positive trend is that the U.S. Department of Defense is investing considerably into microgrid systems in order to make military bases less reliant on the utility power network, as well as improve reliability, decrease energy costs, and reduce their carbon "boot print".

3.2 Successful policy changes

Although barriers may exist relative to existing policy and regulatory requirements, there are a number of cases where successes have been observed in changing relevant policy issues.

Despite the regulatory and legislative barriers within the United States, the market for solar, in particular, is very bright. Driven primarily by third-party financing and lower equipment costs, residential installations are growing to record levels. The U.S. solar market, overall, had a strong first quarter in 2013 with 723 MW of photovoltaic capacity installed, which represents a 33% increase in deployment levels over Q1 2012. The growth in Q1 2013 was driven in part by a record first quarter for both the residential and utility segments, which installed 164 MW and 318 MW respectively. This growth will continue throughout the year with 4,400 MW of PV and 938 MW of concentrating solar power (CSP) are expected to come online in calendar year 2013. This has also got the attention of many traditional utilities, but also competitive retail energy providers where state energy markets are competitive.

Specific locales where policies have been favorable include California, Hawaii, Arizona, and New Jersey. California is now proposing raising its current Renewable Portfolio Standard (RPS) requirement of 33% of electric energy procurements by 2020 to 51% by 2030. Minnesota increased the RPS by 1.5% to 31.5% for its largest utility, Xcel Energy, and to 26.5% for all other investor owned utilities. Much of the future renewable energy growth in the U.S. will be met through distributed photovoltaic (PV). The allocation of distributed PV additions between residential customers, commercial/industrial customers (including aggregators such as community-based PV projects) and utility-scale PV installations will depend to a large extent on the evolution of market/regulatory protocols.

Interconnection costs and lengthy approval process times have historically been barriers to DG adoption. However, some utilities have implemented "fast-track" interconnection policies for small generation, typically under 10 kW. This prevents excessive engineering fees burdening small installations, provides a simplified process for small generation, and benefits more costly applications such as residential PV.

Utilities with smaller distribution footprints, such as municipal and rural cooperatives, seem to prefer controlling PV solar arrays to minimize impact on their distribution system. However, they can't take advantage of tax credits. So, they use a third party for the investment vehicle to get the tax credit to their customers. The Clean Energy Collective[41] is providing the means to do this for one Minnesota cooperative.

In **Canada** 5 GW in distributed generation has been added to the grid by 2013. Leadership in renewable generation and DG integration lies with the provinces, which set up the energy policy. While each province's approach to smart grid differs according to their needs, a balance of common economic, energy and environmental policy drivers can be found. In Ontario, the Green Energy Act passed in 2009, is an example of successful policy that established the Feed-in-Tariff program,

[41] http://www.whe.org/for-my-home/products-services/wh-solar-community.html

with more than 9000 MW of connection requests on a 10,700 MW goal by 2018. In Nova Scotia, integrating distributed and renewable generation is a major driver for smart grid. The province set up a target for 25% of its energy to be supplied by renewable energy by 2015, increasing to 40% by 2020. With over 320 MW of wind already installed, the province experienced 37.5% of its total energy generation from wind in September 2012.

In **Norway**, the unique Swedish-Norwegian green certificate scheme has substantially increased the interest for launching new renewable DG projects. In total, about 26 TWh of new renewable generation is expected by 2020. This is the only economic incentive launched for renewables in Norway and is regarded by the regulator to be the most cost-efficient support scheme. The regulator has also launched simplified rules for DG installation in buildings, which might give more incentive to DG systems such as rooftop PV and similar in-house generation.

In **Taiwan**, there is a project to develop a "million rooftop PVs" started in March 2012. Economic incentives have encouraged the increase in installed DG capacity from 118 MW to 282 MW since this policy became effective.

Japanese officials are also making successful changes in policy decisions. The Surplus Electricity Purchase System that started November 1, 2009 has shifted into a Feed-in Tariff System started as of July 1, 2012, whereby both the purchase price and duration of all facilities approved under the old system were guaranteed.

Similarly, **South Korea** has adopted a variety of support schemes such as feed-in tariffs (FIT) and other economic incentives over last 10 years. While FIT have been effective, a more recent change has really impacted DG development. In 2012, the government modified the FIT into a Renewable Portfolio Standard (RPS). As a result, since RPS enforcement, new DG capacity installed during the past year is about 80% higher compared to DG capacity built during 10 years under FIT support policy.

The regulatory / policy trends are positive for the connection of distributed generation, particularly for renewables, within the country of **Ireland**. Ireland's target for renewable electricity generation (legally binding) is of the order of 40%. Half of all renewables are connected at the distribution level. There are currently 980MW of connected wind farms to the distribution system and a further 260 MW of non-wind distributed generation (the system peak is of the order of 5000 MW). Non-wind generation is comprised of biogas (4 MW), CHP (59 MW), diesel (10 MW), small hydro (26 MW), and landfill gas (62 MW). There is little or no solar PV connected to the system in Ireland.

For micro generation installations in Ireland, an "inform, consent and fit" process now applies. Owners must inform ESB Networks (ESBN) of any planned installation and follow a formal application process. ESBN is required to respond to an application within 20 business days. In the event that no response is forthcoming, then the application will be deemed to have been granted. This arrangement will apply to both residential and commercial installations. In any local area, micro-generation can be installed up to an initial limit of 40% of the substation transformer capacity serving that locality.

Finally, within **Australia**, the development of a tailored connection application process for small generation is still in draft. This policy will seek to provide an initial information exchange and assessment, followed by a detailed process with all information available. The government is pursuing the development of processes to facilitate the use of demand side solutions, including distributed generation to address network constraint- i.e., as an alternative to network augmentation.

3.3 Addressing policy and regulatory trends

As previously stated, the prevalence of third-party financing schemes in the **United States** is having a strong impact to making solar PV systems more affordable to the residential sector. In some cases, developers (e.g., SolarCity) are bundling PV with PHEV and energy storage technology, in order to monetize the demand response value of the energy portfolio investment. In some cases, municipalities (e.g., San Francisco, Cincinnati) are becoming active energy brokers, taking on the role of building community-based DG systems (mostly in the form of renewables) to bring cleaner, cheaper, and more reliable energy to their constituents.

This market-based approach is also found in **Norway,** where the overall objective is the development of the Norwegian energy system under a socio-economic efficiency platform. While in Taiwan, the focus has been on improving forecasting tools, such that policymakers will have improved information about resource variability and can make more informed dispatch decisions to maintain system reliability.

In **Australia**, the government is seeking to develop a market-driven approach to both the supply and demand side of consumer energy consumption. The final report for the AEMC Power of Choice review[42] was presented to the Federal and state Ministers of the Standing Council on Energy and Resources for their consideration in November 2012. It sets out the final recommendations and a detailed implementation plan by Federal and state governments. The overall objective is to provide that the community's demand for energy services is met by the lowest cost combination of demand and supply side options. This package provides households, businesses and industry with more opportunities to make informed choices about the way they use electricity and manage expenditure.

The policy framework in Australia has both top-down and bottom-up aspects. The Australian Energy Markets Commission is the market development body. It is able to set National Electricity Rules based on assessment of rule change proposals submitted by any person. The AEMC is currently responding to a rule change request from embedded generator proponents, which aims to streamline the connection process and improve clarity to the process and obligations on the parties.

As it relates to the connection of small-scale DG systems, **Ireland** has formulated a structured approach such that renewable generators wishing to connect to the transmission or distribution systems have been subject to group processing of connection applications through a series of successive "Gates". These requests are processed in batch groups. However, based on their level of interaction and geographic location, the applications within the gate are divided into specific groups by the TSO and DSO for processing purposes. The system operators study the groups and assess their overall impact on the electrical system, identifying requirements of each group before issuing the connection offer to the individual applications within each group. Renewable generator applications with a Maximum Export Capacity (MEC) less than 0.5 MW may seek exemption from the group processing approach by applying to the system operators. Any such exemption requires approval from the regulator.

3.4 Environmental and social benefits

Beyond the market-driven economic drivers that impact DG development and its interconnection to the distribution grid, there are a number of environmental and social benefits providing a strong context to policy and regulatory schemes in a number of global locations.

The electricity supply framework in **Australia** has an economic efficiency objective. Environmental and social benefits are generally considered within those policy areas and, as a result, the electricity supply industry is subject to these policy outcomes. This approach avoids duplicative or incompatible policies and provides a greater level of transparency for policy on environmental and social policy-making.

The largest North American initiative for the reduction in carbon emissions has been the closing of coal-fired generation by 2014 in Ontario, **Canada** as mandated by the provincial government. This was made directly possible through a combination of initiatives to fill the resource gap with 10,700 MW of renewable energy by 2018 in combination with a time-of-use rate that encourages on-peak conservation.

Following the 2011 earthquake in **Japan**, solar PV and electric storage systems have been drawing attention for reliable back-up. CHP and cogeneration systems using fuel cells and/or gas engine, provide for thermal and electric energy needs, are also becoming more popular among residential customers recently (e.g., fuel cell system as Ene-farm, gas generation system as Ecowill). Because of the social utility of these systems, there are cases that subsidies are provided by local government support.

In some cases, the primary social benefits of DG can relate to the overall national energy policy objectives of reduction of greenhouse gases (GHG) and the security of energy supply, with a main focus on renewable electricity generation. **Ireland**, as an example, has a mandatory target of 16% renewable energy by 2020. This is apportioned across heating, transport and electricity, with the electricity target set at 40% renewable generation by 2020. The largest share of this DG capability will be in the form of wind, with an expected 50% of this generation connected at distribution level. Apart from helping to meet renewables targets, this target will seek to have a major economic benefit of reduction of energy imports (Ireland currently imports 80% of its energy). The resultant decarbonization of electricity supply is also expected to assist with the other targets through the deployment of electric vehicles and electric heating, thus reducing the GHG emissions.

[42] http://www.aemc.gov.au/market-reviews/open/power-of-choice-update-page.html

In a similar fashion, the government of **Taiwan** has announced energy policies in response to reducing its own decarbonization efforts. These policies are also aimed at achieving a "nuclear-free homeland". Therefore, renewable targets are set for 14.8% in total capacity by 2025 and 16.1% by 2030. A project entitled a "thousand wind turbines" seeks to greatly increase Taiwan's installed base of wind power capacity to more than 4,200 MW with a combination of both inland and off-shore locations, as well as a "million rooftop PVs" to reach an installed PV capacity of 3,100 MW.

In June 2013, President Obama released, " The President's Climate Action Plan"[43], which outlines several incentive schemes, some of which apply to DG systems.

- Directs EPA to work closely with states, industry and other stakeholder to establish carbon pollution standards for both new and existing power plants.
- Makes up to $8 billion in loan guarantee authority available for a wide array of advanced fossil energy and efficiency projects to support investments in innovative technologies (details to be determined).
- Directs DOI to permit enough renewables project—like wind and solar – on public lands by 2020 to power more than 6 million homes and sets a new goal to install 100 MW of renewables on federally assisted housing by 2020 while maintaining the commitment to deploy renewables on military installations.
- Sets a goal to reduce carbon pollution by at least 3 billion metric tons cumulatively by 2030 – more than half of the annual carbon pollution from the U.S. energy sector – through efficiency standards set over the course of the Administration for appliances and federal buildings.

Also from the White House, a recent report was released entitled "Economic Benefits of Increasing Electric Grid Resilience to Weather Outages"[44], which outlines the need to use power electronics, energy storage, and microgrid technologies to "increase system flexibility and robustness". This recommendation also mirrors that of the GridWise Alliance in its own recent report "Improving Electric Grid Reliability and Resilience"[45], with Recommendation #5: Distributed Generation technologies, such as microgrids and mobile generators, can enhance the resilience of electric infrastructure serving critical loads.

3.5 Regulatory positions for DG systems

Within the **United States**, one of the prevailing issues is "fair compensation", which seeks to address the loss of utility revenue without overburdening a smaller number of remaining rate payers (many of which may be at lower income levels), and without unfairly burdening those that are trying to self-generate for various reasons.

Ways in which this issue is being addressed include:

1. Tighter definitions of DG that can accelerate clean technologies that provide a societal benefit, while discouraging "free rider" technologies taking advantage of economic incentives,
2. Fair recovery schemes for utilities that prevent excessive revenue loss when end-users decouple or self-generate, and
3. Fair fees for end-users that self-generate and rely on the existing power grid as back-up, such that the fees are not so excessive that they render DG economically infeasible.

The other key question that needs to be addressed is how to achieve visibility and modulate and control DG in real-time to ensure system reliability and safety and to optimize production costs and, how to balance GHG reduction goals in the economic equation?

While DG provides local power resources, management of load and environmental benefits, DG also creates variability in its offering – both from the nature of the resource and the uncertainty in response to various programs. In many cases, the impact of DG on the grid is not visible to the utility and system operator, as they cannot "see" where and when a DG source generates, nor do they have the ability to control that source at the distribution level when it does. Renewable-generated power has the disadvantage of being variable, affected as it is by cloudiness and wind speed. The result is that the utility must regulate and adjust larger central-generation assets to address the imbalance DG creates. This results in an increase in

[43] http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf
[44] http://energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report_FINAL.pdf
[45] http://www.gridwise.org/report_download.asp?id=10

production costs, and can impact generation efficiency as well as congestion and distribution infrastructure stress.

Variability in distributed energy resources comes from a variety of different sources. Uncertainty of each distributed resource relates to forecasted responses and is associated with DG monitoring to improve capabilities to forecast other supply and demand responses. Some DG systems are directly controlled by distribution providers or third parties working with the distribution provider so the system operator receives benefits from efforts by these agents. However, the indication is that the system operator would provide a more efficient means overall in terms of monitoring and control of customer-owned DG systems, particularly those that are inverter-based.

In **Australia**, the National Electricity Rules have just introduced new requirements for Distribution Network Service Providers[46] (DNSP) to more aggressively consider demand response including demand side engagement in planning for network augmentations. The National Electricity Rules make provision for incentive schemes to operate Clause 6.6.3, Demand Management (DM) and embedded generation connection incentive scheme. More specific to the inclusion of Distributed Generation to meet demand response and achieve legitimacy in the market, a new Market Participant category has been introduced into the National Electricity Rules – a "Market Small Generation Aggregator".[47] There are also further rule changes planned for 2015 where retailers and demand response aggregators will be allowed to bid DM into the NEM alongside traditional Generation.

In some locales, such as **Japan**, the DG connection rules are well-established and relatively unchallenged. DG grid connection requests are approved by the electric utilities, and the model contracts for such approval are published by the Agency for Natural Resources and Energy. The tariffs (purchase price) and duration of the FIT are reviewed and updated annually by consultation with the Committee on Feed-in Tariffs and Related Matters, under the jurisdiction of the Agency for Natural Resources and Energy.

The same can be stated for **Ireland**, where the Commission for Energy Regulation (CER) has a role in promoting the use of renewable and sustainable forms of energy. This role is complimentary to the role of the Minister for Communications, Energy and Natural Resources who is responsible for renewable energy policy. In carrying out its functions, renewable, sustainable and alternative energy sources are defined in the legislation as wind, hydro, biomass, waste including waste heat, biofuel, geothermal, fuel cells, tidal, solar and wave. To help promote the use of these sources of energy, the CER has worked to facilitate the connection of renewable generators to the electricity network including the development of a group processing approach to speed up such connections. They also include specific rules in the electricity wholesale trading arrangements to facilitate renewable generators to sell their electricity to end customers.

In **Korea**, the rules and standards are for less clearer. From a technical point of view, the utility is experiencing strong pressure to respond to an often excessive demand for access to the network, while at the same time ensuring that DG connections do not violate the technical standards of the networks. To address this need in a timely and effective manner, simplified methodologies and practical rules of thumbs still need to be established.

In **Canada** the majority of the connection costs are born by the distributed generators. However, utilities do make investments at the bulk level that enable additional distributed generation capacity. The regulatory regime calls for this costs to be shared among all electricity users.

3.6 Emerging policies and regulations

Utility participation in DG, whether in ownership or control, is important to an efficient local grid. Policies that encourage DG also must take into consideration the fair allocation of distribution costs and benefits to all users that rely on the grid, however intermittent.

Common and industry acceptable standards will have to be examined more closely. These standards will include visibility as part of DG interconnection standards and for access to time-based pricing tariffs (e.g., RTP, dispatchable DR) for various distributed resources. Additional communication impacts involve communication standards such as smart inverter communications.

Wireless technology life cycles are at least 2-3 times shorter than DG asset lives, so adoption of any common carrier wireless services saves costs at the risk of early obsolescence. An open input/output standard may allow faster adoption of widely available low cost communications. System operator procedures will need to be developed for creating visibility and

[46] http://www.aemc.gov.au/electricity/rule-changes/completed/distribution-network-planning-and-expansion-framework.html
[47] http://www.aemc.gov.au/electricity/rule-changes/completed/small-generation-aggregator-framework.html

control in the distributed resources (including forecasting, scheduling, voltage management and planning requirements). Settlements and charges will have to be developed for the communications costs and/or socialized market benefits used to cover DG visibility costs borne by owners / aggregators. Control costs will be part of the overall economics of demand response – market payments for DR will have to cover the convenience and technology costs.

In June 2013, within the **United States**, the California Public Utilities Commission (CPUC) released an order that would call for the state's three investor-owned utilities to procure 1.3 GW of energy storage by 2020, along with market mechanisms to start the procurement process as in 2014. This is directly attributable to the assertive position taken by the State to install renewable energy and DG systems. As a result, the California Energy Commission chartered a study[48] that specifies a methodology to assess the economics of various storage options to reach this regulated storage target.

To counter balance the variability of renewable energy the province of Ontario in **Canada** has enacted a procurement process for 50 MW of energy storage. The province continues to show leadership internationally with regulatory reform intended to benefit Ontario's energy, environment and economy through smart grid. In the last year the government recognized storage technologies as a technology area with significant potential for system and economic benefit. In December 2012 the Independent Electricity System Operator (IESO) of Ontario procured 10 MW of regulation capacity in a pilot to test the ability of alternative sources of stored energy to provide regulation and other services to the grid.

The new government in **Norway** is currently planning to implement reduced taxation of renewable energy generation and more favorable depreciation rules to harmonize renewable investments in Norway with those in Sweden, so that the investment incentives are more equal compared to the situation today. The government of **Taiwan** has announced a "solar community" and carried out cluster PV community pilots to assess the feasibility and performance in 2013. The central government authorized the local to rent out the public rooftop to company to setup the PV system with incentive. The citizen could see the PV system nearby public buildings.

The incoming **Australian** government has campaigned with the intention to abolish the existing carbon tax and to reduce the Clean Energy initiative funding. Whether the carbon tax change will be supported through parliament is yet to be demonstrated; however, this is likely to impact future renewable distributed generation prospects.

In **Japan**, a project to promote regional development with active use of local renewable energy sources (solar, wind, mid-small hydroelectric, geothermal, biomass) is currently conducted by Ministry of Environment. Another objective of this project is to foster leaders and coordinators who play a prominent role in realizing renewable energy business. On the other hand, the Ministry of Economy, Trade and Industry budgeted JPY25 billion as a subsidy to promote the introduction of DG, including gas cogeneration and private power generation.

In 2012, the **Irish** Government published a new "Strategy for Renewable Energy 2012 -2020"[49]. This document sets out five strategic goals – increasing on and offshore wind, building a sustainable bioenergy sector, fostering R&D in renewables such as wave and tidal, growing sustainable transport, and building out robust and efficient networks. It contains specific commitments to maintaining appropriate REFIT tariffs and to promoting increased micro-generation. It also commits to the necessary electricity infrastructure development to facilitate the strategy.

[48] http://www.cpuc.ca.gov/NR/rdonlyres/A7FF0A4E-44FA-4281-8F8F-CFB773AC2181/0/DNVKEMA_EnergyStorageCostEffectiveness_Report.pdf
[49] http://www.dcenr.gov.ie/NR/rdonlyres/9472D68A-40F4-41B8-B8FD-F5F788D4207A/0/RenewableEnergyStrategy2012_2020.pdf

4.1 Impact on electricity costs

Electricity costs are of paramount concern for regulators, rate payers and electric utilities. In many jurisdictions the cost of electricity is a key political issue and the topic of much public debate. Governments and regulators are looking to balance environmental and economic goals associated with renewable distributed generation with the cost to the consumer of a more expensive generation mix. While renewable distributed generation offers many economic, environmental and security benefits, the general impact has been to increase the cost of electricity. For example, in Australia early indications show that distributed generation and other "green schemes" are adding approximately 3 cents to a retail price of 30c/kWh[50].

The two key drivers of this increasing cost are the government-sponsored incentive programs that encourage renewable distributed generation, as well as the higher costs of current renewable generation technology compared with traditional centralized generation. However, both of these factors are changing across many markets with governments revising or retiring their incentive programs as the technologies become more efficient to manufacture. The government incentives have generated the demand, and thus, the economies of scale required to reduce the overall cost of generation. In the coming years, the impact to electricity costs of renewable distributed generation will become less. In some markets, we have even seen positive impacts of renewable distributed generation on the market clearing price for traditional generation sources. The long-term consequences of lower market prices created by excess renewable generation will need to be addressed as centralized generation facilities will still be required in the coming years. It will be important to balance the lower market prices created by the existence of non-dispatchable renewable distributed generation with the need for investments in centralized generation.

4.2 Additional value of DG

Electricity is not the only value that renewable distributed generators bring to the system. The other important function is the reduction of carbon emission, the economic and employment stimulus associated with the manufacture and construction of distributed generation facilities, and the increased national security from energy independence.

In Australia, Ergon (DNSP), together with the community of Magnetic Island, have used solar distributed generation in concert with energy efficiency and electricity demand management to achieved outstanding results in reducing peak demand, energy consumption and greenhouse gas emissions. In addition, it has also deferred the building of a costly third submarine cable to the island by at least eight years, which in turn reduces capital costs and price pressure.

In many markets, distributed generation is being utilized to provide increased reliability and lower electricity costs for remote rural communities. In both Canada and Australia, renewable generation is being used to increase reliability and reduce the dependence on diesel-fired generation. While diesel generation will be required to provide stability in generation, the renewable distributed generation is lowering fuel costs.

In Japan after the 2011 earthquake, utilizing distributed generation as a reliable backup power supply is gaining traction, especially for data centers and other critical loads. Demonstrations using distributed generation to improve power quality (voltage dip, voltage unbalance, frequency variation, etc.) are being conducted.

Hospitals in both the United States and Japan are piloting the use of microgrids to provide some form of back-up power during natural disasters. The typical diesel/gas backup generators lack reliability as a result of not running often enough. Distributed generation that is designed and intended to run on a regular basis as well as providing back-up power could solve this problem. Even for residential use, solar has been drawing attention as stand-alone generation source for emergencies. The emergence of lower cost energy storage and distributed generation solutions are likely to increase the adoption of micro grids during system emergencies.

In Australia, Canada, and Ireland, job creation is also claimed as a key benefit of renewable distributed generation. In Canada, the Long Term Energy Plan of the biggest province puts the 3 year job creation at 50,000[51]. However, the development of large-scale solar photovoltaic manufacturing in China has reduced the manufacturing jobs available in other markets.

In addition to the carbon reduction and job creation, energy independence has been cited by Ireland, Japan and Korea as a key driver of the distributed generation initiatives. Japan has a low energy self-sufficiency rate. Since the 2011 earthquake, importation of liquefied natural gas for generation has increased substantially. Distributed generations will improve the energy self-sufficient of the country.

[50] http://www.aemc.gov.au/market-reviews/completed/retail-electricity-price-movements-2012.html
[51] http://www.energy.gov.on.ca/en/ltep/making-choices/

4.3 Impact of connection costs

In many markets, the distributed generators are paying most of the costs of interconnection. However in some markets various other charges (ancillary services, etc) that apply to traditional generation are waived to encourage the development of renewable distributed generation. In Japan for example, solar and wind power generation systems are exempted from some of the ancillary service charges (reserve power and voltage frequency regulation) charged by utilities to traditional centralized generation sources.

The size of the distributed generator also factors into the cost of interconnection. In most markets, there are different rules for small residential programs (under 5 to 10kW) that reduce the burden on the customer for the interconnection cost. Often an engineering study is not required. The main requirement for these "micro" distributed generators is to provide anti-islanding protection that avoids back feeding into a faulted area where the utility supply has been disrupted. These integration costs are typically minimal and can be provided from the distributed generators invertor.

For generators above a certain threshold, the majority of the costs are borne by the generator.

While total costs vary between markets based on local labor rates, the costs are typically 5-15% of an overall distributed generation project capital costs.

Utilities are working to streamline their processes and develop standardized interconnection equipment to lower cost.

In Canada, the use of utility-owned WiMAX networks is being piloted to provide a communication medium for protections and telemetry communications. Currently, distributed generators need to pay for wireline protections or use a freewave radio bandwidth (where possible) for their transfer trip protections. Using WiMAX would reduce the cost of interconnection as it allows for point-to-multi-point communications and avoid the leased communications costs.

In Ireland, to improve the efficiency of the application and engineering process, it is done in batches through a series of successive "Gates", as discussed above.

In many jurisdictions, technical solution are being sought to reduce the cost of connection including the use of Distribution Management Systems to utilize distributed generators for reactive power control to actively manage voltage on connected feeders. In addition, the coordinated controls of distributed generators along with dispatchable loads are being used to connect generation without requiring the upgrade to the feeder or transformer.

4.4 Ancillary service markets for DG

Many jurisdictions around the world are examining the value of distributed generator enabled ancillary services. The distributed generation that produces DC converted to AC through power electronics has an ability to provide traditional ancillary services and to provide both active and reactive power. As there are regional differences in many countries, this development has not proven even. In Western Australia the market facilitates more ancillary services as compared to Eastern Australia that has higher capacities and fewer requirements due to extensive interconnections.

Almost all of the survey countries discussed utilizing distributed generation to provide reactive power for the overall system. Technology is being piloted that allows the dynamic change of power factor at the distributed generator's invertor to support reactive energy on the grid.

In Norway there are no special incentives/arrangements for distributed generator-based ancillary services compared to other types of generation. The transmission system operator in Norway (Statnett) has a grid connection code giving requirements for generation plants of different types and capacities. Plants with a capacity > 0,5 MVA shall be equipped with voltage controllers, while plants with a capacity > 10 MVA shall be equipped with turbine controllers.

4.5 Risk of the DG model

Within the industry, there is growing discussion on the risks associated with transitioning generation from centralized facilities to distributed customer-owned facilities. The cost of electricity for consumers with on-premise generation reduced in alignment with reduced consumption from the grid. However, the cost of electricity to other consumers is increasing as recovery of payments is spread across other electricity users. To ensure that the services provided by the network can be sustainably met as the uptake of embedded generation continues, tariffing will necessarily respond. Ultimately the cost benefit should be a function of reduced network losses and the differential in long run marginal cost of traditional energy sources and embedded generation alternatives.

The outlook of electricity systems is changing rapidly on a global scale. Although different countries are typically characterized by a different generation mix and distribution system structure based on economic and geographical properties, the results of this GSGF study confirm that most nations worldwide experience a significant increase in integration of distributed generation (DG) in general, and renewables generation such as solar PV, wind and biomass in particular. Regarding the latter, many countries even committed themselves to challenging targets. However, since power grids and market regulation were traditionally designed to support large, centralized generation, various technological, regulatory and economic issues have emerged. This report discusses these challenges, as well as their potential solutions, in detail. Furthermore, country-specific trends and innovative developments are analyzed for Denmark, Ireland, Japan, Canada, Korea, Australia and the USA.

From a technological perspective, it is found that maintaining power quality, managing voltage and frequency levels, network losses, increased loads, standardization and interoperability are major issues related to DG integration on the distribution system level. Some countries (e.g. Japan) also experience problems on the transmission system level, where balancing issues arise due to the variability of many DG technologies, and where a lack of grid capacity often constitutes a bottleneck. Without interference, these issues may jeopardize system reliability and safety. To address these issues, many countries are publicly funding R&D projects related to smart grids and DG integration. In order to mitigate considerable expenses related to the replacement of ageing grid infrastructure and the investment in additional capacity, several countries are exploring the possibilities of active demand participation which, spurred by ICT and metering developments, is believed to be a valuable option to facilitate DG integration. Also electricity storage both on the transmission (e.g. pumped hydro) and distribution (e.g. electric vehicles) level receives substantial interest.

Another principal driver to adoption of DG systems is energy policy and regulation. In this study, it is found that policy is generally (especially in Europe) based on security of supply, sustainability and competition. A major issue, however, is that regulatory measures change frequently and vary between and even within countries. This creates regulatory instability and complexity, thus making investors reluctant to fund innovative solutions. Another problem lies with the way in which utilities and grid operators are regulated. A strong emphasis on cost-efficiency limits industry incentives to make R&D expenses. Furthermore, a lack of technical standards often hinders the connection process of DG. Connection requirements such as maximum hosting capacity of DG also deter DG integration. Many countries are in the process of reviewing outdated regulations in order to encourage and stimulate renewables generation. In particular, they resort to mechanisms such as: feed-in tariffs (FIT), tax reductions, subsidies, power purchase agreements, loan guarantees, accelerated depreciation. These measures have led to a considerable increase in DG investment. Examples of successful policy measures include the green certificate scheme in Sweden and Norway, third-party financing options in the US and introduction of Feed-in-Tariff (projects over 10 KW) and microFIT (projects under 10KW) finance programs in Ontario, Canada.

Integration of DG also has profound economic consequences. Governments worldwide are looking to balance environmental goals related to renewable DG with the economic impact on consumers of a more expensive generation mix. The results of this survey show that in all countries, the costs associated with renewable DG are decreasing, and regulatory incentive schemes are being adjusted or lifted as technologies mature and become more cost-efficient. Some markets already exhibit positive effects of renewable generation on the market clearing price for traditional sources. Furthermore, it is shown that DG can increase system reliability (e.g. in rural communities in Canada and Australia, but also in Japan after the 2011 natural disaster). DG is also believed to stimulate economic progress and employment through manufacturing and construction of new facilities and infrastructure. Lastly, it can be argued that increased integration of DG decreases the energy dependence on other countries, and thus increases national security of supply.