

GSGF >> REPORT

STATUS AND INSIGHTS ON MICROGRIDS:
FROM PILOT TO COMMERCIAL DEPLOYMENT

AUG 2017



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LIST OF ABBREVIATIONS

This report uses the following standardized units and abbreviations.

Abbreviation	Meaning
CAD	Canadian Dollar
CPUC	California Public Utilities Commission
CRE	Commission de régulation de l'énergie (The French Energy Regulator)
DER	Distributed Energy Resource
DOE	Department of Energy
DSO	Distribution System Operator
EMS	Energy Management System
GHG	Green House Gas
GSGF	Global Smart Grid Federation
GWh	Gigawatt-hour
HV	High Voltage
IEC	International Electrotechnical Commission
IEEE	The Institute of Electrical and Electronics Engineers, Inc.
IT	Information Technology
KEPCO	Korea Electric Power Corporation
kW	Kilowatt
kWh	Kilowatt-hour
LV	Low Voltage
MV	Medium Voltage
MW	Megawatt
MWh	Megawatt-hour
NEDO	New Energy and Industrial Technology Development Organization (in Japan)
PV	Photovoltaic
REV	Reforming the Energy Vision (in New York State)
T&D	Transmission and Distribution
TEPCO	Tokyo Electric Power Company
TS	Technical Specifications
USD	The United States dollar
VPP	Virtual Power Plant
WG	Work Group

The Global Smart Grid Federation (GSGF) annually sets up multiple working groups (WG) on important smart grid related topics. In 2015, three WGs were established: the Power Grid Electrical Energy Storage WG, the Flexibility WG, and the Cyber Security WG. In 2016, a WG related to the status and insights on microgrids was established. This WG consists of members from industry and research institutes from several countries around the world. Multiple questionnaires and meetings were conducted, in which the members shared insights on challenges and opportunities for microgrids in their respective countries.

This white paper is based on the results of those activities and will focus its discussion on microgrids that satisfy the following characteristics: (1) microgrids that are connected to the grid, and (2) microgrids that can be islanded or controlled to minimize the effect of intermittent generation on the grid.

The structure of the white paper is as follows: the first chapter offers an introduction to microgrids and the focus of this white paper; the second chapter identifies various functions of microgrids and barriers to their commercialization based on WG discussions and questionnaires; the third chapter provides case studies of existing microgrid pilot projects; the fourth chapter proposes some solutions for promoting microgrid commercialization; and the fifth chapter concludes the white paper.

The white paper introduces global case studies of microgrids, many of which have analyzed various value streams including ancillary services, demand response, and electricity bill reduction. As an additional value to customers, these microgrid projects have also offered resiliency by being able to operate in an islanded mode.

The projects introduced in this white paper are all built fully or partially on external financial support (e.g. subsidies from the government). In order for microgrids to become commercially available, cost of microgrid technologies will need to be reduced and revenue sources from microgrid business will need to be clarified.

It has been perceived among the WG members that the cost of microgrid technologies will further decrease in the next several years due to the rapid decline in the cost of renewable energy technologies and energy storage. On the other hand, commercial deployment of microgrids has struggled due to uncertainty surrounding their business models. Regulations, which were originally developed for the conventional centralized power grid, will need to be reconsidered and modified as new technologies, such as microgrids, emerge on the system. Currently, under many regulations, it is uncertain how and by whom the services and values provided by microgrids can be valued and remunerated (e.g. through the market, electricity tariffs, etc.). Changes on the regulatory side could enable new revenue sources for microgrid businesses. If revenue sources become clearer, risks associated with microgrid projects could be reduced, facilitating financing for these projects as well. With ongoing cost reductions and changes in regulatory framework that enable microgrid business models, microgrids will shift from pilot to commercial deployment.

¹ More info on <http://www.smartenergydemand.eu/wp-content/uploads/2015/09/Mapping-Demand-Response-in-Euro>

1 NECESSITY FOR MICROGRIDS (INTRODUCTION/OVERVIEW)

Background of the working group

Changing power grid

The power grid today is in drastic transition. Faced with climate change and the need for reducing greenhouse gas (GHG) emissions, deployment of renewables is rapidly accelerating at a global scale. However, renewable energy is intermittent; solar panels can only generate electricity when the sun shines, and wind turbines when the wind blows. The power grid must deal with these new challenges posed by intermittent renewables by transforming itself from a centralized to a decentralized system that can control various resources on the grid, including generation, demand, and storage assets.

Advancements in information technologies (IT) are supporting and accelerating such transformation. Consumers have become prosumers, and various resources on the grid are now connected and able to communicate with each other. Innovative business models are arising in the new decentralized power system; utilities are not the only players on the power system anymore.

The importance of resilient power supply is more widely recognized, stemming from recent experiences of catastrophic natural disasters. When the Great East Japan Earthquake hit in 2011, power supply stopped in more than 4.5 million households in six prefectures¹. The influences of the earthquake were not limited to the earthquake-stricken area; Tokyo Electric Power Company (TEPCO) was forced to implement rolling blackouts as well. The next year in 2012, Hurricane Sandy hit the East Coast of the United States, causing blackouts for 8.5 million people, keeping more than 1.3 million people without power for a week². Experiences of such unforeseeable disasters have led people to realize the importance of resilient power supply and energy security. In some households equipped with solar photovoltaic (PV) panels and battery storage, there is a tendency to prefer self-consuming the generated electricity, relying less on the centralized power grid.

Why we need microgrids

The power grid is in need of solutions that can support its transition into a more decentralized and reliable system. Microgrids are one such solution.

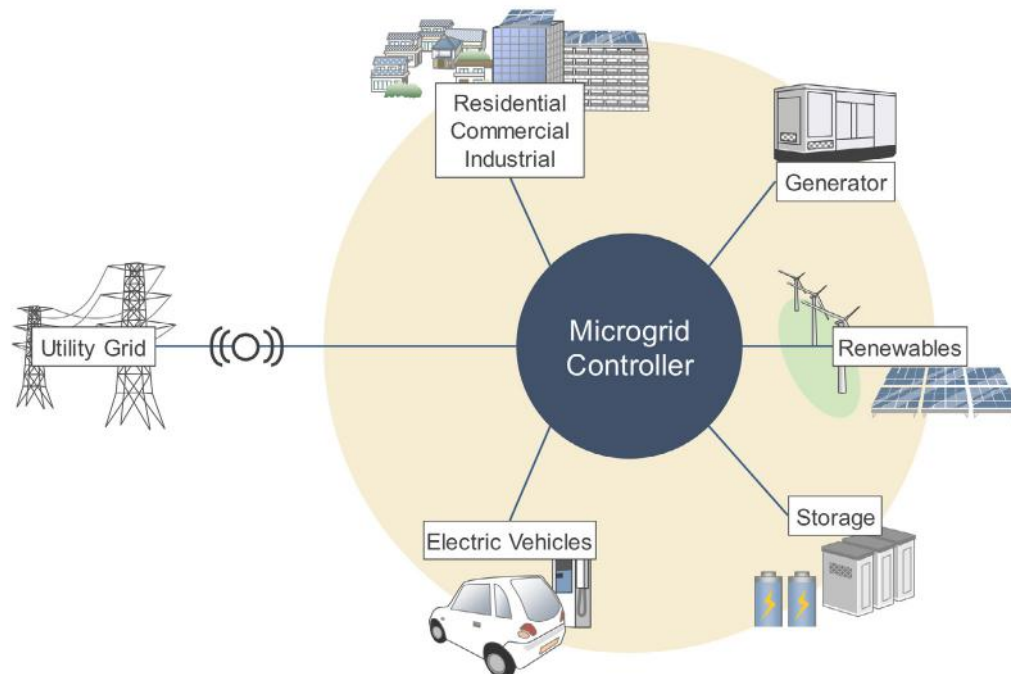


Figure 1-1 Components of a microgrid

Microgrids contribute to reducing GHG footprint and pollution by enabling a higher penetration of renewables within the system. Microgrids work to balance fluctuations from renewables at the local level, by utilizing various storage and load resources. Microgrids can thus play an important role in achieving challenging goals related to GHG emissions and renewables.

¹<http://www.bousai.go.jp/kaigirep/chousakai/tohokukyokun/9/pdf/sub2.pdf>

²http://www.huffingtonpost.com/2013/09/09/microgrids-hurricane-sandy_n_3895982.html

Additionally, microgrids are able to provide reliable power supply even when the supporting grid is down. With advanced control, microgrids can be “islanded” from the centralized power grid and continue to supply power to the customers. Therefore, customers in microgrids are offered a higher level of resiliency in power supply.

Functions of microgrids are further explained in the next chapter.

Scope of the white paper

The definition of a microgrid varies depending on region; no unified global definition of a microgrid exists. Examples from French regulator Commission de régulation de l'énergie (CRE), the European Commission, and the United States Department of Energy (DOE) illustrate how the definition of a microgrid can differ depending on country and region.

- *Les microgrids sont des réseaux électriques de petite taille, conçus pour fournir un approvisionnement électrique fiable et de meilleure qualité à un petit nombre de consommateurs. Ils agrègent de multiples installations de production locales et diffuses (micro-turbines, piles à combustible, petits générateurs diesel, panneaux photovoltaïques, mini-éoliennes, petite hydraulique), des installations de consommation, des installations de stockage et des outils de supervision et de gestion de la demande. Ils peuvent être raccordés directement au réseau de distribution ou fonctionner en mode îloté. Le concept est en train de s'élargir aux réseaux de chaleur et de gaz.*

Source: Smart Grids CRE, “Les microgrids”³

- *Microgrids comprise [low voltage] distribution systems with distributed energy sources (micro-turbines, fuel cells, PV, etc.) together with storage devices (flywheels, energy capacitors and batteries) and controllable loads, offering considerable control capabilities over the network operation.*

Source: European Commission Community “European distributed energy resources projects”⁴

- *A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. It can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode.*

Source: DOE “The U.S. Department of Energy's Microgrid Initiative”⁵

The commonality between these definitions is that a microgrid consists of different loads and generation resources that are aggregated and controlled. In some definitions, such as that of CRE and DOE, the islanding function of microgrids is included, while other definitions do not necessarily require microgrids to be able to operate in an islanded mode.

This paper will focus its discussion on microgrids that satisfy the following characteristics: (1) microgrids that are connected to the grid, and (2) microgrids that can be islanded or can be controlled to minimize the effect of intermittent generations on the grid.

While there can be various sizes of microgrids, from single customer microgrid to full substation microgrid as shown in the figure below, this white paper provides case studies mainly of microgrids up to full substation scale.

³<http://www.smartgrids-cre.fr/index.php?p=microgrids>

Provisional translation: “Microgrids are small power grids which are designed to provide reliable and quality power supply to a small number of consumers. They combine multiple local generation facilities (microturbines, fuel cells, small diesel generators, PV panels, mini-wind turbines, small hydro), consumer facilities, storage facilities, and management and control tools. They can be connected directly to the distribution network or be operated in an isolated mode. The concept is being extended to heat and gas networks.”

⁴<http://www.microgrids.eu/micro2000/presentations/46.pdf>

⁵<https://energy.gov/sites/prod/files/2016/06/f32/The%20US%20Department%20of%20Energy%27s%20Microgrid%20Initiative.pdf>

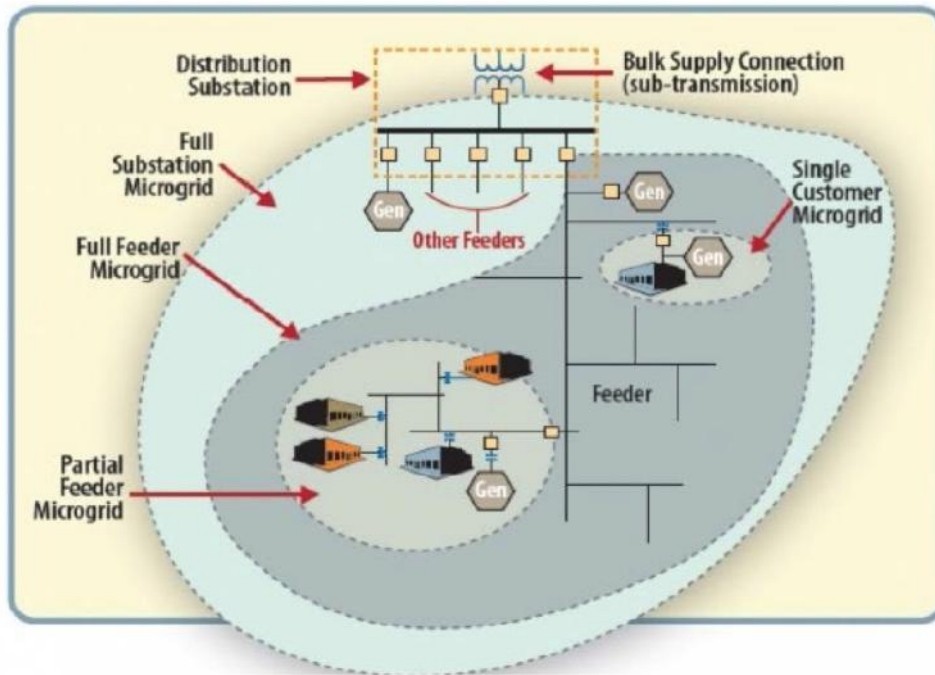


Figure 1-2 Microgrids by scale
 Source: DOE "DOE Microgrids Program Overview"⁶

The structure of the white paper is as follows: the second chapter identifies various functions of microgrids and barriers to their commercialization based on WG discussions and questionnaires; the third chapter provides case studies of existing microgrid pilot projects; the fourth chapter proposes some solutions for promoting microgrid commercialization; and the fifth chapter concludes the white paper.

⁶http://www.nrel.gov/international/pdfs/5a_ton_reif15.pdf

2 CURRENT STATUS OF MICROGRID DEPLOYMENT

Functions of microgrids

Microgrid projects from various countries were collected by GSGF members, via workshops, telephone conferences, and participation in international events. Each microgrid has a different combination of functions based on their surrounding environment. The need for microgrids and their expected functions differ according to the conditions of the existing power grid (e.g. fuel cost volatility, electricity tariff, reliability, etc.), political conditions (e.g. goals for GHG emissions and renewables, interconnections with neighboring countries, etc.), and geographical conditions (e.g. solar radiation, wind, fuel cost, etc.).

Microgrids can perform their functions and provide value for both customers located within the microgrid (e.g. residential and commercial consumers) and network operators located outside of the microgrid (e.g. transmission system operator and distribution system operator). Functions performed for customers within the microgrid include: enabling renewables deployment and carbon footprint reduction; increased resiliency and PV self-consumption; uninterrupted power supply; and electricity bill reduction. Functions performed for network operators outside of the microgrid include: enhanced grid and system operation; and transmission and distribution (T&D) investment deferral.

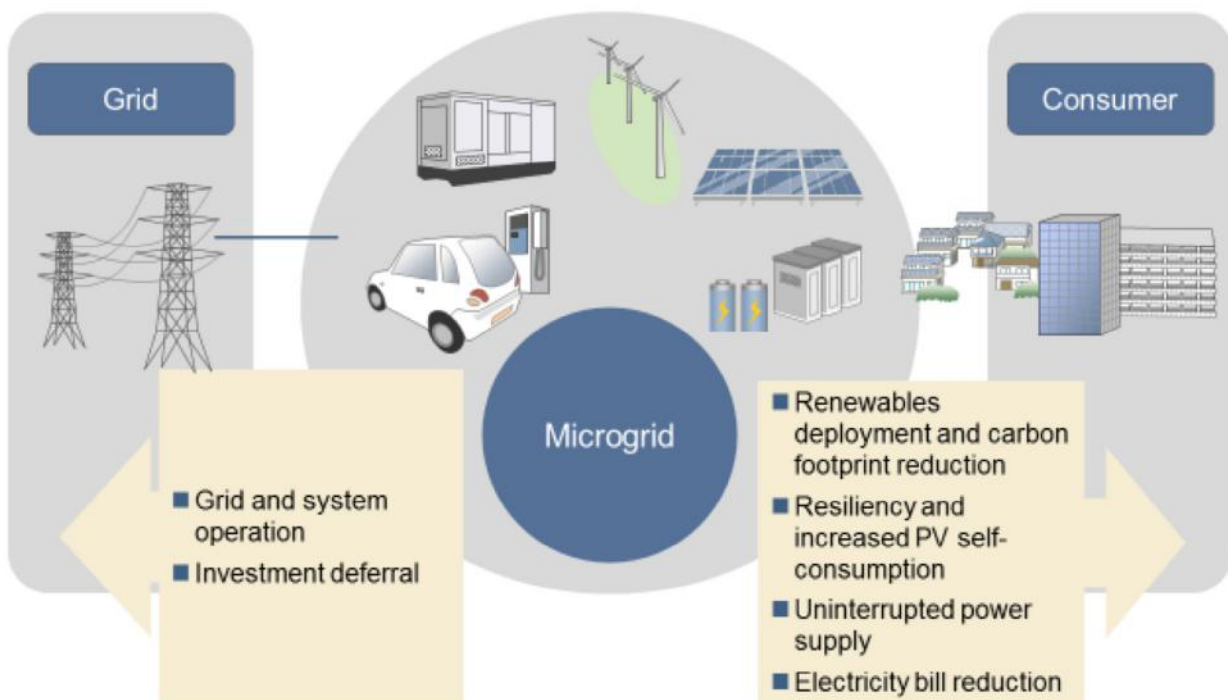


Figure 2-1 Functions of microgrids

Renewables deployment and carbon footprint reduction

While environmental policies in many countries are demanding higher rates of renewable deployment for carbon footprint reduction, renewables, such as PV and wind generation, are not able to provide stable power supply; they can only generate intermittently, when the sun shines or the wind blows. As a result, distributed renewables cause small (but large-scale when aggregated) fluctuations in the grid, which the conventional operation system was not designed to handle. For the conventional power grid to adjust to such systems, it would require a redesign of market structure and operation parameters, which would take a long time and come at enormous cost. On the other hand, microgrids consisting of flexible loads, storage, and advanced control systems are able to integrate larger amounts of intermittent renewables into the system at the local level. They are able to coordinate between different distributed energy resources (DER) and balance power demand and supply locally and efficiently.

Resiliency and increased PV self-consumption

Microgrids can be intentionally islanded from the centralized power grid and continue to supply power to their customers during unexpected power outages, such as natural disasters and cyberattacks. This is especially important for critical loads, such as hospitals, military bases, and public facilities designated for disaster evacuation. Governments that recognize value in resiliency are offering subsidies for microgrids; for example, the state of New York in the United States provides microgrid funding through the NY Prize program. In the program, microgrids are described as “connecting multiple users in a neighborhood, in the event of power outage, offering energy independence as well as local power generation and distribution.”⁷

Uninterrupted power supply

In many developing countries, even in electrified areas with power supply from the centralized power grid, the centralized power supply is frequently disrupted. When there is a fault on the centralized power grid or there is load shedding, microgrids can automatically switch to islanded operation, providing uninterrupted power supply to their customers. The provision of uninterrupted power supply is particularly important for business operations that require continuous power supply; microgrids can contribute to improving these businesses’ productivity.

Electricity bill reduction

In areas with high cost of electricity from fossil fuels, such as in remote areas and on islands, microgrids can reduce electricity bills for customers. Microgrids, with advanced control technologies, can generate electricity mainly from renewables only adding a small cost for fuels. Additionally, as renewables do not require fuel cost, electricity tariff is not influenced by the volatility of fuel cost.

Grid and system operation

Various loads including electric vehicles, generation resources, and storage can be aggregated to provide services in the energy market, including demand response and ancillary services. Such business model (commonly called a Virtual Power Plant) is becoming more feasible and popular thanks to improved technologies in load prediction, aggregation, and operation maximization. Microgrids providing such services can generate stable revenue, increasing the feasibility for a business case.

T&D investment deferral

By managing peak power demand within the microgrid, distribution network investments or upgrade costs may be deferred, offering distribution network operators an economic benefit. This business case is feasible particularly in remote distribution areas located at the edge of the distribution grid.

Most of the microgrid projects collected through the work group activities had the goal of integrating larger amounts of renewables into the system. Across many projects, microgrids provided higher level of resiliency to their customers by being able to be intentionally islanded from the centralized power grid. Some projects aimed to strengthen the business case for microgrids by quantifying various grid and system services such as demand response and ancillary services. Microgrids in countries with relatively high electricity tariffs also provided the benefit of electricity bill reduction for their customers.

Barriers to microgrid deployment

Most of the microgrid case studies were granted financial support, such as subsidies provided by municipalities or the federal government. For microgrids to be deployed on a commercial scale, their economics must be improved by reducing the cost of microgrid technologies and increasing the revenue of microgrid businesses.

It is often considered that power supply from the existing grid is more economically viable compared with power supply from microgrids⁸. However, it is expected that rapid decline in the cost of renewable energy technologies and energy storage will improve the economic feasibility of microgrid projects in the coming years. In addition to such trends, actions for further reducing the cost of microgrids, including their communication and control technologies, would promote commercial microgrid deployment as well.

⁷<https://www.nyserda.ny.gov/All-Programs/Programs/NY-Prize/Resources-for-applicants/Microgrids-101>

⁸It is important to keep in mind that cost of power supply in a microgrid and electricity tariff cannot be simply compared, as structure of electricity tariff is complex, at times involving subsidies.

Furthermore, revenue sources from microgrid projects must be analyzed so that business models can be clarified. In most regions around the world, the value provided by microgrids is not appropriately identified under the current regulatory framework, and therefore the cost of providing such value is not properly allocated. For example, while some microgrids are able to provide ancillary services, they may not be eligible to provide such services under the current regulatory framework. Lack of clarity around revenue sources poses a serious risk for financial institutions as well, which may become a barrier for financing the project. Additionally, under many regulations, it is unclear which entities are eligible to participate in microgrid businesses; such uncertainty is a barrier for many potential entrants in the microgrid market.

Business opportunities for microgrids

In regions where grid parity has already been achieved, there may be a positive business case for single customer microgrids, which only contain load from a single building or facility. Such microgrids reduce electricity bills for the customers as generation from renewables is cheaper than the electricity purchased from the centralized power grid. Additionally, there may also be a positive business case for microgrids installed in developing countries that provide uninterrupted power supply for critical loads; microgrids are able to offer direct economic value to customers by increasing their productivity.

However, most microgrids in developed countries that contain multiple loads are not economically viable without subsidies. In order for these microgrids to become economically viable, the cost of microgrid technologies would need to be further reduced, and stable revenue streams from the energy market (e.g. ancillary services) would need to be established. The benefits of higher renewables penetration and improved resiliency may not be sufficient to make a positive business case for commercial microgrids; these benefits would need to be offered in combination with other economic benefits of the microgrids.

3 CASE STUDIES

In this chapter, several case studies from various countries are explored.

Higher renewables penetration

Microgrids utilizing diesel generators as their main source of energy have existed for decades. However, with advanced control technologies, microgrids are now able to integrate a higher rate of renewables into the system than the conventional central grid. Such control technologies are also able to integrate more renewables without causing negative effects on the centralized power grid.

Los Alamos Microgrid– United States

From 2012 to 2014, a smart grid demonstration project was conducted in the state of New Mexico, United States, all of which was funded by the New Energy and Industrial Technology Development Organization (NEDO) in Japan. There were two main objectives: (1) to control the microgrid and smooth the fluctuation of renewables (PV) at the connection point; and (2) to conduct and analyze the effect of demand response programs in microgrids.

To demonstrate the first objective, a 1 MW PV system, a 1MW/6 MWh sodium-sulfur battery, and a 0.8MW/2.3MWh lead-acid battery were implemented. These assets were controlled with Toshiba's μ EMS (Micro Energy Management System), which mitigated PV fluctuations with the batteries to maintain a stable tie-line power flow. The EMS was responsible for forecasting PV generation and load, creating operation plans for the batteries, controlling the batteries according to the plan. The project analyzed the performance of the system by calculating the load factor, derived by dividing average tie-line power flow by maximum tie-line power flow. As a result, it was proven that μ EMS improved the load factor by more than 10% over the case without battery control. Figure below shows that the actual tie-line power (red line) is nearly flat, maintaining a stable power flow.

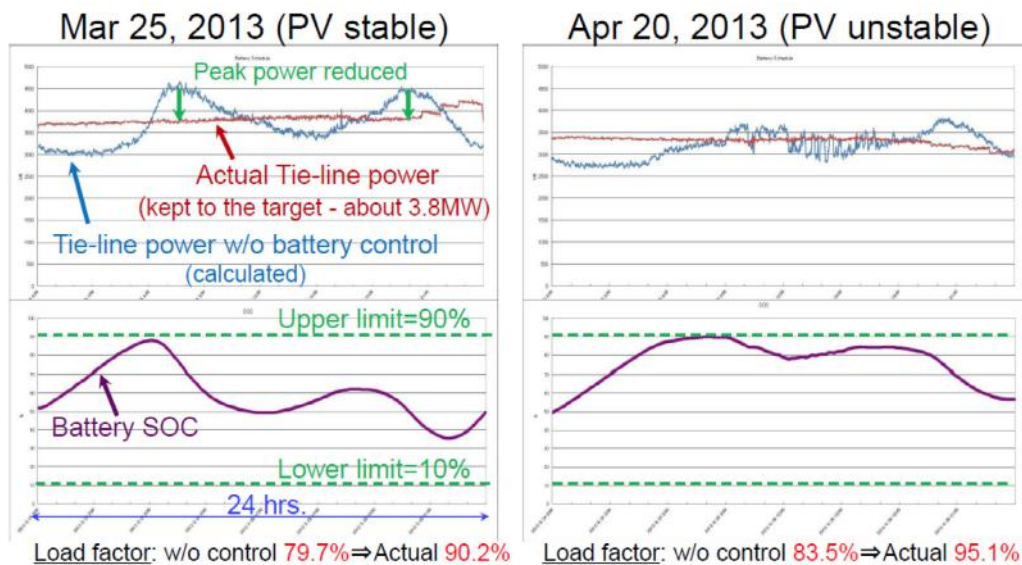


Figure 3-1 Result of μ EMS control demonstration
Source: Presentation material provided by Toshiba

To demonstrate the second objective, "smart houses" equipped with home energy management systems, a 3 kW PV system, and a 24 kWh thermal storage system participated in demand response. Smart Houses that are able to respond against price signals from utility showed a great potential for demand response by residential housings. There was also a demonstration of CPP (Critical Peak Price) type demand response with nearly 900 houses of volunteers. Peak demand reduction, which amounted to as high as 10.49% during the summer, was not the only role that demand response played within the demonstration project. It also showed that integrating demand response into the microgrid reduced the required battery capacity, as shown in the figure below. As batteries often have the highest impact on microgrid cost, integration of demand response programs may improve the economics.

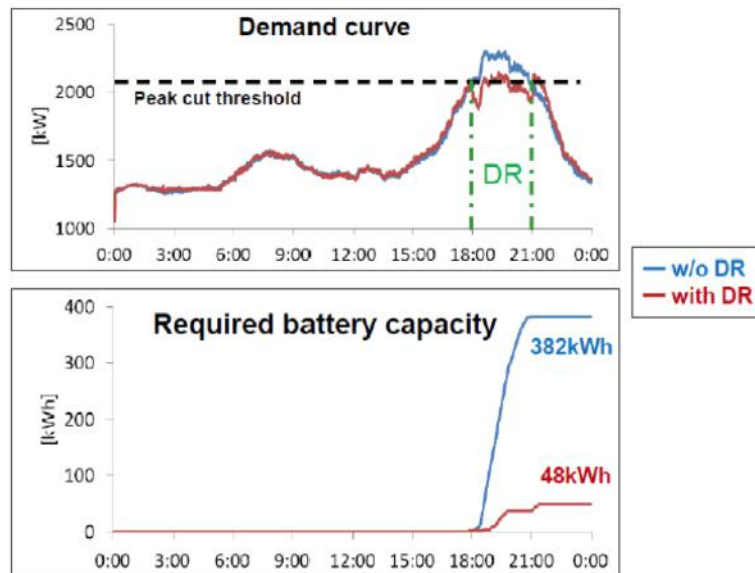


Figure 3-2 Reduction of required battery capacity with demand response
Source: NEDO, "NEDO Microgrid Case Study"⁹

This project implies that microgrids can enable further integration of renewables by maintaining stable power flow even in the face of intermittent generation. In addition, it implies that demand response is not only a means to achieve peak demand reduction, but also to reduce battery capacity, which contributes to lower microgrid costs.

Increased resiliency and energy security

Nice Grid- France

Nice Grid is a demonstration project funded by the European Commission as one of the GRID4EU projects . A total of 30 M€ has been invested in this project¹⁰, of which 10 M€ came from consortium members¹¹ and 11 M€ from national and European public support. It is the first smart solar-energy district demonstration project to be conducted in France. The project started in 2012 as a five-year project. In December 2015, it was decided that the demonstration period would be extended for one additional year.

This ambitious project, which has brought together a broad range of stakeholders, is located in the municipality of Carros, in the administrative department of Alpes-Maritimes, near the French Riviera. The area is rich in its renewable capacity; its PV capacity is as large as 2.5 MW. The 11,500 inhabitants of the city include residential, industrial, and commercial customers, making this region ideal for a well-balanced demonstration project. 550 companies are located in its 188 ha industrial area.



Figure 3-3 Microgrid site at Carros
Source: Nice Grid¹²

⁹<http://www.nedo.go.jp/content/100762757.pdf>

¹⁰For more information on GRID4EU projects, refer to its final report: http://grid4eu.blob.core.windows.net/media-prod/29375/grid4eu-final-report_normal-res.pdf

¹¹The consortium members consist of GE Grid, SAFT, EDF SA, Armines, RTE, NetSeenergy, Daikin, Socomec and NKE Watteco

¹²<https://www.nicegrid.fr/>

The microgrid system consists of a 2.5 MW PV system and 1.3 MW of lithium-ion batteries. There are four types of batteries, including a 1MW/560kWh battery at the primary high voltage (HV)/medium voltage (MV) substation, a 250kW/620kWh battery at a MV/low voltage (LV) substation, two 33kW/160kWh batteries on a LV feeder, and 20 4kW/4kWh residential batteries. Alstom's Network Energy Manager solution optimizes the balance between energy consumption and generation at the secondary distribution network level. The demonstration has 300 household and 12 business client participants.

There were four goals set in this demonstration project: to optimize the operation of distribution network with high PV penetration using electricity storage; to reduce peak demand; to test the islanding mode on an LV district; and to give consumers an active role as prosumers.

The 1st street district in Carros was designated as the islanding area. The district is supplied by a 400 kVA transformer, equipped with a 250 kW/620 kWh storage asset with four power converters. It consists of eight clients (storages, garages, business offices, etc.) loading up to 100 kW, and three PV plants of 430 kW total. Due to high penetration of PV, excess generation from PV is fed back into the MV grid every day in this area.

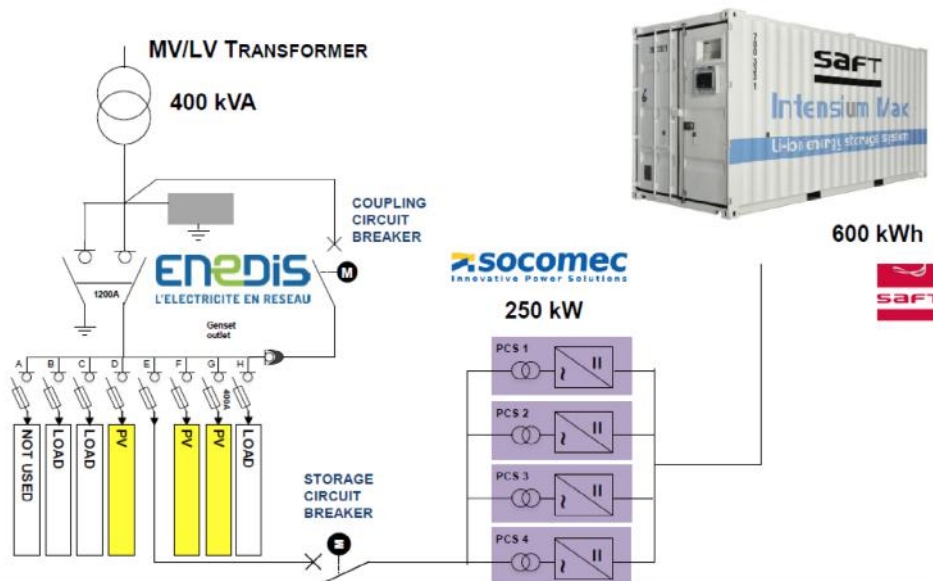


Figure 3-4 Configurations of the islanding district
Source: Presentation material provided by Enedis

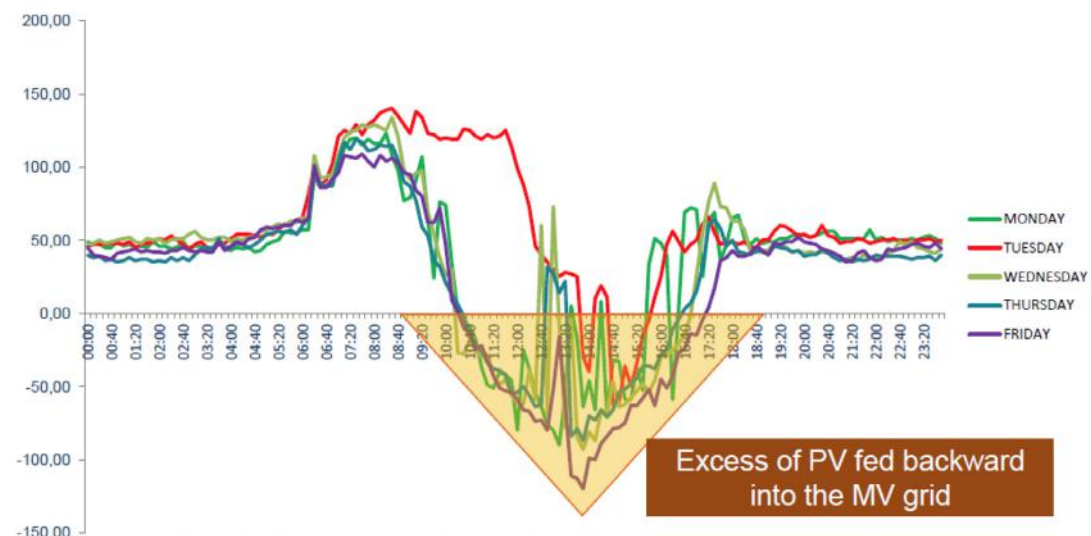


Figure 3 5 Load curve at the secondary substation of the islanding area
Source: Presentation material provided by Enedis

Two types of islanding were tested. Scheduled islanding is conducted when the centralized power grid needs to cancel power exchanges with the microgrid as a load-shedding means. In general, scheduled islanding is forecasted and can be prepared for on day ahead. Unforeseen islanding occurs unexpectedly when there is a failure in the centralized distribution grid. The microgrid offers an automatic blackstart, distributing backup power in less than 10 s. In either case, uninterrupted power supply is offered in the microgrid at all times, even during disconnection and reconnection (synchronization) phases. The islanding operations are compliant to EN50160 criterions to ensure the quality of the distributed energy (frequency and voltage deviation, harmonic distortion, etc.).

Islanding testing took place in October 2015. With scheduled islanding, Nice Grid was able to achieve a world record islanding duration of 5 hours. Both frequency deviation and voltage deviation during islanding were compliant with EN50160; frequency deviation was 0.04~0.14%, satisfying the below 1% requirement and voltage deviation was 0.81%~2.17%, satisfying the below 10% requirement.

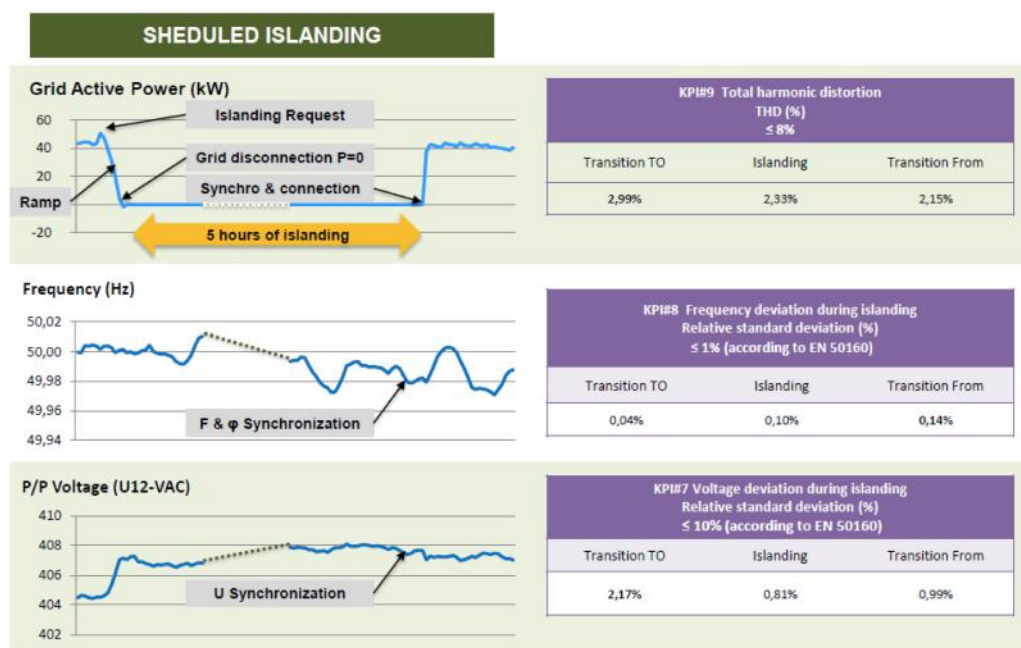


Figure 3-6 Results of scheduled islanding
Source: Presentation material provided by Enedis

With unforeseen islanding, the microgrid was able to achieve an islanding duration of 2 hours. The islanding mode with the unforeseen islanding also was compliant with the EN50160 criterion.

The Nice Grid project has demonstrated that with the installation of microgrids, it is possible to have higher penetration of renewables while maintaining conventional power supply quality, and that islanding modes of microgrids can offer additional security of power supply even when the centralized power grid is unable to supply power.

Nice Grid will conduct further demonstrations under the Interflex Project¹³. There are three use cases for the project. The first is to conduct automatic islanding without any interruption of service while adhering to the power quality standards. The second is to consider the business case of providing multiservice with centralized storage systems, including ancillary services, self-consumption, and mitigation of local grid constraints on the distribution grid; the results will be used to develop regulatory recommendations for storage, such as grid fees and operation. The third is to set local flexibility mechanisms operated by and for the distribution system operator (DSO).

Maale Gilboa microgrid– Israel

A microgrid project is ongoing in the rural cooperative community of “Maale Gilboa” in Israel. The project budget is 700,000 €, half of which is funded by the government.

Israel, although located in the continent, can be considered as an island from the power supply perspective. The Israeli grid is not connected to any other grids; it cannot rely on the external countries to supply power. Its power demand has

¹³Interflex project, funded by EU Commission in the framework of Horizon 2020, has selected six demonstration projects in five countries, with technical focuses on demand response, energy carrier integration, islanding, storage, grid automation, and electric vehicles.

been increasing, with projected annual growth of approximately 2-3% up to 2020. In such country, microgrids can play a particularly valuable role in improving energy security.

The annual demand within the microgrid is 3 GWh coming from 108 residences, a manufacturing plant, 17 agricultural buildings, 71 municipal facilities, and eight lighting sites; of these loads, part of the manufacturing plant, the computer rooms and the cow milking facility is designated as the critical load, which can be islanded. The microgrid consists of 12 PV plants of 475 kW in total, a 15 kW wind turbine, and two emergency diesel generators; the battery and the diesel generators are utilized for the critical loads during islanding. The microgrid is monitored and controlled with a microgrid controller, grid measurements, cyber security system, smart metering system and sensors, all of which are interoperable.

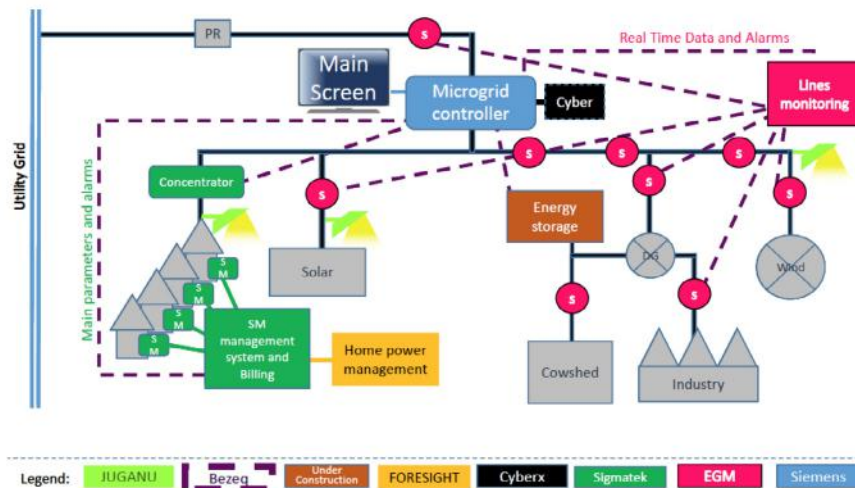


Figure 3-7 Maale Gilboa Microgrid architecture
Source: Presentation material provided by MicroGrid Israel

The project aims to demonstrate various microgrid functions, including load shedding, Volt/VAR control, demand response, optimal generation dispatch, energy storage integration, and smart metering. Operation of the grid will be tested on different operating modes: minimum cost, maximum reliability, minimum emissions, and peak shaving.

The microgrid will enable efficient integration of renewables, optimize system operation, improve reliability, and enable integration of microgrids as a distribution asset to reduce system losses and increase overall system efficiency. Economic analysis of the various microgrid benefits will be conducted.

Providing economic benefits from the energy market and bill reduction

POWER.HOUSE microgrid– Canada

In 2016, Canadian distribution company Alectra Utilities launched a pilot project called Power.House to create a virtual power plant (VPP) of residential solar and storage resources. The project budget was \$1.4 million Canadian Dollars (CAD) and received partial funding from the Independent Electricity System Operator Conservation Fund of 500,000 CAD.¹⁴

There were 20 households participating in this project. Each house was equipped with a solution provided by Sunverge and Roberston Bright Inc., consisting of a 5 kW solar PV array, a 6.8 kW/11.4kWh lithium-ion battery, a hybrid inverter, and an EMS. The 20 houses were aggregated to create a VPP.

The participants of the project were asked for an up-front payment of 3,500 CAD and monthly service fee of 20 CAD over a five-year contract. The assets were owned, maintained and operated by the utility. The project offered its participants reduced electricity bills (providing customers a 5-year payback period) and additional resiliency.

¹⁴<http://www.ieso.ca/-/media/files/ieso/document-library/funding/conservation-fund/conservation-fund-portfolio-february-2017.pdf>

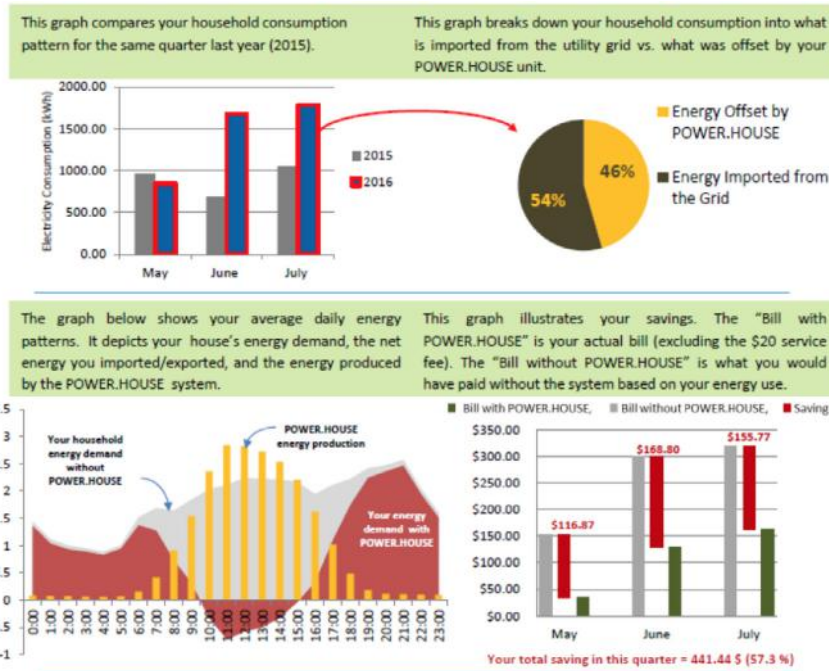


Figure 3-8 POWER.HOUSE customer portal
Source: Presentation material provided by Alectra Utilities

The project identified nine value streams for the VPP: frequency regulation, demand response, operating reserve, end-of-day solar ramp, time-of-use pricing arbitrage, solar net metering, distribution deferral, outage support, and transmission deferral. From the technical aspect, it was concluded that the VPP could fulfill technical requirements for all the aforementioned value streams. From the economical aspect, the project allowed its participants to reduce their bill by 77% during the first year (the savings amount was particularly large during the first year as the fuel prices significantly increased this year).

Within the aforementioned value streams, frequency regulation, demand response, operating reserve, and end-of-day solar ramp were identified as particularly promising value streams for the project.

These use cases will be further investigated within the project. This project implies that acquiring various revenue streams is important in making the project economically feasible. Additionally, depending on the value that the microgrid offers, cost allocation should be reconsidered, so that the cost burden is adequately allocated.

Alternative solution to grid investment

Penetanguishene microgrid by Alectra Utilities—Canada

A microgrid has been installed in Penetanguishene, Ontario by the Canadian distribution company Alectra Utilities. The distribution company, in partnership with Korea Electric Power Corporation (KEPCO) has deployed the microgrid as part of its asset deferral strategy.

Prior to implementing the project, the town of Penetanguishene was suffering from frequent short outages of under 10 minutes. In order to eliminate these outages, Alectra Utilities built a microgrid of 750kVA/500kWh lithium-ion battery system, five circuit automatic switches, step voltage regulator, a turnkey Microgrid Distributed Energy Resource Automation System (MiDAS)¹⁵, and autonomous function and SCADA integration. The microgrid controller enables the microgrid to operate in a grid-connected or in an islanded mode, so that the microgrid can supply power when there is a loss of supply from the transmission lines.

Since implementing the microgrid, the area has not experienced any power supply interruptions, proving that the microgrid was successful from the technical standpoint.

¹⁵More information available at <https://www.powerstream.ca/attachments/MiDAS-Your-Microgrid-Solution-brochure.pdf>

Marcus Garvey Microgrid by Consolidated Edison– United States

Faced with the rising peak demand, Consolidated Edison, a utility in New York, is planning to invest 200 M\$ in demand side management (including microgrids) as an alternative solution for investing more than 1 G\$ in a substation. This is led by the Brooklyn Queens Neighborhood Program initiative, which is part of the New York State's Reforming the Energy Vision (REV) Initiative to accelerate the utilization of distributed energy resources in the existing power system.

A microgrid project is planned for implementation as part of the initiative. 1 M\$ will be lent by non-profit finance group New York City Energy Efficiency Corporation. The microgrid is planned to be implemented at a housing complex called Marcus Garvey, deploying a total of 400 kW rooftop PV, 400 kW fuel cell, and 300kW/1200kWh battery.

4 PROPOSED SOLUTIONS FOR PROMOTING MICROGRIDS

Microgrids are important assets towards building a distributed energy system, providing various values for consumers inside the microgrid and for network operators outside the microgrid. For customers inside the microgrid, they are able to handle larger amounts of renewables and reduce carbon footprint, offer higher reliability and resiliency in power supply, and in some cases reduce electricity bills. For network operators outside the microgrid, they can offer various grid and system services, and under some circumstances, may be a more economic investment alternative. However, various barriers need to be removed for their further promotion. Currently, there may be a positive business case for microgrids under limited conditions, such as single customer microgrids in regions which have already achieved grid parity and in regions with low quality power supply.

This chapter proposes some possible solutions that may facilitate the commercialization of microgrids.

Improving microgrid economics

Rapid decrease in the cost of renewables has contributed to improved microgrid economics. In the future, this trend is expected to continue due to a decline in the cost of energy storage. However, in addition to cost reduction in component technologies, measures to reduce cost of microgrids as integrated systems are also necessary in order for microgrids to move from pilot to commercial phase.

Modular and scalable solutions

Manufacturers often develop microgrids as customized solutions tailor-made for each customer, which requires large design and engineering costs. To achieve commercial deployment of microgrids, manufacturers must offer modular and scalable solutions, simplifying the microgrid installation process.

One example of such modular and scalable solution is offered by ABB. The containerized solution can be transported, installed and commissioned in a safe and fast manner. Type of generation resource can be chosen by the customer, ranging from renewables to diesel generators.



Figure 4 1 Modular and scalable microgrid product by ABB¹⁶
Source: ABB¹⁷

Such modular solutions can facilitate financing of microgrid projects as well. In some cases, microgrid projects had difficulty obtaining financing due to their limited scale and complex risk analyses. The development of modular and scalable microgrids can increase the volume of deployments, allowing financial institutions to aggregate installations and perform risk analyses on the total portfolio. This can facilitate financing for smaller microgrid installations that might otherwise have been considered too risky by financial institutions.

Standardized microgrid control and communication technologies

Extensive work has already been conducted on standardization of microgrid components (e.g. PV, battery, power conditioning system (PCS), etc.). However, it is crucial that work continues towards interoperability between microgrid components, so that multi-vendor microgrid systems can be established. Such multi-vendor systems would allow various combinations of components by different vendors, driving to cost competitiveness.

¹⁶Each container includes a control system, HVAC, PCS, and batteries. Multiple units of the battery component can be added to meet needs from 50 kW to 4600 kW.

¹⁷<http://www.abb.com/cawp/seitp202/BD6B7A09C76F6070C1258045004560AF.aspx>

Agencies such as the International Electrotechnical Commission (IEC) and the Institute of Electrical and Electronics Engineers (IEEE) are working to create such standards. For instance, IEC Technical Committee 8 (System Aspects for Electrical Energy Supply) Working Group 7 (General Planning, Design, Operation and Control of Microgrids) has formulated Technical Specification (TS) 62898-1 (Microgrids Part 1: Guidelines for microgrid planning and specification), and is working on TS 62898-2 (Microgrids Part 2- Guidelines for microgrid operation and control). While these are guidelines, specific standards for protection, energy management, and communication are to be developed. Meanwhile, the IEEE Standards Association is developing P2030.7 (Standard for the specification for microgrid controllers), to define which elements within the microgrid system must be standardized and which can remain proprietary.

Peer-to-peer energy trading: Blockchain

As DER penetration grows and the electricity system becomes more decentralized than ever, it will become possible to trade energy on a peer-to-peer basis without a central control room. The excess PV power of a neighbor may be directly traded with another neighbor. When such peer to peer trading becomes common enough, system operation may become so efficient as to void the need for any central control center or third-party intermediary to host energy trading. This would reduce both the installation and the operation cost of microgrids.

Blockchain, which was originally developed in the financial sector, is starting to be applied in the energy sector as well. Peer-to-peer trading of energy, as one of the possible use cases of using blockchain, can rapidly accelerate the decentralization of the power system. Peer-to-peer trading can be efficiently conducted with smart contracts, a type of machine-to-machine contract that automatically carries out a certain contract according to a set of rules. With the same approach of the smart contracts, blockchain technology can be utilized not only for financial transactions but also for network control and system balancing as well.

Blockchain is already being utilized for a microgrid project in Brooklyn, New York. Excess electricity generated from a participating resident can be traded directly with his/her neighbor using blockchain. The first peer-to-peer transaction was successfully conducted in April 2016. The microgrid even allows its customers to choose from where to purchase their electricity (from the microgrid or the utility).

On the other hand, it needs to be noted that current blockchain technologies require minimum of 10 seconds for each transaction valuation. Therefore, the existing blockchain technology is currently not suitable for energy trading that requires a shorter transaction time. For this reason the Austrian Grid Singularity and Rocky Mountain Institute (US) initiated the non profit organization “Energy Web Foundation” (EWF). The technology partner of EWF are now developing a high performance blockchain technology to be capable of real time trading, system balancing but also grid management. There is ongoing work to shorten this transaction time for increasing blockchain applications in the energy sector.

Grid Singularity already developed a trading agent, the D3A, where they already showing in proof-of-concepts (PoC) the capability of blockchain. With the same trading agent, they are combining on the lowest level internet-of-things (IoT) devices, allowing peer-to-peer trading by connecting several households or even manage micro grids with balancing and voltage control.



Figure 4-2 Lowest Level House #1



Figure 4-3 Next Level Trading; Left Street #1 and Right Region #1

Enabling Microgrid Business Models

Along with reducing the cost of microgrid technologies, microgrid business models must be developed in tandem with regulatory and market structure reforms. Since the conventional power grid and existing regulations were not designed for distributed local solutions and technologies, there remains uncertainty surrounding how microgrids should be treated under the current regulatory framework; by whom they can be owned and operated¹⁸, or what procedures would need to be taken for interconnection with the centralized power grid. Additionally, such complexity is amplified, by the fact that these rules can vary by country. As a result, reforms of regulatory and market structures could support the development of microgrid business models.

Currently, under many regulations, it is uncertain how and by whom the services and values provided by microgrids can be evaluated and remunerated (e.g. through the market, electricity tariffs, etc.). Changes on the regulatory side could enable new revenue sources for microgrid businesses. If revenue sources become clearer, risks associated with microgrid projects may be reduced, facilitating financing for these projects as well. Altogether, these changes can support the development of microgrid business models.

The need for regulatory reform is exemplified by the “REV” initiative in New York. The state recognizes that the conventional power system needs to become more sustainable by utilizing clean energy technologies and other clean distributed generation alternatives. The objective of the initiative is to modify the regulatory framework to encourage utilities to implement clean and efficient power system operations. Through this regulatory reform, the initiative aims to provide incentives for utilities to adopt new roles and business models in the transformed power system.

DSOs in Europe have been providing various recommendations to the European Commission towards the development of regulations that support a decentralized power system with more renewables. Microgrids are mentioned with much interest in such recommendations, as deployment of microgrids at a larger scale would imply a restructuring of the power system for DSOs. It is crucial to the power sector that the roles of microgrids are defined and their costs are allocated properly. Below are some statements provided by DSOs regarding microgrids:

- *“It is equally important to make sure that the microgrid structures associated with local energy communities are not resulting in unfair distribution of benefits at the expense of the connected customers. DSOs must nevertheless not be forced to lease their*

¹⁸For instance, who (e.g. TSO, DSO, or third party) can own and operate storage, one of the core components of a microgrid, under current regulations is under consideration in Europe.

networks.”

Source: European Distribution System Operators for Smart Grids “EDSO position paper on the Clean Energy Package”¹⁹

- *“Microgrids must be appropriately defined on a level playing field with existing grids. The legislation must reflect the fact that, in most situations, DSOs are best placed to evaluate the need for microgrids as well as the opportunities to establish and run them*

Source: Eurelectric “Winter Package Solutions: Eurelectric’s Key Policy Recommendations”²⁰

Alongside regulatory uncertainties, microgrid business models are also impacted by inconsistencies in the interconnection policies of different jurisdictions. These rules are typically outlined in technical documents called grid codes, which specify operational parameters necessary to ensure safe network operation. In Europe, grid codes for DSOs vary by country, which can be a barrier for those planning to do microgrid business in multiple markets. There are several organizations that bundle different DSOs, but such organizations are currently being restructured; each DSO’s views and situations are not unified or organized. Although it may be challenging to harmonize DSO grid codes, which are diverse as they reflect the local characteristics of the region, such work can contribute to the promotion of microgrids.

In the United States, California Public Utilities Commission (CPUC) proposes some additional factors that may need to be considered as part of interconnection rules:

- *Does the interconnection tariff envision the ability of a microgrid to act as a resource that is capable of consuming and producing electricity in short bursts of time and alternating between production and consumption?*
- *Does the limitation of generator size inadvertently limit the types of services a microgrid may be capable of performing, such as voltage or reliability support?*
- *How should the maximum total generation or load located at a point in the distribution system be evaluated? What safety protocols should be put in place? How are system upgrades evaluated?*
- *How are the costs of any distribution system upgrades allocated?*

Source: California Public Utilities Commission “Microgrids: A Regulatory Perspective”²¹

Clarifying the functions and ownership models of microgrids through regulation is critical, both for the potential entrants into microgrid markets and the operators of the power grid. Market entrants need to know by whom microgrids can be owned and operated, and how microgrids can earn their revenue. Meanwhile, grid operators need to know what roles microgrids can play and how they might interact with other assets, so that the power grid as a whole continues to function effectively and the associated costs are properly allocated.

¹⁹https://www.edsoforsmartgrids.eu/wp-content/uploads/14032017-EDSO-reaction-to-CEPackage_final_clean_version.pdf

²⁰http://www.eurelectric.org/media/293202/winter_package_solutions-2016-030-0496-01-e.pdf

²¹www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5118

5 CONCLUSION

Microgrids are increasing in importance as the power system is transforming. Installation of renewable energy is increasing as global concerns around climate change become more serious. Natural disasters have caused people to reconsider the value of reliable power supply. The conventional centralized power grid is transforming into a more decentralized one, accelerated by advancements in IT, which are allowing new diverse energy choices and business models to arise. Microgrids will have an important role in such environment, due to their ability to integrate more renewables, offer resiliency, and create new revenue sources.

While there are high expectations for microgrids, their implementation is still in demonstration phase. The projects introduced in this white paper were all built fully or partially on external financial support (e.g. subsidies from the government). In order for microgrids to become commercially available, cost of microgrid technologies will need to be reduced. Cost of microgrid component technologies, such as renewables and energy storage, is rapidly decreasing, which is expected to contribute to further improvements in microgrid economics. There is ongoing work in reducing the cost of microgrids as integrated systems as well. For instance, the rise of modular and scalable microgrid systems will facilitate installation processes and reduce the complexity of risk analyses for financial institutions. Standardization of microgrid interoperability, such as control and communication technologies, is ongoing, and should enable multi-vendor microgrid systems, increasing their cost competitiveness. In the future, it may be possible to conduct peer to peer trading of energy within the microgrid using blockchain technologies, further driving down microgrid cost. These trends in microgrid technologies are expected to reduce the cost of microgrid. In parallel, more work on the regulatory side will be needed to support the development of microgrid business models. In particular, the ownership models of microgrids should be straightened out by clarifying by whom microgrids can be owned and operated in the regulations. Additionally, the services and values offered by microgrids should be properly evaluated and remunerated; for instance, by allowing microgrids to participate in various electricity markets. When such revenue sources become available for microgrids, their economic viability will improve, increasing entrance of microgrid businesses and promoting their commercialization.

Commercial deployment of microgrids has struggled due to high costs and uncertainty surrounding their business models. However, with ongoing cost reductions and changes in regulatory frameworks to encourage microgrid business models, microgrids will shift from pilot to commercial deployment.

APPENDICES



Table A-1 Working group board member list

Affiliation	Affiliation	Status
JSCA/NEDO	Makoto Watanabe	Leader of the working group
Smart Grid Canada	Charlotte Candea	Co-Leader of the working group
Belgium	Jef Beerten Jan Desmet	Member
Canada	Alex Bettencourt Amritha Chandramouli	Member
Israel	Amos Lasker Amir Cohen, David Pincu Karine Roch	Member
India	Ravi Seethapathy Rahul Vikram	Member
France	Valerie-Anne Lencznar Gilles Rocchia Maxence Bocquel	Member
Japan	Kenichi Nagai Yoshiko Kawai Yuichiro Shimura Satoko Horie	Member
South Korea	Jung Ji-Han Kim Youngkook, Joon Kyoeng Lee Choi Dae Hee Sang-ho Ahn	Member
Sweden	Bo Normark	Member
United States	Steve Hauser Sunil Cherian	Member



Microgrid with a focus on resiliency and reliability Work Group Charter

November 7th, 2016

1. Background of this WG

Microgrids are gathering increased attention due to their ability to efficiently integrate more renewable energy sources at a local level and to improve power quality for important loads.

Another benefit of microgrids is that they can be intentionally isolated from the conventional grid and can offer resiliency under situations of energy supply emergencies.

For example, in Japan, microgrid research, developments, and its demonstration projects are implemented so actively since microgrids can provide:

- Improvement of energy security in terms of utilizing renewable energy at the local level by providing stable energy supply with a self-sustaining system at the local level.
- Multiple power quality reliable supply at specific areas.
- Resiliency after disasters.

To meet such expectations for microgrids, various demonstration projects have been carried out in the world. However, up to now, among these projects, not so many projects have led to actual business activities. Thus, the WG aims to collect information regarding for what applications microgrids have been used in the past and what is a plan on how to utilize microgrids in the future, so as to examine issues/challenges which may arise in implementing microgrids based on actual cases provided by WG members and to clarify mainly regulatory challenges rather than technical issues.

Under this circumstance, it is envisioned that the WG will consider the following contents.

1. Microgrid benefits
(Review of issues on the future grid in association with changes in the external environment and potential functions microgrids can provide to solve these issues)
2. Case study
(Collection and analysis of actual cases about efforts to facilitate microgrids)
3. Challenges towards diffusion of microgrids and recommendations for solutions

2. Statement of Work (SOW)

1. Microgrid benefits
 - Review of issues on the future grid in association with changes in the external environment
 - Review of microgrid benefits which can be provided in such changes
(Ensuring resiliency in case of emergency such as natural disasters)
2. Case study
(Collection and analysis of actual cases about efforts to facilitate microgrids)
 - Collection of actual cases (collected from the WG members)
 - For what applications microgrids have been used in the past.
 - What is a plan on how to utilize microgrids in the future.

- Analysis of actual cases
 - Review of potential functions microgrids can provide
 - Review of actual cases to identify best practices and challenges during the process of diffusing microgrids in the member countries to implement such functions.
3. Challenges towards diffusion of microgrids and recommendations for solutions
- Identification of challenges to be solved
(Review of global issues which may arise based on the section (2))
 - Review of current efforts to solve challenges
 - Recommendations for diffusion of microgrids

3. Schedule

Schedule	To do
Aug. to Oct. 2016	Member recruitment
Nov. 2016	Kick-off meeting
	Confirm the charter of this working group
Winter 2016	Case study collection
	Presentations from members (Teleconference)
Winter 2016	Clarify the barriers, especially from regulatory aspects, to diffuse microgrids
Feb. 2017	Complete draft white paper
March. 2017	Review draft report
Apr. 2017	Publish white paper

Note: Ad-hoc teleconferences will be conducted on an as-needed basis.

Table C-1 Schedule of the activities of the working group

Date	Activities
April 2016	GSGF board of directors approved of setting up the work group.
November 2016	Stated the work group activities. First teleconference
December 2016	Distribution of questionnaire Second teleconference
January 2017	Third teleconference
February 2017	Fourth teleconference
April 2017	Preliminary draft white paper
May 2017	Face-to-face discussions with some members Second draft white paper
June 2017	Member feedback
July 2017	Finalizing and publishing of white paper

