Microgrid
Enabling resilient and cost effective access to power

Maxine Ghavi, Head of Microgrid Program
www.abb.com/microgrids
Energy and grid transformation

Transition from a centralized to a distributed grid

New developments are accelerating the transition
Energy and grid transformation
Global trend – Big shift in the electrical value chain

**Generation mix**
- Renewable share: ~40% of capacity by 2035
- Greater volatility, less predictability
- More feed-in nodes

**Power transmission and distribution**
- Increasing complexity
- Control/ information flow is key value driver
- Transmission: Longer distances, higher voltages

**Micro-/ Nano-grids**
- On-and off-grid
- Control/ automation on “local” level
- Energy storage is key
## Microgrid segments and main drivers

Covering a diverse range of applications

<table>
<thead>
<tr>
<th>Segments</th>
<th>Typical customers</th>
<th>Social</th>
<th>Economic</th>
<th>Environmental</th>
<th>Operational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Island utilities</td>
<td>(Local) utility, IPP*</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Remote communities</td>
<td>(Local) utility, IPP, Governmental development institution, development bank</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Industrial and</td>
<td>Mining company, IPP, Oil &amp; Gas company, Datacenter, Hotels &amp; resorts, Food &amp;</td>
<td>✓</td>
<td>(✓)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>commercial</td>
<td>Beverage</td>
<td></td>
<td></td>
<td></td>
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<td>Defense</td>
<td>Governmental defense institution</td>
<td>(✓)</td>
<td>(✓)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Urban communities</td>
<td>(Local) utility, IPP</td>
<td>(✓)</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Institutions and</td>
<td>Private education institution, IPP, Government education institution</td>
<td>(✓)</td>
<td></td>
<td></td>
<td>(✓)</td>
</tr>
<tr>
<td>campuses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Main drivers**

- Social
- Economic
- Environmental
- Operational

- Access to electricity
- Fuel & cost savings
- Reduce CO2 footprint
- Fuel independence
- Uninterrupted supply

✓: Main driver
(✓): Secondary driver
Hybrid or Islanded Microgrid

Access to power in remote locations, power quality plus lower cost and environmental impact
Grid connected Microgrid

Grid resiliency, power quality, self consumption and lower environmental impact
Driver: Fuel independence and lower LCOE

Secure power generation and fuel cost savings

**Average Oil price USD$/Barrel is volatile**

Fossil fuel cost is volatile

Steady decline of renewable energy cost, making it economically viable

An optimized energy mix leads to a lower cost of electricity

<table>
<thead>
<tr>
<th>Year</th>
<th>Diesel Generator - 1$/L</th>
<th>Diesel Generator - 0.7$/L</th>
<th>Diesel Generator - 1.5$/L</th>
<th>Hybrid PV-Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>$93/Barrel</td>
<td>$93/Barrel</td>
<td>$93/Barrel</td>
<td>$93/Barrel</td>
</tr>
<tr>
<td>2006</td>
<td>$7,000/kW</td>
<td>$7,000/kW</td>
<td>$7,000/kW</td>
<td>$7,000/kW</td>
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<tr>
<td>2007</td>
<td>$5,000/kW</td>
<td>$5,000/kW</td>
<td>$5,000/kW</td>
<td>$5,000/kW</td>
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<tr>
<td>2008</td>
<td>$3,500/kW</td>
<td>$3,500/kW</td>
<td>$3,500/kW</td>
<td>$3,500/kW</td>
</tr>
<tr>
<td>2009</td>
<td>$133.88/Barrel</td>
<td>$133.88/Barrel</td>
<td>$133.88/Barrel</td>
<td>$133.88/Barrel</td>
</tr>
<tr>
<td>2010</td>
<td>$54.65/Barrel</td>
<td>$54.65/Barrel</td>
<td>$54.65/Barrel</td>
<td>$54.65/Barrel</td>
</tr>
<tr>
<td>2012</td>
<td>$1,250,000</td>
<td>$1,250,000</td>
<td>$1,250,000</td>
<td>$1,250,000</td>
</tr>
<tr>
<td>2013</td>
<td>$1,000,000</td>
<td>$1,000,000</td>
<td>$1,000,000</td>
<td>$1,000,000</td>
</tr>
<tr>
<td>2014</td>
<td>$750,000</td>
<td>$750,000</td>
<td>$750,000</td>
<td>$750,000</td>
</tr>
<tr>
<td>2015</td>
<td>$500,000</td>
<td>$500,000</td>
<td>$500,000</td>
<td>$500,000</td>
</tr>
<tr>
<td>2016</td>
<td>$250,000</td>
<td>$250,000</td>
<td>$250,000</td>
<td>$250,000</td>
</tr>
<tr>
<td>2017</td>
<td>$13,000/kW</td>
<td>$13,000/kW</td>
<td>$13,000/kW</td>
<td>$13,000/kW</td>
</tr>
</tbody>
</table>

LCOE: Levelized Cost of Electricity

Sources:
1. US Energy Information Administration – Independent Statistics and Analysis
2. Alliance for Rural electrification (ARE). Projections made from a case study based in Ecuador with real natural conditions
**Driver: Uninterrupted power supply**

Managing power fluctuations from renewables

---

### Solar power variations

<table>
<thead>
<tr>
<th>Time [days]</th>
<th>Power [kW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>16:10:00</td>
<td>10000</td>
</tr>
<tr>
<td>19:56:40</td>
<td>5000</td>
</tr>
<tr>
<td>23:43:20</td>
<td>0</td>
</tr>
</tbody>
</table>

### Wind power variations

<table>
<thead>
<tr>
<th>Time [hours]</th>
<th>Power [kW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>6000</td>
</tr>
<tr>
<td>5</td>
<td>5000</td>
</tr>
<tr>
<td>6</td>
<td>4000</td>
</tr>
<tr>
<td>7</td>
<td>3000</td>
</tr>
<tr>
<td>8</td>
<td>2000</td>
</tr>
<tr>
<td>9</td>
<td>1000</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>

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Inherent volatility of renewables can compromise grid stability

Grid stability requirements are traditionally fulfilled by diesel generation (base load)

Optimized microgrid solution maximizes ROI* and fuel savings

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**ROI: Return of Investment**

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July 7, 2017

| Slide 9 |
Driver: Strengthening distribution grids

Maximizing capital efficiency

Microgrids can remove load from the power grid to avoid or defer new power capacity investments by:

- Reducing peak demand
- Reducing system load growth

While simultaneously improving network reliability and availability, and lowering consumer rates.
Microgrid

Generation at the point of consumption and always available

Solar PV power plant
Wind power plant
Remote asset management and data analytics
Commercial loads
Conventional power
Distributed control system
Residential loads
Grid connection
Advanced power distribution and protection
Industrial loads
Modular scalable energy storage and grid stabilization
# Microgrid operational goals and power system functions drive choice of technology

## Operational goals
- Access to electricity
- Maximize reliability
- Uninterrupted supply
- Reduce environmental impact
- Maximize renewable energy contribution
- Fuel & cost savings
- Fuel independence
- Provide grid services

## Power system functions – “8S”
1. Stabilizing
2. Spinning reserve
3. STATCOM (static synchronous compensator)
4. Seamless transition between islanded and grid-connected states
5. Standalone operation
6. Smoothing
7. Shaving
8. Shifting

### Microgrid control system
- Renewable power
- Energy storage and grid stabilization
### Key microgrid technology: energy storage

8S application response times and energy and power requirements

<table>
<thead>
<tr>
<th>Application</th>
<th>Time frame</th>
<th>Energy requirement</th>
<th>Power requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 Standalone</td>
<td>milliseconds</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>S2 Seamless transition</td>
<td>milliseconds/seconds</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>S3 Stabilize (V &amp; f support)</td>
<td>seconds</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>S4 Statcom (power quality)</td>
<td>seconds</td>
<td>zero</td>
<td>high</td>
</tr>
<tr>
<td>S5 Spinning reserve</td>
<td>seconds/minutes</td>
<td>medium</td>
<td>high</td>
</tr>
<tr>
<td>S6 Smoothing</td>
<td>minutes</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td>S7 Shaping (Peak lopping/shaving)</td>
<td>minutes/hours</td>
<td>medium</td>
<td>low</td>
</tr>
<tr>
<td>S8 Shifting (load leveling)</td>
<td>hours</td>
<td>high</td>
<td>low</td>
</tr>
</tbody>
</table>
ABB in Microgrid
ABB - the global microgrid solution partner

ABB the leading provider of microgrid products and end-to-end microgrid solutions

Leading global expertise

- 25+ years experience
- 40+ executed projects
- Innovation, technology & productization leadership
- Global sales & service network

Broad portfolio of products & services

- Renewable power
- Conventional power
- Microgrid control system
- Energy storage and grid stabilization
- Power distribution and protection

Consulting
Service
3rd party financing
Our experience, capabilities and tools enable our customers to plan and operate the Microgrid reliably and at maximum economic benefit.

Consulting is offered throughout the complete lifecycle of a project with the goal to find the optimal solution that maximizes the value of the assets and financial investment.

- Feasibility studies and simulations
- Grid studies
- Renewables engineering
## ABB in Microgrid

Electrical balance of plant

### Plant electrification, automation, power distribution and protection

<table>
<thead>
<tr>
<th>Comprehensive scope of plant electrification and automation systems</th>
<th>Low and medium voltage products and solutions for protection, control and measurement meeting the demands from all types of power distribution grids.</th>
</tr>
</thead>
<tbody>
<tr>
<td>– Solar inverters</td>
<td>– Switchgears</td>
</tr>
<tr>
<td>– Plant automation, optimization and control and remote monitoring</td>
<td>– Transformers</td>
</tr>
<tr>
<td>– Control systems, drives, instrumentation, power converters and inverters</td>
<td>– Circuit Breakers</td>
</tr>
<tr>
<td></td>
<td>– Substations</td>
</tr>
<tr>
<td></td>
<td>– Protection and control</td>
</tr>
<tr>
<td></td>
<td>– Measurement and monitoring</td>
</tr>
</tbody>
</table>
ABB in Microgrid

Grid stabilization and energy storage

**PowerStore**

- Containerized plug-and-play solution in various ratings
- Fully productized and scalable to address all market segment applications.
  - Seamless transition from grid connected to islanded mode
  - Stabilizes against voltage and frequency variations
  - “Virtual Generator” can form the grid, integrating up to 100% of renewable energy
  - Microgrid Plus Controller
    - Maximizes fossil fuel savings and optimizes use of renewable energy
    - Guarantees optimum loading and spinning reserve in fossil fuel generators
    - Distributed logic enhances reliability and scalability for future system expansions
ABB in Microgrid
Integrated solar PV solutions

For remote communities and small industries
Operations include off-grid, in parallel with diesel generators or weak grids

Key components
- Solar inverter
- Power converter
- Protections
- Control system
- Remote monitoring
- Batteries

PowerStore Hybrid; > 60kW (integrated battery)
MGS100; 20kW-60kW (external battery)
ABB in Microgrid

PV/Diesel kit

Cost-effective kit optimized for hybrid solar PV-diesel applications

A kit, solar inverter plus microgrid controller, for off-grid and grid-connected applications

Simple and cost competitive
- “out-of-the-box” solution
- No application engineering needed

Flexible and scalable
- Fully compatible with ABB solar inverters (TRIO, PVS800) and diesel genset controllers from leading vendors
- Can be integrated with ABB SCADA system
ABB in Microgrid

The circuit breaker with integrated microgrid control

**Advanced protection: Emax 2**

The first intelligent circuit breaker to protect and optimize low voltage Microgrids.

- Embedded Microgrid control algorithm
- Optimizing utility power, solar, diesel generation, loads and energy storage
- Complete series of embedded protections to satisfy both on grid and off grid systems
- Ensuring protection for loads and generators without using external devices
- Plug and play, scalable logic to interconnect and coordinate devices
- Embedded sensors release data enabling remote monitoring
Remote monitoring a key component in lifecycle management

Remote services for operation and maintenance

A comprehensive solution for unattended sites to increase productivity, improve energy efficiency and reduce operational costs.

Management of customers and plants from the same web portal, providing
- Energy production reports
- Interventions
- Energy production forecasts
- Real time data production
- List of customers and plants
Grid transformation and emerging technologies
Enabling new applications & services redefining microgrid
ABB in microgrid - References
Hybrid power plant

Marble Bar, PV/Diesel

Project name
Marble Bar

Country
Western Australia, Australia

Customer
– Horizon Power
– Government of WA

Completion date
2010

ABB solution

Turnkey solution for a greenfield Microgrid project
PV/diesel Microgrid with PowerStore grid-stabilizing technology and Microgrid Plus System

The resulting Microgrid system consists of:
– Diesel (4 x 320kW)
– PV (1 x 300kW)
– PowerStore-flywheel (1 x 500kW)
– Microgrid Plus System

Customer benefits

Minimize diesel consumption, 405,000 litres of fuel saved annually
Minimum environmental impact, 1,100 tonnes CO2 avoided annually
Reliable and stable power supply
60% of the day time electricity demand is generated by the PV plant

About the project

Marble bar and Nullagine are the world’s first high penetration, solar photovoltaic diesel power stations
Integration of renewables
Kodiak Island, PowerStore/Wind/Hydro/Diesel

Two PowerStore flywheels act in parallel to shave off peak load and to reduce the stress placed on an existing battery energy storage system.

The resulting Microgrid system consists of:
- PowerStore Flywheel (2 MW/33 MWs)
- Wind (6 x 1.5 MW)
- Hydro (3 x 11 MW)
- Diesel (1 x 17.6 MW, 1 x 9 MW, 1 x 3.6 MW, 1 x 0.76 MW)

Customer benefits
- Stabilizing - frequency regulation
- Provide frequency support for a new crane
- Help to manage the intermittencies from a 9 MW wind farm
- Reduced reliance on diesel generators

About the project
- Two PowerStore Flywheels act in parallel in order to deliver optimal grid stabilization on Kodiak Island

Project name
Kodiak Island

Location
Alaska

Customer
Kodiak Electric Association (KEA)

Completion date
2015
Reliable power in presence of a weak grid
Johannesburg, PV/diesel/Storage and grid

Project name
Longmeadow

Location
South Africa

Customer
Longmeadow Business Estate

Completion date
2016

ABB solution
PV/diesel Microgrid with battery-based system to maximize solar contribution and ensure security of power supply at ABB’s premises in Johannesburg

The resulting Microgrid system consists of:
– 750 kWdc rooftop PV plant, including ABB PV inverter
– 1 MVA/380 kWh battery-based PowerStore
– Microgrid Plus System

Customer benefits
Reliable and stable power supply
Optimized renewable energy contribution to the facility
Ability to island from the grid in case of an outage
CO2 reduction: over 1,000 tons/year
Up to 100% renewable energy penetration

About the project
The Microgrid solution is for the 96,000 sqm facility houses hosting ABB South Africa’s headquarters as well as manufacturing facilities with around 1,000 employees. The innovative solution will help to maximize the use of solar energy and ensure uninterrupted power supply.
Reliable power in presence of a weak grid
Red Cross Logistics Center (Kenya), PV/diesel/Storage and grid

Project name
Red Cross Logistics Center

Location
Nairobi, Kenya

Customer
International Committee of the Red Cross

Completion date
2017

ABB solution

Supply, installation and commissioning supervision of a PowerStore-battery.

The resulting Microgrid system consists of:
- PowerStore Battery (150 kW/100kWh)
- Microgrid Plus Control System
- Solar PV (1 x 30 kWp)
- Diesel (1 x 150 kW)

Customer benefits¹

Reliable and stable power supply despite outages and power quality issues.
Reduced fuel costs and carbon footprint

About the project

"Reliable power is essential for our staff to continue their life-saving work uninterrupted in the field. (…) the ABB microgrid solution is in line with the ICRC’s goal to use environmentally friendly technologies. Solutions like this are proof that cooperation between the corporate and humanitarian sectors is not only possible, but imperative"

Peter Maurer, ICRC President
Ancillary power system services
AusNet Services, grid energy storage system

**ABB solution**
- Design, engineering, installation and testing of PowerStore-Battery, transformer and diesel generator
- Microgrid Plus System for overall system management
- Based on transportable containerized solution

**Customer benefits**
- Manage peak demand – Active and reactive power support during high demand periods
- Transition into isolated/Off-grid operation on command or in emergency cases without supply interruption
- Delay of power line investments

**About the project**
- First Embedded Generation system with Battery Grid Energy Storage for distribution network support in Australia

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**Project name**
SP AusNet GESS

**Country**
Victoria, Australia

**Customer**
SP AusNet

**Completion date**
2014
Integration of renewables
Finolhu Villas Resort, off-grid PV/diesel/storage microgrid

Project name
Finolhu Resort

Country
Gasfinolhu, Maldives

Customer
Club Med

Completion date
2014

ABB solution
Provision of 40 TRIO-27.6 kW solar inverters for the 1MW solar PV plant installed in the Finolhu Villas Island resort.
ABB supplied the inverters to T&D, a system integrator.

Customer benefits
Minimize diesel fuel expenditure – return on investment of the solar PV plant plus storage is less than 8 years
Branding as the first 100% sustainable resort in the Maldives
– 100% renewable energy production
– Waste management and recycling system also in place

About the project
First 100% sustainable resort in the Maldives. The PV panels were integrated into the resort’s architecture from the design phase.
## Integration of renewables

**AGIBA, PV/diesel hybrid microgrid for oil extraction**

### ABB solution

100 units solar inverter PVI-10.0-TL for the 100kW solar PV plant installed at an oil extraction site.

### Customer benefits

Minimizing operational expenses derived from diesel fuel use

### About the project

Nine out of ten exploratory wells are over 15,000 ft deep. Crude pumping is an energy intensive activity whose costs have been reduced thanks to microgrid technology.