Enabling a stronger, smarter and greener distribution grid
Webinar series for distribution utilities
Unlocking new benefits with energy storage services
Digital transformation from the field to the boardroom

Sustainability, Reliability, Efficiency & Performance

Regulation

Active network management requirements

Flexible demand management

Digital substations & smart field devices

Cybersecurity & secure connectivity

Energy transformation

Affordability

Sustainability

Emissions

Modern distribution control room

Reliability

Security

Residential Consumers & Prosumers

Transportation Infrastructure

Asset health, lifecycle & maintenance mgmt.

Control & Operations Center

Plant & field work mgmt.

Fleet & remote mgmt.

Transmission

Customer relationship value enhancement

Leverage of:

- Big data, AI, ML, 5G, Cloud applications, Analytics & BI

- DER integration & management

- Multi-purpose communication networks & edge compute capabilities

- Energy storage Aggregation Value stacking

- Digital substation & smart field devices

- Multi-purpose communication networks & edge compute capabilities

- Modern distribution control room

- Energy trilemma

- Cybersecurity & secure connectivity

- Digital transformation from the field to the boardroom

- Asset health, lifecycle & maintenance mgmt.

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- Transmission

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  - Multi-purpose communication networks & edge compute capabilities
  - Modern distribution control room
  - Energy trilemma
  - Cybersecurity & secure connectivity

- Digital transformation from the field to the boardroom

Internal
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Digital transformation from the field to the boardroom

- Sustainability, Reliability, Efficiency & Performance
- Regulation
- Active network management requirements
- Flexible demand management
- Asset health, lifecycle & maintenance mgmt.
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- Digital substation & smart field devices
- Multi-purpose communication networks & edge compute capabilities
- Energy storage
- Der integration & management
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- Customer relationship value enhancement

Modern distribution control room

Cybersecurity & secure connectivity

Connected Enterprise
Falling renewable generation costs

The cost of solar and wind power is expected to keep plummeting

- Utility-scale solar PV
- Onshore wind

$50/megawatt-hour

2018 2030 2040 2050

Note: U.S. forecast, figures show levelized cost of energy which is the end-to-end cost of setting up a power plant
Source: Bloomberg New Energy Finance

Falling battery prices

Lithium-ion battery price, historical and forecast

Li-ion battery price ($/kWh, 2017 real)

2025 implied price: $96/kWh
2030 implied price: $70/kWh

Source: Bloomberg NEF
...lead to accelerated adoption and fundamentally reshape the grid

Power generation mix

Batteries prevent renewable curtailment

Source: Bloomberg NEF, IEA
Advanced control algorithms lead to value stacking by enabling new grid support services.

Renewable integration

Seamless transition between on and off-grid

Centralized or decentralized control

Optimal battery technologies based on the application

Energy storage systems – enabling resilient and cost-effective access to power
Examples of use cases with high and rapid potential ROI for the DSO

01. Manage demand growth and DER hosting on radial feeders
   - Distribution utility invests in a Microgrid solution to manage the expected demand growth, which results in paying less peak demand charge.
   - Voltage regulators need to switch less due to the battery voltage regulation.

02. Unlocking new value through network stabilization
   - Installation of BESS provides a seamless transition to island state and reduces the need to start up a diesel generator during short outages. Additional solar PV allows to shut it off completely during daylight.

03. Enabling 100% carbon-free generation for island utility grids
   - Installation of BESS provide the required reserve to allow turning most diesel generators off.
   - Increased PV and wind capacity enables more energy contributions from renewable sources.
   - A hybrid approach lowers operating costs.

Use case
- Hitachi Energy Microgrid Plus control System
- Hitachi Energy Ability PowerStore™
- Ciscuit Breaker Substation
- Voltage Regulator
- Solar PV
- Aggregated Load

Business value
- Increase revenues with more cost-effective grid ancillary services, reduce CAPEX by deferring infrastructure upgrades, reduce OPEX by reduced peak demand and increase hosting capacity.
- Reduce overall energy costs, lower CO2 emissions and increase operating reliability & resilience.
- Increase reserves for additional DER and thus support island’s renewable goals, improve reliability and power quality, reduce OPEX (CO2 emissions, fuel costs).
Manage demand growth and DER hosting on radial feeders
Require capacity upgrades for demand growth

Many easting networks cannot host expected EV demand and solar PV generation
→ Opportunities for decentralized, non-wires alternatives

Utilities will need to manage dynamic loads and distributed generation
### Below-average reliability performance

<table>
<thead>
<tr>
<th>Utility Type</th>
<th>Sales (million kWh)</th>
<th>Fraction of distribution line miles (related to total US)</th>
<th>Customer Per mile of distribution line (density)</th>
<th>SAIDI (minutes per customer per year)</th>
<th>SAIFI (per customer per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperative Utility (Co-op)</td>
<td></td>
<td>41%</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Municipal Utility (Muni)</td>
<td></td>
<td>3%</td>
<td>66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investor-Owned Utility (IOU)</td>
<td></td>
<td>56%</td>
<td>38</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend:**
- Red: Residential
- Black: Commercial
- Gray: Industrial
- Red: Without major events
- Black: With major events

**US utility categories and reliability performances**
Voltage issues with significant solar photovoltaic penetration

Utility Network

Over Voltage: The PV generation increases the line voltage at the feed-in point.

Voltage Fluctuations: Clouds cause frequent voltage changes. Voltage regulators have ~30 second operational delay.

Load forecast, substation capacity

US Solar Global Horizontal Irradiance Map with Planned and Operating Solar Generating Units (By Hitachi Energy Ability™ Velocity Suite)

In the existence of solar PV, VRs need to get replaced every year due to hundreds of thousands operation (mechanical switching) per year

Impact of PV on the long radial feeder voltage regulation
**Radial Feeder Business Case – Problem Definition**

**Distribution Utility Challenges**
- Peak demand exceeds the substation capacity in 5 years.
- The capacity upgrade is required to manage the load growth.
- The utility pays the peak demand charges to ISO/RTO.
- The reliability performance is below the target and utility pays the penalty.
- The utility is facing increased O&M cost for voltage issues by solar PV.

**Power System Assumptions**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td>8 MWp, 5.5 MW avg, 1% growth rate</td>
</tr>
<tr>
<td>Substation Capacity</td>
<td>8.5 MW</td>
</tr>
<tr>
<td>Solar PV</td>
<td>800 kWp</td>
</tr>
<tr>
<td>Utility Rate</td>
<td>0.12 USD/kWh (50% grid fee), 2% inflation rate</td>
</tr>
<tr>
<td>SAIDI</td>
<td>420 minutes per customer per year</td>
</tr>
<tr>
<td>SAIFI</td>
<td>3 times per customer per year</td>
</tr>
<tr>
<td>Reliability Impact</td>
<td>125 kUSD-Year as a Penalty/ Reward, 2% inflation rate</td>
</tr>
<tr>
<td>Demand Charge</td>
<td>100 USD/kW-Year as transmission charge, 12 USD/kW-Month as a capacity charge, 2% growth rate</td>
</tr>
<tr>
<td>System O&amp;M Cost</td>
<td>425 kUSD, including maintenance for VRs.</td>
</tr>
</tbody>
</table>

**Location:** Long radial feeders with geographic restrictions
Break down of Cost Benefit Analysis (20 years project life, 9% discount rate)
The microgrid is the economic solution for improving the performance of this radial feeder.

<table>
<thead>
<tr>
<th>Scenario 1: Distribution System Upgrade</th>
<th>Scenario 2: Microgrid</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pros/ Cons</strong></td>
<td><strong>Pros/ Cons</strong></td>
</tr>
<tr>
<td>✓ Manage the expected demand growth</td>
<td>✓ Manage the expected demand growth</td>
</tr>
<tr>
<td>❌ Peak demand charges remain high</td>
<td>✓ Reduce peak demand charges by 20%</td>
</tr>
<tr>
<td>❌ Reliability performance is not improved</td>
<td>✓ Improve reliability performance</td>
</tr>
<tr>
<td>❌ Voltage regulation is not improved</td>
<td>✓ Decrease system O&amp;M costs of voltage regulators by 25%</td>
</tr>
<tr>
<td>❌ Risk of slower deployment due to permitting delays</td>
<td>✓ Potentially quicker deployment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Net Present Value</th>
<th>0.4 MUSD</th>
<th>4.3 MUSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRR</td>
<td>10%</td>
<td>15%</td>
</tr>
<tr>
<td>Payback Period</td>
<td>10 years</td>
<td>6 years</td>
</tr>
</tbody>
</table>
Microgrid benefits for radial feeders

Key Takeaways

- Defer Distribution Capacity Upgrades
- Manage Demand Growth
- Provide Peak Shaving
- Improve Reliability and Resiliency
- Provide Voltage Regulation
- Increase Renewable Hosting Capacity
- Potentially Quicker Deployment
- De-risk the Electric Vehicle Revolution

Reference Project: Hitachi Energy BESS for Baltimore Gas and Electric (BG&E) utility to reduce peak demand. BESS would avoid the distribution equipment to exceed its thermal capacity.
Unlocking new value through network stabilization
Introduction to South Australia’s network

**Significant renewable penetration**

- Renewable capacity: 2400 MW
- Average demand: 1400 MW
  → 170%

**Two Connections to Australia NEM:**
- 650 MW AC (275 kV)
- 220 MW HVDC (150 kV)

**System blackout → SIPS**
- September 28, 2016

A mainland grid run primarily on renewables
Part of the largest utility microgrid in Australia, the Dalrymple BESS features a virtual synchronous machine enabling it to stabilize the grid and run on 100% renewables (wind/solar).
Stacking value for commercial success

- Over 170% peak renewable penetrations
- Revenue from energy market: 3.2 MUSD/yr
- Local network benefit: 0.9 MUSD/yr

91 MW Wattle Point Wind Farm
- BESS supports reliability & renewables

30 MW Dalrymple BESS project
- BESS keeps solar PV and wind generating

Rooftop solar PV
- BESS reduces outages from 8 hours to 30 mins

Local consumers

Local network seamlessly connects and disconnects from larger grid

Network connection
- Services
- Revenue
Key functionalities PowerStore provides to stabilize the grid

- stabilises and strengthens the grid
- mitigates impact of rate of change of frequency (RoCoF) events
- effective during both normal and islanded operation
- instantaneous injection

Virtual inertia

- grid-forming inverter with proprietary controls
- increases local network reliability
- operate entirely on renewable sources (wind and solar)
- 100+ km of lines with 91MW wind farm and >2MW of distributed solar PV

Seamless islanding

- provides a stable alternative
- clears faults in the network
- limits network oscillations from phase locked loop (PLL) issues common with existing inverter based resources

Fault current injection

- fast response (< than 250 msec) for an external command
- instantaneous response to events sensed locally
- voltage and frequency support

Fast power injection

- PowerStore is a black start energization source
- allows DER to couple and restart power supply after an outage event
- after local black start, can serve as black start resource for wider network

Black start

- fast response (< than 250 msec) for an external command
- instantaneous response to events sensed locally
- voltage and frequency support
Unplanned islanding (without the wind farm)

The grid forming BESS performs a seamless transition into islanded state without interruptions.

**Three-phase voltage**

- **Trend:** Waveform Voltage, PQZIP 25/09/2018 05:04:11 PM

  - a. 132 kV breaker upstream opens, islanding
  - b. Upstream line is disconnected

**Three-phase current**

- **Trend:** Waveform Current, PQZIP 25/09/2018 05:04:11 PM

  - a. Waveform V12 Min/Max
  - b. Waveform V23 Min/Max
  - a. Waveform V31 Min/Max
  - a. Waveform I1 Min/Max
  - b. Waveform I2 Min/Max
  - a. Waveform I3 Min/Max
Fault current injection

33kV line-to-ground voltages

Reactive power output from BESS

The BESS rides through major faults and network disturbances
Fast active power injection

System Integrity Protection Scheme (SIPS)

- Designed to prevent South Australian system separation from the NEM
- Acts to pre-empt a large RoCoF event
- Based on measurements taken along the Heywood interconnector
- Takes over BESS virtual inertia response
- Triggers grid-scale BESS to inject power and, if required, sheds load to restore balance between supply and demand
- Requires the BESS to inject full power in 250 msec

ESCRi BESS is a critical part of Stage 1 of ElectraNet’s System Integrity Protection Scheme (SIPS)
Virtual inertia provides inherent response to network disturbances, stabilizing the entire network.

**Positive RoCoF event in South Australia**

- Green = positive RoCoF, purple = negative RoCoF

**Active Power response**

- Inertial response initially to grid frequency (left) prior to Frequency Support setpoint (red dotted line)
BESS ramps voltage up to energise transformers

BESS picks up 33 kV load feeder – P/Q profiles

BESS voltage ramp eliminates transformer inrush during 33kV network black start. Feeder pick up at full load presents no issues.
Sharing the experience from ESCRI-SA Dalrymple BESS

See the project in operation for yourself

Project went into commercial operation in late 2018
All plots presented here are based on actual measured data
Numerous reports and data available

See live operation at: www.escri-sa.com.au
Enabling 100% carbon-free generation for island utility grids
Opportunities in island utilities and remote locations

Drivers for Grid Edge Solutions

More affordable
- Imported fuel makes electricity two to five times more expensive than in the mainland
- Energy storage increases fuel efficiency

Stronger grid
- Energy storage stabilizes frequency and voltage, improves power quality
- Renewables are a local source decoupled from international fuel markets

Maximized renewables
- Quick development and installation
- Reduction of islands’ contribution to climate change
Islands with renewable goals

Map of selected islands with renewable goals

Renewable target by 2030
Business case for an island utility

Scenarios
- Island load of 11.2 MW average with 15 MW peak
- 9 x 2 MW diesel generators, all manually operated
- The grid suffers from occasional voltage and frequency issues

Base Case
- Solar installed cost: USD 1.5 / Wp
- Battery cost: USD 300/kWh
- Delivered diesel fuel cost: USD 0.75 / L
- 9% discount rate with 2% inflation rate over 20-year project life

Assumptions
- **Base case**: Diesel-only
- **Renewable ready**: Battery Energy Storage System and Diesel
- **Medium renewable**: Moderate solar PV with BESS and Diesel
- **High renewable**: Lots of solar PV with BESS and Diesel

A techno-economic case study
The transition from diesel-only to 100% renewable penetration

**Base case: diesel only**
- Generators are manually switched
- One generator as reserve
- Unable to accept more renewables

**Renewable ready**
- Larger BESS provides more reserve
- BESS and PV maximize fuel savings and reduce generator hours

**Renewable ready**
- Larger BESS provides more reserve
- BESS and PV maximize fuel savings and reduce generator hours

**High renewable**
- Increased renewable contributions
- During sunny daylight hours, all generators could be shut down

Smart controls enable an incremental pathway to affordable, strong, renewable electricity
Comparing the investments in the 4 different scenarios

<table>
<thead>
<tr>
<th></th>
<th>Base case: diesel only</th>
<th>Renewable ready</th>
<th>Medium renewable</th>
<th>High renewable</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCOE(^1) (USD/MWh)</td>
<td>[Image]</td>
<td>-2%</td>
<td>-13%</td>
<td>-18%</td>
</tr>
<tr>
<td>Power Quality</td>
<td>Poor</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Renewable Contribution(^2)</td>
<td></td>
<td>20%</td>
<td>35% Solar 20% Diesel</td>
<td></td>
</tr>
<tr>
<td>Investment (MUSD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRR(^3)</td>
<td>-</td>
<td>27%</td>
<td>24%</td>
<td>19%</td>
</tr>
<tr>
<td>Payback (years)</td>
<td>-</td>
<td>3.8</td>
<td>4.1</td>
<td>5.3</td>
</tr>
</tbody>
</table>

Incremental hybridization for lower costs, stronger grids, and increased renewable contribution
Island utilities: Robben Island, PowerStore/Solar/Diesel

About the Project

• **Project name:** Robben Island
• **Location:** South Africa
• **Customer:** Department of Tourism, South Africa
• **Completion date:** 2017

Solution

• PowerStore Battery (500 kW/837 kWh)
• e-mesh Control System
• Solar PV (667 kWp)
• Diesel (1 x 500 kW)

Customer Benefits

• Lower fuel costs and carbon emissions by 75%
• Enabling the island to run on solar power for at least 9 months of the year
• Remote monitoring of the entire system from Cape Town
• Remote set-up eliminates the need to maintain a workforce on the island

Grid Edge Solution enables Robben Island to run on solar power for at least 9 months in a year
About the Project

- **Project name:** Deering and Buckland Microgrid
- **Location:** Alaska, United States of America
- **Customer:** NANA Regional Corporation, Inc
- **Completion date:** 2018

Solution

- PowerStore Battery (400 kW/ 400 kWh)
- e-mesh Control System
- Solar PV (50 kWp)
- Wind (2 x 100 kW)
- Diesel (2 x 475 kW, 1 x 175 kW)

Customer Benefits

- Stable, reliable and affordable power to the local community
- Maximum utilization of wind power
- Help communities achieve 100% renewable penetration
- Help customer to reach its goal - reduce reliance on imported diesel by up to 75 percent, by 2030

Remote communities: Buckland, PowerStore/Wind/Diesel

Grid Edge Solution enables Robben Island to run on solar power for at least 9 months in a year
About the Project

- **Project name**: Porto Santo
- **Location**: Porto Santo Island – Madeira, Portugal
- **Customer**: Empresa de Electricidade da Madeira (EEM)
- **Completion date**: 2019

Solution

- PowerStore Battery (4 MW/3 MWh)
- e-mesh Control System
- Solar PV (2.25 MWp)
- Wind (1.5 MW)
- Diesel (4 x 4 MW)
- Network Manager ADMS

Customer Benefits

- Increase the contribution of renewables in the energy mix from 15 to 30 percent
- Stabilize the power system to address frequency and voltage fluctuations
- Reliable power supply, supported by renewable energy
- Meet the enhanced electricity demand during summers with a high inflow of tourists

Grid Edge Solution enables the island of Porto Santo to achieve clean-energy goals
24 Hour Production Mix

BESS providing frequency support during high renewable contributions
Key Takeaways

**BESS allows to:**

- Maximize fuel savings through the highest possible renewable integration
- Provide high power quality by stabilizing the power systems against fluctuations in voltage and frequency
- Ensure a reliable, stable and sustainable energy future
- Minimize deployment time through fast and safe installation and commissioning on-site
Key take-away messages
BESS unlock new benefits and enhance resiliency for the DSO. Can be used...
HITACHI
Inspire the Next