Reducing energy costs and environmental impacts of off-grid mines
Hamideh Bitaraf, Microgrid Advisor, ABB

Agenda

1. Microgrid for Island Utilities
2. Overview of off-grid mining electricity operations
3. How microgrids create value in mining
4. What ABB has to offer
5. Mining microgrid case study
6. The pitch: creating microgrid opportunities
Island utilities
Jamaica Public Service (JPS), Wind/PV

About the Project
- Project name: JPS Grid Stability
- Location: Jamaica
- Customer: Jamaica Public Services Company Ltd
- Year: 2018

Solution
The resulting Microgrid system consists of:
- PowerStore Battery (21.5 MW / 16.6 MWh)
- PowerStore Flywheel (3 x 1 MW / 16.5 MWh)

Customer Benefits
- Maximum utilization of solar and wind energy
- Reliable power to 5 million populace in the island
- Power availability during intermittency of renewable sources
- Reduced dependency on fossil fuels and lower carbon footprint

Island utilities
WEB Aruba, Wind/PV/Thermal

About the Project
- Project name: WEB Aruba
- Location: Aruba, Southern Caribbean
- Customer: WEB Aruba N.V

Solution
The resulting Microgrid system consists of:
- Microgrid Plus Control System
- Solar PV (1 x 6 MWP)
- Wind (20 x 3 MW)
- Steam turbine (1 x 136 MW)
- Gas turbine (1 x 20 MW)
- Reciprocating engine (10 x 9 MW)

Customer Benefits
- Integration of complex energy mix - Wind, PV and Thermal
- Maximum utilization of renewable energy
- 24-hour forecast of both renewable output and system load
- Manage the peak demand, 134 MW

The microgrid solution allows for integration of a complex energy generation portfolio and maximizes the use of renewable energy, enabling WEB Aruba to meet the peak demand (134 MW) of the tourist island
Global installed base

Microgrids and BESS

Worldwide: 331 MW

Europe: 9.79 MW

Asia: 70.18 MW

Middle East: 200 kW

Australia: 75.28 MW

Africa: 3.95 MW

South America: 20.18 MW

North America: 151.6 MW

Energy transformation of off-grid mining

Incremental hybridization to low carbon & energy cost future using renewables and storage

Status quo: Diesel or gas generation main provider off-grid mine electricity

Today: Up to 50% fuel reduction possible without subsidies leading to increased shift to renewables

Next few years: Clear business case to further reduce diesel in increments moving towards 100% renewables

ABB supports mining customers to capture the economic and operating benefits along the transformation
Microgrid

Generation at the point of consumption and always available

**Microgrid definition**

Distributed energy resources and loads that can be operated in a controlled, coordinated way either connected to the main power grid or in "islanded" mode.

Microgrids are low or medium voltage grids without power transmission capabilities and are typically not geographically spread out.

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**How microgrids create value in off-grid mining**

Key drivers of value creation and cost savings

**Operational goals**

- Providing essential off-grid quality power with blackstart capability
- Improving resiliency by having storage, generation and loads optimally coordinated
- Reducing reliance on diesel and associated supply chain risk and CO2 emissions

Lower operating costs, higher up-times and higher gross margins for mines

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1 LCOE: Levelized Cost of Energy per kWh over the life of the asset including all installation, financing and running costs
What ABB has to offer
ABB - the global microgrid solution partner

Leading global expertise

25+ years experience
40+ executed projects

Broad portfolio of products & services

Renewable power

Microgrid control system

Conventional power

Energy storage and grid stabilization

Power distribution and protection

Consulting

Service

3rd party financing

The resulting microgrid system consists of:

- ABB: PowerStore Battery (2 x 2 MW/1.4 MWh) with Transformer and RMU
- ABB: Microgrid Plus Control System
- ABB: Solar PV (10.6 MWp) with ABB Transformer and RMU
- Existing: Diesel (22 MW)

Customer Benefits

- Expected diesel fuel saving of 5 million liters per year - reduction by 20%
- Expected CO₂ reduction: 12,000 tons
- Grid stabilization, spinning reserve, STATCOM features
- Load smoothing

About the Project

- The new hybrid solar facility is the largest integrated off-grid solar and battery storage plant in Australia

Customer reference - ABB provided a complete renewables integration solution

Project name
DeGrussa Copper-Gold Mine

Location
Western Australia, Australia

Customer
juwi Renewable Energy

Completion date
2016
ABB microgrids deliver 30 to 50% fuel reduction
Future projects benefit from lower PV prices

ABB references already show 30 to 50% fuel reduction possible with subsidies

<table>
<thead>
<tr>
<th>Mining microgrid case study</th>
<th>Decreasing Solar PV costs to improve future business cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Various solar and storage scenarios tested using HOMER optimization tool</td>
<td>Global Large Commercial PV system prices (1 to 5MW) USD/ Wp</td>
</tr>
<tr>
<td>Example: remote brownfield gold mining operation</td>
<td>- PV prices have reduced over 30% in past 2 years and continue to fall globally</td>
</tr>
<tr>
<td>Power System</td>
<td>- Commercial and utility scale systems reducing faster than household solar with the $1/ Wp already reached for utility scale</td>
</tr>
<tr>
<td>- 5 MW average load</td>
<td>- Commercial and utility scale systems reducing faster than household solar with the $1/ Wp already reached for utility scale</td>
</tr>
<tr>
<td>- 6.3 MW peak load</td>
<td>- Commercial and utility scale systems reducing faster than household solar with the $1/ Wp already reached for utility scale</td>
</tr>
<tr>
<td>- 6 x 1.2 MW diesel generators</td>
<td>- Commercial and utility scale systems reducing faster than household solar with the $1/ Wp already reached for utility scale</td>
</tr>
<tr>
<td>Business Case</td>
<td>- Commercial and utility scale systems reducing faster than household solar with the $1/ Wp already reached for utility scale</td>
</tr>
<tr>
<td>- Delivered Fuel Cost: $1US/ l</td>
<td>- Commercial and utility scale systems reducing faster than household solar with the $1/ Wp already reached for utility scale</td>
</tr>
<tr>
<td>- Solar installed cost: $2US/ Wp</td>
<td>- Commercial and utility scale systems reducing faster than household solar with the $1/ Wp already reached for utility scale</td>
</tr>
<tr>
<td>- Average cost of capital: 11%</td>
<td>- Commercial and utility scale systems reducing faster than household solar with the $1/ Wp already reached for utility scale</td>
</tr>
<tr>
<td>- Subsidies: none</td>
<td>- Commercial and utility scale systems reducing faster than household solar with the $1/ Wp already reached for utility scale</td>
</tr>
</tbody>
</table>

Example: remote brownfield gold mining operation

Goal of the study

Determine when the Levelized Cost of Energy (LCOE) of 3 scenarios is lower than the diesel only base case

- Diesel & Storage
- Diesel & Solar PV
- Diesel & Solar & Storage
We analyzed the benefits of a hybrid power system

Four incremental hybridization scenarios

1. **Base case - Diesel**
   - 6 generator system (1.2 MW each)
   - 1 generator equivalent required as operating reserve at all times.
   - All generators that are on typically operate at same level.

2. **Diesel + BESS**
   - BESS removes need for operating reserve.
   - BESS can also delay or remove need to start up a generator during short term peaks.

3. **Diesel + solar PV**
   - Solar PV size limited in this case due to generator ramping limitation.
   - Additional generators must stay online in case of shading for 75% of solar production (potential reductions when using advanced forecasting).

4. **Diesel + BESS + solar PV**
   - BESS provides required ramping.
   - During daylight hours all generators can be shut down completely.

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Mining microgrid business case

Up to 28% reduction in fuel and CO2 possible when combining diesel with BESS and solar PV

<table>
<thead>
<tr>
<th></th>
<th>Base case - Diesel</th>
<th>Diesel + BESS</th>
<th>Diesel + solar PV</th>
<th>Diesel + BESS + solar PV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel consumption (ML)</td>
<td>11.8</td>
<td>11.4</td>
<td>9.6</td>
<td>9.6</td>
</tr>
<tr>
<td>Investment ($M)</td>
<td>1</td>
<td>3.2</td>
<td>10.5</td>
<td></td>
</tr>
<tr>
<td>IRR (%)</td>
<td>36%</td>
<td>9.0</td>
<td>11.6</td>
<td></td>
</tr>
<tr>
<td>LCOE ($/MWh)</td>
<td>304</td>
<td>296 (-1.4%)</td>
<td>289 (-5%)</td>
<td>273 (-11%)</td>
</tr>
<tr>
<td>Payback (years)</td>
<td>2.7</td>
<td>5.2</td>
<td>5.2</td>
<td></td>
</tr>
</tbody>
</table>

Source: Based on Homer analysis using proprietary Homer Pro Software; all numbers in USD

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### Sensitivity analysis - Key driver of LCOE saving

Diesel price the largest single driver of LCOE savings, followed by solar PV price

<table>
<thead>
<tr>
<th>Sensitivity driver</th>
<th>Low case</th>
<th>Base case</th>
<th>High case</th>
<th>LCOE savings impact (pp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel price (USD/L)</td>
<td>0.5</td>
<td>1.0</td>
<td>1.5</td>
<td>-6.5</td>
</tr>
<tr>
<td>Solar PV price - Installed (USD/Wp)</td>
<td>1.5</td>
<td>2.0</td>
<td>2.5</td>
<td>-3.5</td>
</tr>
<tr>
<td>Solar irradiation (kWh/m²/day)</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>-3.7</td>
</tr>
<tr>
<td>Installed battery price excl. converter ($/kWh)</td>
<td>300</td>
<td>400</td>
<td>500</td>
<td>-3.4</td>
</tr>
</tbody>
</table>

### Mining microgrid case study

Low solar PV price and high diesel price leads to large systems with up to 40% fuel saving

<table>
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<th>Configuration sensitivity to prices</th>
<th>Fuel reduction (%)</th>
<th>LCOE reduction (%)</th>
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<tbody>
<tr>
<td>Configuration sensitivity to prices</td>
<td>Fuel reduction (%)</td>
<td>LCOE reduction (%)</td>
</tr>
<tr>
<td>Diesel price (USD/L)</td>
<td>43%</td>
<td>27%</td>
</tr>
<tr>
<td>Solar PV price (USD/Wp)</td>
<td>41%</td>
<td>21%</td>
</tr>
<tr>
<td>BESS size (MWh)</td>
<td>30%</td>
<td>17%</td>
</tr>
<tr>
<td>Solar PV size (MW PV)</td>
<td>28%</td>
<td>11%</td>
</tr>
<tr>
<td>Solar PV size (MW PV)</td>
<td>18%</td>
<td>5%</td>
</tr>
<tr>
<td>BESS size (MWh)</td>
<td>18%</td>
<td>4%</td>
</tr>
</tbody>
</table>
The pitch: creating microgrid opportunities

Three questions to ask your customer

1. How are you generating power at your mine site?
   - IPP versus InHouse; when do contracts expire
   - Diesel versus Gas; who carries the fuel supply risk?

2. What is the current cost and quality of energy supplied?
   - $/MWh including O&M and replacement cost
   - Outages? Cost per outage and how often

3. What is the corporate energy efficiency, CO2 and cost reduction target?
   - CO2 reduction targets; extra corporate funds
   - Energy efficiency targets

Next Step: Lead qualification through high level assessment tool

ABB Microgrid Advisory Services

Microgrid End-to-end Solution