Utility-Scale Battery Energy Storage
A Technologically Proven, Cost Competitive Solution That Can Solve Multiple Grid Problems

HECO Grid Planning Symposium
November 16, 2017
About the AES Corporation:

Mission: Improving lives by providing safe, reliable and sustainable energy solutions in every market we serve.
AES Energy Storage - The global leader in grid-scale energy storage

>500 MW
In operation, construction or late stage development

>4 Million MWhs of reliable service
AES Energy Storage - Celebrating 10 years of operating experience delivering safe, reliable utility-scale energy storage solutions

Contains Forward Looking Statements
To meet the growing demand for energy storage, we just announced a new energy storage joint venture
A new global energy storage technology and services company
Storage Value Proposition on Island Grids
Island markets have certain unique characteristics that set themselves apart

Sparse transmission and limited power generation options make islands unique

<table>
<thead>
<tr>
<th>Market Attribute</th>
<th>Island Grids</th>
<th>Mainland</th>
</tr>
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<tbody>
<tr>
<td>Fuel prices</td>
<td>Typically tend to be high (imported fuel in many cases)</td>
<td>Tends to be low due to lower transportation costs and available supply</td>
</tr>
<tr>
<td>Power supply stack</td>
<td>Fewer generation units leading to significant gradation in cost</td>
<td>Wide variation of units and interconnected nature brings diversity in supply stack.</td>
</tr>
<tr>
<td>Transmission</td>
<td>Usually pretty sparse and not very networked</td>
<td>Highly networked with several redundancies available to meet contingencies</td>
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<tr>
<td>Loss of generation or transmission failure</td>
<td>High system impact due to generation loss or transmission failure</td>
<td>Generally options may be available due to highly networked transmission grid</td>
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- Spinning reserves, frequency regulation and transmission system reliability have very high value in island markets.
- Few generation units have to provide these critical ancillary services leading to inefficient operation; in non-island markets, many units take equal responsibility for these services.
Dec 5, 2016 event – prolonged loss of 15 MW solar generation in a small Caribbean island for 30 minutes.

Thermal unit B6 (RED line) attempts to pick up load, but is not able to maintain frequency at 50 Hz.

GT6 (GREEN line) comes online and leads to over-frequency.

Ability to control frequency with renewable generation is challenging in small island grids.
Introduction of energy storage helps arrest frequency deviations faster in island markets with renewable generation.
Storage Provides Contingency Response, Frequency Regulation and Other Ancillary Services Freeing Up Traditional Units to Operate Efficiently

Key Assumptions

- 600 MW Installed capacity in island. Cheapest unit = $30/MWh, Most expensive unit = $200/MWh
- Base load unit holds back 15% capacity (37.5 MW) for contingency/spin reserves.
- 37.5 MW increase in base load unit avoids dispatch of $200/MWh most expensive unit.

Storage Value

- **Storage benefit** = 37.5 MW * $200/MWh * 2,000 hours (typical capacity factor for simple cycle gas turbines) = $15 MM/Year
- **Storage cost** (assuming 1-hour system) = 37.5 MW * $1000/kW = $37.5 MM
- **Simple payback** = less than 3 years

Key questions on storage capacity and duration required for this application have to be addressed in each island market; existing supply stack and resources that currently provide ancillary services are usually enough to develop first-cut storage value proposition.
Longer duration systems provide multiple services, flexibly

Storage can provide multiple services, simultaneously (stacking) or by scheduling

The figure illustrates how storage can stack services:

- Period 1: dispatch Negative Reserve (Demand Turn Up) while maintaining 100MW of resource as Response capability
- Period 2: Provide 100MW Response capability
- Period 3: dispatch positive Reserve (Fast Reserve) while maintaining Response capability
- Period 4: maintain its state of Charge adequately to prepare next Day
- All periods: minimum state of charge maintained to provide Black Start if required
AES Advancion® unlocks more value from renewable plants

Three main applications for pairing and co-locating storage with renewables

<table>
<thead>
<tr>
<th>Grid Stability</th>
<th>Renewable Plant Stability</th>
<th>Renewable Firm Energy</th>
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<tbody>
<tr>
<td>• Grid services such as frequency regulation</td>
<td>• Smoothing and ramp limiting service to keep</td>
<td>• Predictable and firm renewable energy</td>
</tr>
<tr>
<td>delivered from the renewable plant paired with</td>
<td>renewable output stable</td>
<td>delivery</td>
</tr>
<tr>
<td>storage</td>
<td></td>
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</tbody>
</table>

Contains Forward Looking Statements 13
Renewable Plant Stability

- Types of plant stability cases:
  - Includes cases where the utility requires technical limitations on renewable output (e.g. ramp limits)
  - Curtailment avoidance due to market drivers or interconnection limits

Without Advancion®

Purchase from spot market to mitigate variability

Resulting in a smooth and predictable production shape

Advancion® output complements renewable energy
Firm Renewable Energy

Firm Renewable Peaking Capacity

- Motivation for using storage to deliver firm renewable energy is the **rapidly declining cost of fuel** – *i.e.* electricity from renewables

- As “fuel” and storage costs decline, they will displace traditional alternatives in an expanding set of markets

- KIUC PPA for 11 cents/kWh is already more competitive than alternatives for the window it will deliver energy within
Using renewable source as fuel, storage can provide firm baseload energy

Size: Solar PV capacity roughly 3x baseload, storage capacity 2x baseload, duration ~8 hours

Ideal for large, steady, isolated load scenarios – such as islands and mines
Three T&D value plays for energy storage

1. **N-1 Capacity Release**
   - Automatic power injection to support grid stability during contingency.
   - Increase the operational capacity of existing line (value creation from existing assets).
   - Arrests line overloads and frequency/voltage deviations until grid is redispatched

2. **Peak Load Relief**
   - Injects power downstream of thermal constraints during peak hours
   - Avoids or defers new transmission capex to meet load
   - Improves power quality and voltage conservation

3. **Feeder Reliability**
   - Supports greater penetration of intermittent distributed resources
   - Injects real and reactive power to maintain voltage stability, improve power quality
   - Reduces wear and tear on existing equipment
   - Defers cost of traditional poles and wires solution
1 Capacity Release - Operational Construct

• Assuming Lines, X, Y and Z are rated at 500 MW capacity, N-1 limit across interface from A to B is 1000 MW.

• To increase throughput across the interface to 1500 MW, consider storage additions at nodes B and E that provide temporary post-contingency relief. These batteries are generally on stand-by – upon sensing a line-trip (through frequency or direct line flow input feed) they ramp to full output to provide counter-flows.
Peak Load Relief – Operational Construct

**Off-Peak**
- Flow -150 MW
- Limit – 200 MW
- Load: 250 MW
- • Charging 50 MW
- • A/S

**Peak**
- Flow -200 MW
- Limit – 200 MW
- Load: 450 MW
- • Discharging 50 MW
Battery nodes help address voltage issues and enable penetration of distributed solar PV

Rationale

- Significant increase in distributed solar PV on feeders causes “voltage stiffness” in feeders.
- In some cases, this can restrict the amount of solar that can be integrated at the feeder level.
- Appropriately positioned storage systems (~1-2 MW scale) can help address voltage issues and also provide additional benefits like Volt/Var control to the feeder.
AES Project Examples On Island Grids
Storage in Islands

Dominican Republic

SERVICES
- Capacity release for generation facility
- Ancillary services

10 MW Energy Storage Array
Santo Domingo, DR
Storage in Islands

The Philippines

SERVICES

- Frequency regulation
- Ancillary services to the grid
Frequency Control

Energy storage for critical spinning reserves, replacing oil & standby

SERVICES
• Primary & secondary reserves
• Contingency management

IMPACT
✓ Avoided load shedding
✓ Increased energy & reduced costs
✓ Inertia-like performance

12 MW Energy Storage Array
Los Andes, Atacama, Chile
Renewable Integration

Solving peak energy demand through solar + storage in Hawaii

Hawaii co-op signs deal for solar+storage project at 11c/kWh
Thank you!

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