Addressing Radial Feeder Challenges with Microgrid Value Stacking

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Hamideh Bitaraf, Ph.D., Senior Microgrid Advisor
Microgrids and Distributed Generation

Presenters

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Power Grids, Grid Automation, ABB
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Agenda

- Introduction – What is a radial feeder
- Overview of Radial Feeder Challenges
- How can Microgrid help
- What ABB has to offer
- Radial Feeder Microgrid Business Case
- Summary
What is a radial feeder?

Radial feeders are the least expensive, both to construct and for their protection system. A greater level of reliability at a higher cost is achieved with a parallel feeder.
Radial Feeder Challenges and Microgrid Benefits

**Radial Feeder Challenges**
- More likely to require capacity upgrades for demand growth
- Below-average reliability performance
- Voltage issues with significant solar photovoltaic (PV) penetration

**Microgrid benefits**
- Defer distribution system upgrades and manage expected demand growth
- Improve reliability performance and resiliency
- Provide voltage regulation and increase renewable hosting capacity
- Decrease demand charges by peak shaving
Load Growth Challenge
Distribution utility with radial feeders in need for capacity upgrade

Distribution system cannot host the expected demand growth in future due to substation capacity
## Reliability Performance Measurements

*System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI)*

<table>
<thead>
<tr>
<th><strong>System Average Interruption Duration Index</strong> (SAIDI):</th>
<th><strong>System Average Interruption Frequency Index</strong> (SAIFI):</th>
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<tbody>
<tr>
<td>The sum of the restoration time for each sustained interruption multiplied by the sum of the number of customers interrupted, divided by the total number of customers served for the area. This metric is expressed in average minutes per year</td>
<td>The sum of the number of interrupted customers for each power outage greater than five minutes during a given period, divided by the total number of customers served for the area. This metric is expressed in the average number of outages per year</td>
</tr>
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</table>
# Reliability Performance for Utilities

US utility categories and reliability performances

<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>[Image]</td>
<td>41%</td>
<td>8</td>
<td>[Image]</td>
<td>[Image]</td>
</tr>
<tr>
<td>Municipal Utility (Munl)</td>
<td>[Image]</td>
<td>3%</td>
<td>66</td>
<td>[Image]</td>
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<tr>
<td>Investor-Owned Utility (IOU)</td>
<td>[Image]</td>
<td>56%</td>
<td>38</td>
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- **Residential**
- **Commercial**
- **Industrial**
- **Without major events**
- **With major events**
Economic Impacts of Reliability Performance
Examples from US and Finnish Markets

Impacts of reliability performance on utilities

Penalty and Reward Scheme:
Example from US Market, San Diego Gas & Electric

• Utility pays 125 kUSD as a penalty if SAIDI and SAIFI of the worst circuit is above the target
• Utility receives 125 kUSD as a reward if SAIDI and SAIFI of the worst circuit are below the target

Customer compensation for Non-Delivered Energy:
Example from Finnish Electricity Market

• Utility pays 10% to 200% of the annual network fee as a customer compensation for 12 to 288 hours of interruption.
Voltage Issues
Impact of PV on the radial feeder voltage regulation

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

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

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

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Planned and Operating PV Plants

Color by Unit Status
- Operating
- Planned
Microgrid

A reliability solution

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.

* Islanded mode: ability to provide power independently from the main power grid

Microgrids are low or medium voltage grids without power transmission capabilities and are typically not geographically spread out.
### Radial Feeder Business Case – Problem Definition

**Location:** Long radial feeders with geographic restrictions

#### Distribution Utility Challenges

- Capacity upgrade required within 5 years to manage load growth.

#### Power System Assumptions

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Radial Feeder Business Case – Problem Definition
Location: Long radial feeders with geographic restrictions

**Distribution Utility Challenges**
- Capacity upgrade required within 5 years to manage load growth.
- Utility pays transmission and capacity charges to Independent System Operator or Regional Transmission Operator.

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Radial Feeder Business Case – Problem Definition
Location: Long radial feeders with geographic restrictions

Distribution Utility Challenges
• Capacity upgrade required within 5 years to manage load growth.
• Utility pays transmission and capacity charges to Independent System Operator or Regional Transmission Operator.
• Reliability performance is low and utility pays the penalty.

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<td>SAIDI</td>
<td>420 minutes per customer per year</td>
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<td>SAIFI</td>
<td>3 times per customer per year</td>
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<td>Reliability Impact</td>
<td>125 kUSD-Year as a Penalty/ Reward</td>
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Radial Feeder Business Case – Problem Definition
Location: Long radial feeders with geographic restrictions

Distribution Utility Challenges

- Capacity upgrade required within 5 years to manage load growth.
- Utility pays transmission and capacity charges to Independent System Operator or Regional Transmission Operator.
- Reliability performance is low and utility pays the penalty.
- The utility is facing increased O&M cost for voltage issues from solar PV.

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<tr>
<td>Solar PV</td>
<td>800 kWp</td>
</tr>
<tr>
<td>System O&amp;M Cost</td>
<td>425 kUSD, including maintenance for VRs.</td>
</tr>
<tr>
<td>Utility Rate</td>
<td>0.12 USD/kWh</td>
</tr>
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</table>
Radial Feeder Business Case - Scenarios

These scenarios manage the demand growth, but Microgrids have multiple revenue streams.
Scenario 1: Distribution Capacity Upgrade

Qualitative description

1. Distribution utility pays the investment for capacity upgrades to manage the expected demand growth.

2. Distribution utility pays for the capacity charge and transmission charge related to the peak demand.

3. Distribution utility pays the penalty for low reliability performance.

4. The operation and maintenance cost includes voltage regulator replacement due to PV penetration.
Scenario 2: Microgrid Scenario

Qualitative description

Microgrid
1. Distribution utility invests in Microgrid solution to manage the expected demand growth

Peak Demand
2. Distribution utility pays less demand charge due to the energy storage peak shaving capability

Reliability
3. Distribution utility receives the reward for improved reliability performance

Voltage Regulation
4. Voltage regulators need to switch less due to the battery voltage regulation capability

Microgrid improves resiliency and increase hosting capacity of distribution system for renewable integration
Cost Benefit Analysis
Quantitative description

**Scenario 1: Distribution Capacity Upgrade**

**Benefits:**
- Manage the expected demand growth
- Peak demand charges remain high
- Reliability performance is not improved
- Voltage regulation is not improved

**Costs:**

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<tbody>
<tr>
<td>CAPEX</td>
<td>5 MUSD</td>
</tr>
<tr>
<td>OPEX</td>
<td>No additional Cost</td>
</tr>
<tr>
<td>Lead time</td>
<td>5 years</td>
</tr>
</tbody>
</table>

**Scenario 2: Microgrid (Installed capacity of 5.5 MW, 16.5 MWh)**

**Benefits:**
- Manage the expected demand growth by peak shaving
- Reduce peak demand charges by 20%
- Improve reliability performance, rewards of 125 kUSD/yr
- Decrease system O&M costs of voltage regulators by 25%.

**Costs:**

<p>| | |</p>
<table>
<thead>
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<tbody>
<tr>
<td>CAPEX</td>
<td>7.8 MUSD</td>
</tr>
<tr>
<td>OPEX</td>
<td>0.2% Microgrid CAPEX</td>
</tr>
<tr>
<td>Lead time</td>
<td>1 year</td>
</tr>
</tbody>
</table>
Microgrid Impact on Reliability Performance

Reliability performance Indices

Assuming,
• 98% energy storage availability \( (P_{ES}) \)
• 100% probability of transitioning to island mode \( (P_{MG}) \)
• Seamless transition to island mode \( (t_{MG}) \)

Then,
• \( SAIFI = SAIFI_{Base} \left[ P_{MG}P_{ES} + (1 - P_{ES}) \right] = \) 0.06 outages per customer per year
• \( SAIDI = SAIFI_{Base} \left[ P_{MG}P_{ES}t_{MG} + \frac{SAIDI_{Base}}{SAIFI_{Base}} (1 - P_{ES}) \right] = \) 8 minutes per customer per year

Reliability performance improves significantly with the islanding capability
# Radial Feeder Business Case - Results

20 years project life time with 9% discount rate

<table>
<thead>
<tr>
<th>Scenario 1: Distribution System Upgrade</th>
<th>Scenario 2: Microgrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPEX</td>
<td>5 MUSD</td>
</tr>
<tr>
<td>OPEX</td>
<td>27.3 MUSD</td>
</tr>
<tr>
<td>Revenue</td>
<td>32.7 MUSD</td>
</tr>
<tr>
<td>Net Present Value</td>
<td>0.4 MUSD</td>
</tr>
<tr>
<td>Internal Rate of Return</td>
<td>10%</td>
</tr>
<tr>
<td>Payback Period</td>
<td>10 years</td>
</tr>
</tbody>
</table>

A microgrid is the economic solution for radial feeders in need of capacity upgrade
Radial Feeder Business Case- Results, Cont’d.

Break down of Cost Benefit Analysis (20 years project life, 9% discount rate)

Microgrid O&M cost includes the battery replacement and the annual maintenance expenses.
<table>
<thead>
<tr>
<th>Sensitivity Parameter</th>
<th>Low Case (-10%)</th>
<th>Base Case</th>
<th>High Case (+10%)</th>
<th>Impact on Net Present Value Compared to the Base Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microgrid Cost (USD/kWh)</td>
<td>423</td>
<td>470</td>
<td>517</td>
<td>-18%</td>
</tr>
<tr>
<td>Peak Demand Reduction (%)</td>
<td>18</td>
<td>20</td>
<td>22</td>
<td>-10%</td>
</tr>
<tr>
<td>Reliability Reward (kUSD-year)</td>
<td>112.5</td>
<td>125</td>
<td>137.5</td>
<td>-3%</td>
</tr>
<tr>
<td>O&amp;M Cost Reduction for Voltage Regulation (%)</td>
<td>22.5</td>
<td>25</td>
<td>27.5</td>
<td>-2%</td>
</tr>
</tbody>
</table>
Microgrid for Radial Feeders

Key Takeaways

How utilities with radial feeders will benefit from Microgrid?

- Defer Distribution Capacity Upgrades
- Manage Demand Growth
- Improve Reliability and Resiliency
- Provide Voltage Regulation
- Increase Hosting Capacity
- Provide Peak Shaving
Developing a microgrid project
From consulting and advisory services to design and implementation
What ABB has to offer

ABB - global microgrid and battery energy storage system, solution partner

Leading global expertise

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

AND

Broad portfolio of products & services

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

- Consulting
- Service
- 3rd party financing
Global installed base

Microgrids and BESS

Worldwide: 362 MW

- Europe: 10.59 MW
- Asia: 70.68 MW
- Australia: 105.28 MW
- Middle East: 200 kW
- North America: 151.6 MW
- South America: 20.18 MW
- Africa: 3.95 MW