Project Description
ORNL and SNL will design and perform cost/benefit analysis of an industrial-scale microgrid with the goal of sharing lessons learned and best practices with other industries and utilities. The analysis will be performed on the UPS Worldport facility in Louisville, Kentucky.

Value Proposition
- Industrial utility customers often spend hundreds of thousands to millions of dollars in backup systems and standby generation in case of sudden loss of electricity supply due to outside influences such as severe storms.
- Utilities stand to benefit from the modernized grid, however they are often hesitant to invest in new technologies.
- This project aims to demonstrate reliability improvements for industrial customers can also benefit utilities and provide a methodology applicable to other areas of the country.

Project Objectives
- All-hazards risk analysis of facilities
- Cost/benefit analysis of industrial-scale microgrids
- Potential for grid services provision
- Roadmap to industrial microgrid deployments & lessons learned
Industrial Microgrid Analysis and Design for Energy Security and Resiliency

Project Participants and Roles
ORNL – Lead, Efficiency and Ancillary Services Analysis
SNL – Microgrid Design, Cost/Benefit Analysis
UPS – Industry Partner
Waste Management – Industry Partner
Prime Time Computing – Risk Analysis
Burns & McDonnell – Support, Biogas analysis
Harshaw Trane – Support, Biogas analysis
Kentucky Government - Support

<table>
<thead>
<tr>
<th>PROJECT FUNDING</th>
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</thead>
<tbody>
<tr>
<td>Lab</td>
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<tr>
<td>ORNL</td>
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<tr>
<td>SNL</td>
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</table>
Utilizing an all-hazards approach for risk assessment of the Louisville area and UPS facilities

Taking steps to address specific electrical risk through the use of microgrid(s)

Looking at reduced capacity operations to shrink investment in microgrid resources while still allowing facilities to operate during contingencies
Industrial Microgrid Analysis and Design for Energy Security and Resiliency

Approach

► Task 1 – Microgrid Evaluation
  - Analyze three critical industrial facilities with open-source software and provide a narrowed search space of microgrid options

► Task 2 – Risk Analysis
  - Utilize an all-hazards tool to determine current risk and risk reduction as a result of the project

► Task 3 – Energy Efficiency and Ancillary Services
  - Utility rate structures used to identify most valuable services to the grid

► Task 4 – Generation Upgrades
  - Options for combined head and power (CHP) for electrical generation and heat load requirements

► Task 5 – Energy Resiliency and Cost/Benefit Optimization Modeling and Analysis
  - Cost/benefit study for three microgrids serving critical operations
## Milestone (FY16-FY18) Status Due Date

<table>
<thead>
<tr>
<th>Milestone (FY16-FY18)</th>
<th>Status</th>
<th>Due Date</th>
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</thead>
<tbody>
<tr>
<td>Kickoff Meeting with Stakeholders</td>
<td>Complete</td>
<td>4/12/16</td>
</tr>
<tr>
<td>Initial Microgrid Design</td>
<td>Complete – 1 site</td>
<td>10/1/16</td>
</tr>
<tr>
<td>Risk Analysis Completed</td>
<td>Complete - Preliminary</td>
<td>4/1/17</td>
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<tr>
<td>Contracts in Place for Biogas Analysis</td>
<td>On Hold</td>
<td>4/1/17</td>
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<tr>
<td>Energy Efficiency and Ancillary Service Analysis</td>
<td>In Progress</td>
<td>10/1/17</td>
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<tr>
<td>Generation Upgrades Analysis</td>
<td>In Progress</td>
<td>10/1/17</td>
</tr>
<tr>
<td>Cost/Benefit Modelling and Analysis</td>
<td>Complete – 1 site</td>
<td>10/1/17</td>
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Analysis utilizes open-source software
Two site visits to UPS Worldport to tour facilities and infrastructure
Met with utility and industry stakeholders to discuss rate programs and partnerships
Identified critical industrial and electrical infrastructure
Performed microgrid analysis on a critical industrial facility
Data collection underway for two more microgrid sites
Modelling and simulation have resulted in upgrades to existing DOE tools
# Industrial Microgrid Analysis and Design for Energy Security and Resiliency

## Accomplishments to Date

<table>
<thead>
<tr>
<th>Option</th>
<th>Facility A</th>
<th>Facility B</th>
<th>Tie</th>
<th>Cost ($K)</th>
<th>Overall Availability (Ci)</th>
<th>Post-Startup Availability (Ci)</th>
<th>Post Startup Occurrences with Load Loss (Ci)</th>
<th>Overall Diesel Efficiency</th>
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<tr>
<td>Baseline</td>
<td>550 kW</td>
<td>550 kW</td>
<td>No</td>
<td>$740,000</td>
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<td>97.914717%</td>
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<td>550 kW</td>
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<td>99.995262%</td>
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<tr>
<td>Baseline with Additional Facility B Gen</td>
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<td>550 kW (x2)</td>
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<td>550 kW (x2)</td>
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<td>99.945881%</td>
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<td>Facility A Microgrid</td>
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<td>$2,024,500</td>
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<td>99.99745%</td>
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<td>Facility B Microgrid</td>
<td>550 kW</td>
<td>550 kW (x2)</td>
<td>Yes</td>
<td>$2,024,500</td>
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<td>Facility A-B Microgrid</td>
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<td>Recommendation</td>
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<tr>
<td>Please look into using the “Solar Glare Hazard Analysis Tool” to address any issues for integrating solar technologies near the airfield.</td>
<td>The tool has been investigated and discussed with UPS, and currently there is no issue with airfield solar as it pertains to pilot safety.</td>
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<tr>
<td>Please make the deliverable applicable and accessible to others looking to implement microgrids.</td>
<td>Opportunities to make the results more generic are considered while performing testing. The final report will attempt to convey how the results could be applicable to others in industry.</td>
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Communications:
Currently no forums or publications have been public, due to the business sensitive nature of the data and electrical diagrams. A document approved for public release will be made available at the conclusion of the project.

Due to the short nature of this project, we hope to share lessons learned and results with other GMLC projects.
Industrial Microgrid Analysis and Design for Energy Security and Resiliency
Next Steps and Future Plans

• The lab team will continue to refine results based on new data

• Real-time modelling and CHP analysis is underway and should be ready to test in the coming months

• Final report completed by end of FY17
  • Targeted at other industries and utilities interested in microgrids for critical industrial facilities.

• Aim to deliver the results to the hands of industrial consumers and utilities interested in microgrids to stimulate conversation on grid modernization.

• Expect results can be used as lessons learned for other grid modernization projects
## Discovery

- Threat Space
  - Natural and Man-Made Hazards...

## Evaluation Engine

- Stakeholders
- Architects
- Analysts

## Metrics Engine

- Stake Estimation
- Bayesian Analysis
- Threat Analysis

### Table: Stake Estimation

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<th>Stakes</th>
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### Table: Dependency

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### Table: Impact

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### Table: MFC Calculations

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<th>MFC's/ROI's</th>
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### ROI Calculations

- ROI Calculations

### MFC Calculations

- MFC Calculations

### V&V Team

- Controls and Mitigation Costs

### System Custodian

- System Custodian

### Critical Infrastructure/Enterprise System

- Vulnerability
- Vulnerability
- Vulnerability
- Vulnerability

### Real-Time Status

- Risk Reduction

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**Security and Resilience**

5/11/2017
Industrial Microgrid Analysis and Design for Energy Security and Resiliency

Technical Details

\[ Y_i = \sum_{i \leq j \leq m} X^j \times A^i_j, \quad 1 \leq i \leq n \]

- \( Y \): vector of size \( n \)
- \( X \): vector of size \( m \)
- \( A \): \( n \times m \) matrix

\[ Y = A \circ X \]

\[ MFC(S_i) = \sum_{R_j} FC_{i,j} \times P(R_j) \]

- \( ST \): Stakes Matrix
- \( PR \): vector of requirement failure probabilities

\[ MFC = ST \circ PR \]

\[ P(R_i) = \sum_{j=1}^{k+1} \pi(R_i \mid E_j) \times \pi(E_j) \]

- \( DP \): Dependency Matrix
- \( PE \): vector of component failure probabilities

\[ PR = DP \circ PE \]

\[ \pi(E_i) = \sum_{j=1}^{h+1} \pi(E_i \mid V_j) \times \pi(V_j) \]

- \( IM \): Impact Matrix
- \( PT \): vector of threat emergence probabilities

\[ PE = IM \circ PT \]

\[ MFC = ST \circ DP \circ IM \circ PT \]
Industrial Microgrid Analysis and Design for Energy Security and Resiliency

Technical Details

• Simulation of electrical diagram in real time

• Devices modelled in hardware components and interfaced to RTDS

• Communication with microgrid controller through Ethernet

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Raspberry Pi transmits load and irradiance setpoints to RTDS model

Reports measured load back to microgrid controller
Test results of islanding and resynchronization are provided to show the interactions among device level controllers and the master controller.