Microgrid Technology Overview
Microgrid

Any localized grid with its own power generation resources, loads and definable boundaries and acts as a single controllable entity qualifies as a microgrid.

A power grid that:
1. Can operate independently and
2. Operate in conjunction with the area's main electrical grid
Microgrid Components

Cat® Electric Power
Caterpillar: Confidential Green
Caterpillar has been involved with Microgrids for 80+ years.
TPG Case Study
Microgrid at Tucson Proving Ground -- *Project Drivers*

- No utility service at Tucson Proving Ground
- Grid extension is cost-prohibitive (8 miles to Green Valley)
- Site average load is ~300kW. Peak load estimated at 500kW.
- Traditional diesel prime power with 3 x C15 410ekW prime generator sets
- Diesel fuel consumption ~250,000 gallons per year
- Generator set operation 11,000 hours per year
Renewable Energy Project Potential

• Excellent PV energy harvest at Tucson Proving Grounds
  – High performance sunlight // Hot climate
  – High of Cat Thin-Film PV

• Excellent Fuel Consumption Reduction Potential
  – 17 to 33% fuel consumption reduction now…more potential in future
**Solar Panel Arrays:** Cat-Branded Thin Film
- 250 kW Fixed-tilt
- 250 kW Single-Axis Tracker

**Energy Storage:**
- Lithium Ion Battery 250kW
- Ultracap 250kW in 20’ Enclosure

**TPG Offices and Shop Areas**

**Underground Power Cable**

**Existing Powerhouse**

**C15 C15 C15**

**TPG Offices and Shop Areas**

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**Existing Powerhouse**

**C15 C15 C15**

**Cat® Electric Power**

**Caterpillar: Confidential Green**
TPG Microgrid System Diagram

PV Fixed Array 250kW

PV Tracking Array 250kW

Energy Storage
Lithium Ion Battery
250kW / 10 min

Energy Storage
Ultra-capacitor
250kW / 30 sec

3 x Cat C15
410ekW Prime

System Controller
- “Fuel Save” Controller – 1H2016
- MMC – 2X fuel savings -- 2H2016

Cat Switchgear

Site Prime Power Loads
Tucson Proving Ground Microgrid - *Financial Attractiveness*

- Reduces Fuel Cost 33%
- Reduces Genset Maintenance & Repair Cost 25%
- Project IRR: 15% at diesel fuel price $2.98/gallon
Microgrid Products
Cat Solar Photovoltaic (PV)

Series 6 – 405 to 410 W Thin Film
- High Energy Capture (less derate in warm climates)
- Lowest Degradation Rate

PVC400 Shingled-Cell Mono PERC
- High Efficiency for Space Constrained Applications

PVC365/370/375 - 72 Cell Mono PERC
- 425W & 430 W BiFacial
- Low Cap-Ex Product

More than 85 MW of Solar PV sold since the Launch!
HYBRID ENERGY SOLUTIONS

REMOTE MONITORING

CONTROLS

RELIABLE POWER

RENEWABLE SOURCES

TECHNOLOGY ENABLED SOLUTIONS

GENSETS

SOLAR PANELS

ENERGY STORAGE
Cat Energy Storage Packaged Solutions

Factory Built and Tested (Plug-n-play)
- Includes fire suppression equipment
- Options for Environmental Control (HVAC)

Storage

Cat Bi-Directional Inverter (BDP)
Energy Storage Solutions

Grid Stabilization
10’
20’
30’
40’

Module Power Ratings
125 to 2500 peak kW @ 1.0PF (10 sec)
125 to 1875 peak kW @ 1.0PF (10 min)
125 to 1560 cont kW @ 1.0PF (up to 1450 kW-hr)

Module Energy Ratings
287 to 2290 kW-hr at 250 kW @1.0PF Cont rating
1435 kW-hr at 1000 kW @1.0PF Cont rating

Energy (time shift)

BDP250 Based Energy Storage

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Energy Storage Systems (ESS) Product Options

- Multiple configurations for customer specific optimization
- Multiple enclosure types
- Integrated and tested complete systems
- Operation and maintenance friendly in all weather conditions (internal access)
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Caterpillar: Confidential Green
Cat Microgrid Master Controller (MMC)

- Scalable master controller for any size microgrids
- Integrates all energy sources (genset, renewable, utility)
- Optimizes production of energy (lowest cost of electricity)
- Ensures reliable operation
- Open protocol can communicate to almost any source
## Cat MMC Features

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<td>MicroGrid V/I Regulation for distributed assets</td>
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<td>Energy Market Participation</td>
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<td>Weather-based system dispatch</td>
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<td>Enterprise Data Integration</td>
<td>Option</td>
<td>Std.</td>
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- **Controller Options for Every Situation**
- **Power Metering**
- **Comms Solutions**
- **Weather Stations**
Cat Master Microgrid Controller (MMC) User Interface

Cat Connect
Remote Monitoring – Detailed Status
Remote Monitoring – Reports & Trending

Real Power

ENERGY YIELD

11/5/2017 4:23 PM
LOW COST MODE

11/5/2017 4:23 PM

Generator Real Total Power
Generator Real Total Power
Real Power
Real Power
Real Power
Real Power
Real Power

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Project Examples
Industrial / Manufacturing – Hybrid Energy System Example

Customer Provided Schematic

- 3 x CG170-16 (ea. 1556 ekW)
- 150 kWp PV
- 1500 kWp/576 kW-hr ESS

Grid Connected

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Questions?