Caterpillar Microgrid Technology

Paul Newman
Microgrid Sales Manager
North America - West
Microgrid Definition:

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
Caterpillar has been involved with Microgrids for 80+ years
Microgrid Components

- Bi-Directional Inverter/Charger
- Energy Storage Cell
- Load
- Load
- Switchgear
- Switchgear
- PCC
- Load

Components include:
- Microgrid Components
- Switchgear
- Bi-Directional Inverter/Charger
- Energy Storage Cell
- Load
Tucson Proving Grounds 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 is ~ 550kW.
- 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
Remote Hybrid Microgrid – Economics

Economic Justification

Customer Savings

PV / Wind Generator Hybrid

Generator

Fuel

Generator Sets Only
- Low Capital Cost
- Higher Operating Cost

Hybrid
- Higher Capital Cost
- Lower Operating Cost

Customer 10-Year Spend $
Typical Microgrid Operation: Daily Load & Generation Profiles

- **Site Load (kW)**: 75, 150, 225, 300, 375, 450
- **Solar PV Output (kW)**: Maximum at 450 kW
- **Diesel Generator Output (kW)**: Minimum load 150 kW

Graph showing the relationship between power output and time of day.
Typical Microgrid Operation: Daily Load & Generation Profiles

- Extra Solar PV Output
- Time-Shifting with Energy Storage
- Extended Generator Shut-off Period

Power (kW) vs. Time of Day

- 0:00 to 12:00: Power demand exceeds solar output, requiring additional generation.
- 12:00 to 18:00: Solar output peaks, reducing reliance on extra generation.
- 18:00 to 24:00: Utility grid resumes operation as solar output declines.

Note: This diagram illustrates how microgrids can optimize energy use by shifting power demands to times of lower solar output, utilizing energy storage to maintain reliable power supply.
Selection of Optimum PV & Energy Storage Size

Levelized Cost of Energy ($ / kWh-hr)

- Gen
- Diesel generators only 24/7

Optimal PV Sizes

- Increasing PV Size (kW)
- Configuration 1
  - No Energy Storage
  - Engines Always Running

Fuel Reduction Percent (%)
Selection of Optimum PV & Energy Storage Size

- **Gen**: Diesel generators only 24/7
- **MMC**: Cat Microgrid Master Controller

**Levelized Cost of Energy ($ / kWh-hr)**

**Fuel Reduction Percent (%)**

- **Configuration 1**: No Energy Storage, Engines Always Running
- **Configuration 2**: Energy Storage 20 minutes for Cloud-Pass, Engines Off 6 Hours/Day
TPG Microgrid System Diagram

Energy Storage
Lithium Ion Battery
250kW / 10 min

Energy Storage
Ultra-capacitor
250kW / 30 sec

3 x Cat C15
410kW Prime

PV Fixed Array 250kW
x 10

PV Tracking Array 250kW
x 10

Cat Switchgear

Site Prime Power Loads

MMC
20' Hybrid

500kW for ~30s
250kW for ~10min
**Solar Panel Arrays:** Cat-Branded Thin Film manufactured by First Solar
- 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**

**Existing Powerhouse**

**Underground Power Cable**
Tucson Proving Grounds: Remote Monitoring Interface
PHASE 1
- 1.1MW-hr annually
- 37% Fuel reduction
- 18.5% Single Axis Tracker energy capture advantage
- 8% PV Curtailment

PHASE 2
- Interconnect 2\textsuperscript{nd} facility
- PV ready carports
- Additional ESS
- Higher renewable penetration

Tucson Proving Grounds: Remote Monitoring Interface
Tucson Proving Grounds Microgrid – 2015 Financials

Installed Cost before Tax Credit $2.20M
- minus Federal Tax Credit - $0.65M
- minus Arizona Tax Credit - $0.05M
Effective Project Cost after Tax Credit $1.50M ($2.85/W)

Reduces Fuel Cost 33%

Reduces Genset Maintenance & Repair Cost 25%

Project IRR: 15% at diesel fuel price $0.79/L ($2.98/gallon)
**Caterpillar: Confidential Green**

**Configuration**
- 250kW Fixed PV
- 250kW Tracker PV
- Li-Ion & UC 20 min

$2.85/W total cost after tax

- $0.50/L = $1.90/Gal
- $1.00/L = $3.79/Gal
- $1.50/L = $5.69/Gal

**Tucson Proving Grounds Solar PV Project Financial Sensitivities**

IRR% vs. Diesel Fuel Price ($/L)
Thank You!