



Microgrid Technology Overview

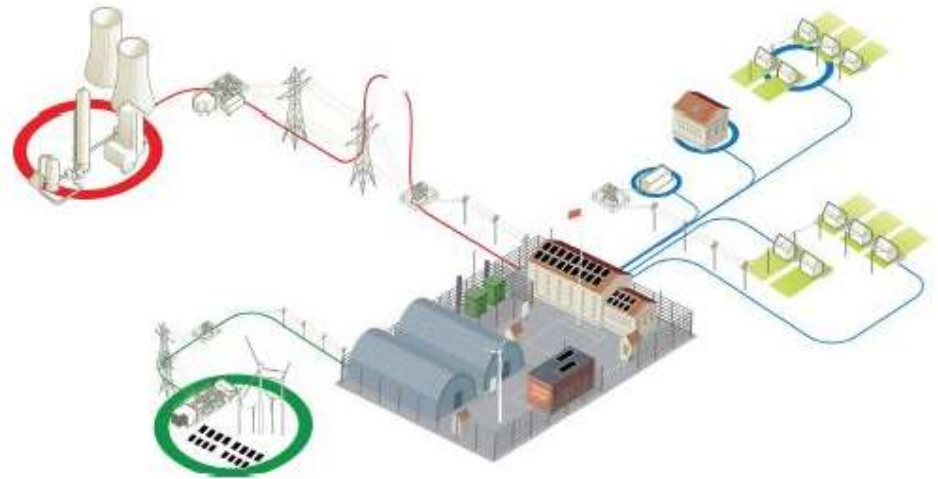


Microgrid

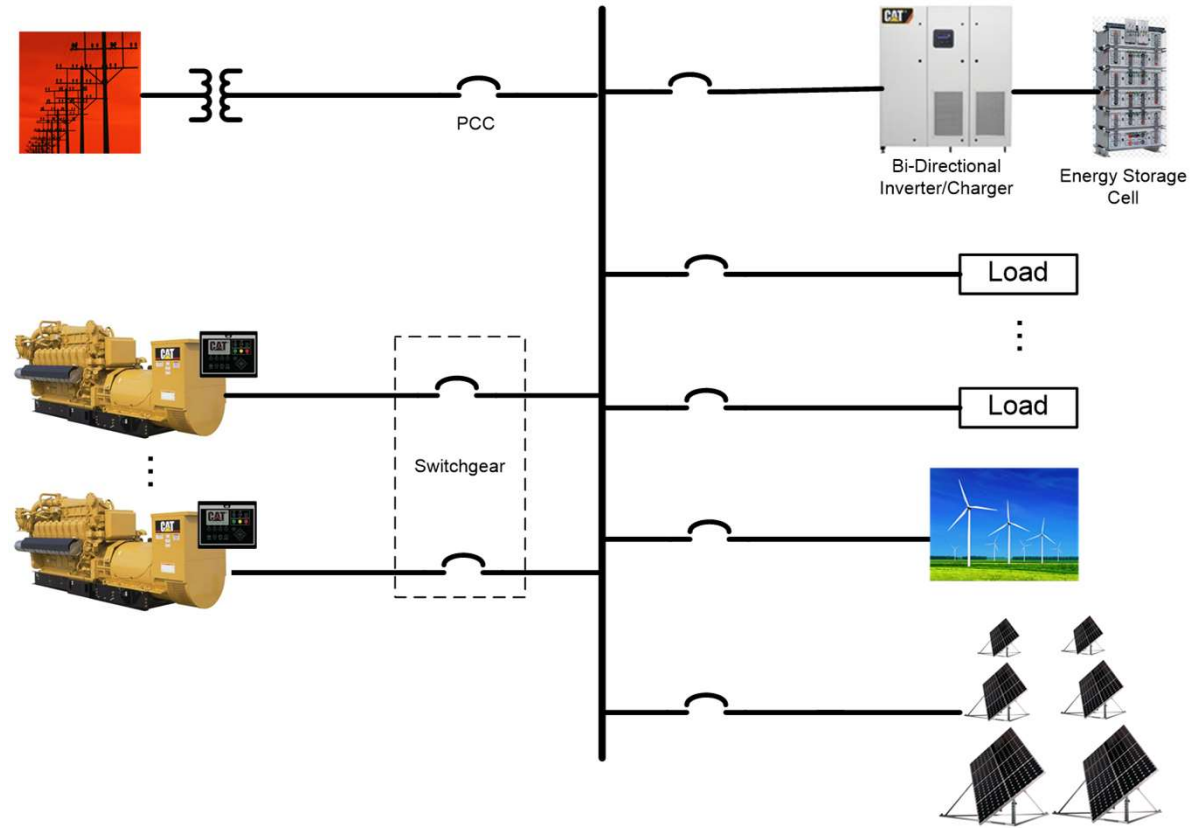
Any localized grid with its own power generation resources, loads and definable boundaries and acts as a single controllable entity qualifies as a microgrid.

A power grid that:

1. Can operate independently and
2. Operate in conjunction with the area's main electrical grid



Microgrid Components



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Caterpillar has been involved
with Microgrids for 80+ years

1938 15kw



TPG Case Study



Microgrid at Tucson Proving Ground -- *Project Drivers*

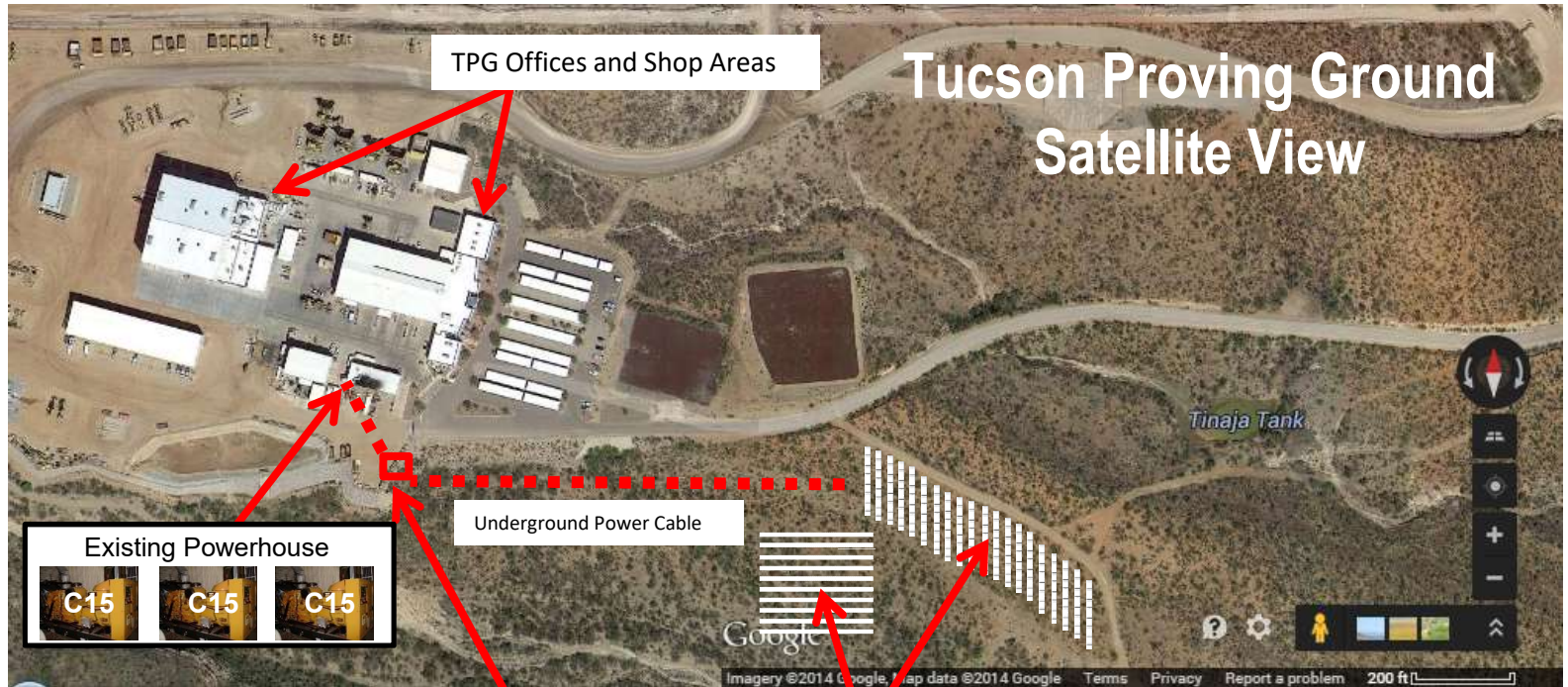
- No utility service at Tucson Proving Ground
- Grid extension is cost-prohibitive (8 miles to Green Valley)
- Site average load is ~300kW. Peak load estimated at 500kW.
- Traditional diesel prime power with 3 x C15 410ekW prime generator sets
- Diesel fuel consumption ~250,000 gallons per year
- Generator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






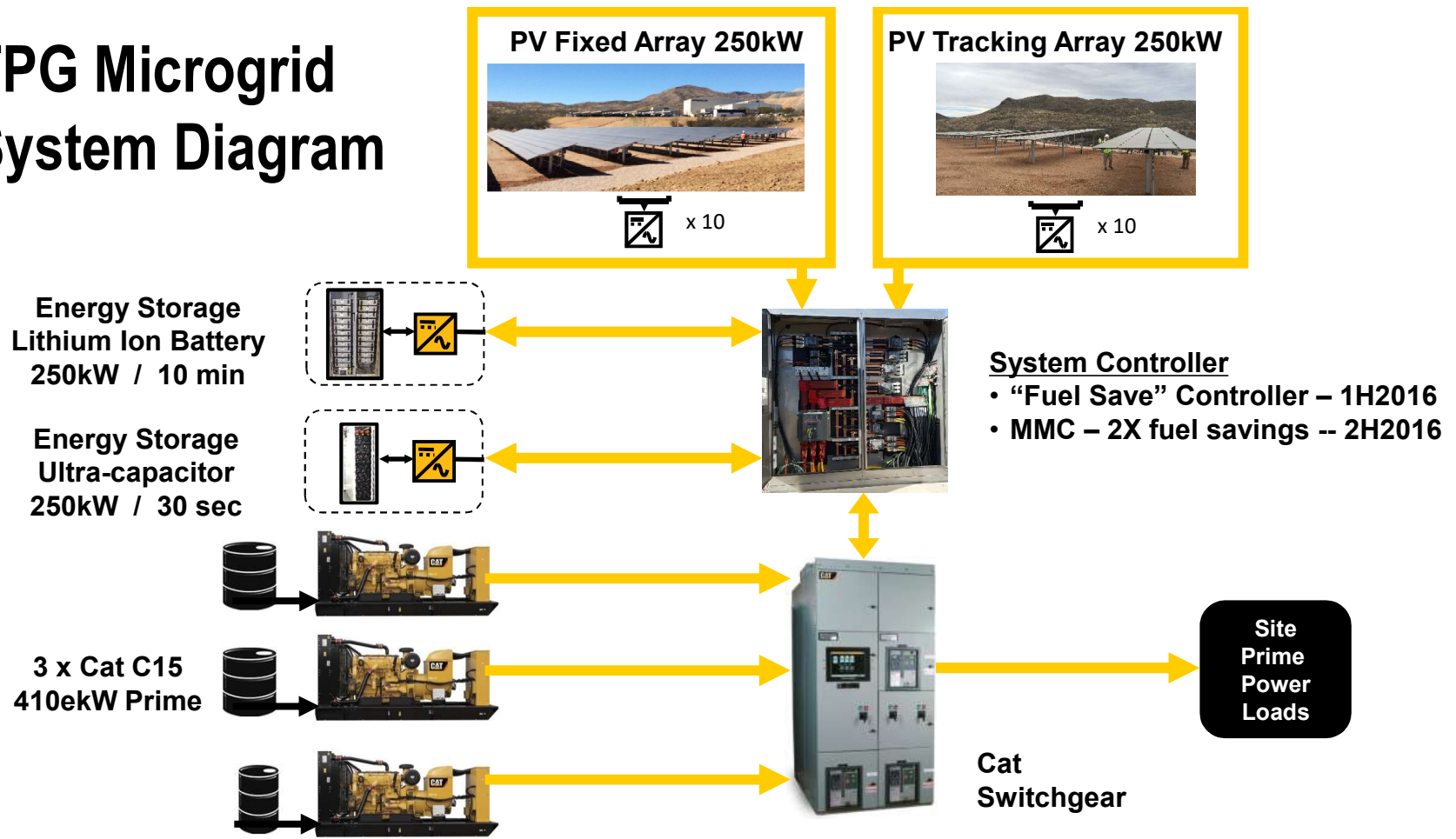
Energy Storage:
Lithium Ion Battery 250kW
Ultracap 250kW
in 20' Enclosure



Solar Panel Arrays: Cat-Branded Thin Film
- 250 kW Fixed-tilt
- 250 kW Single-Axis Tracker



TPG Microgrid System Diagram



Tucson Proving Ground Microgrid - *Financial Attractiveness*

Reduces Fuel Cost 33%

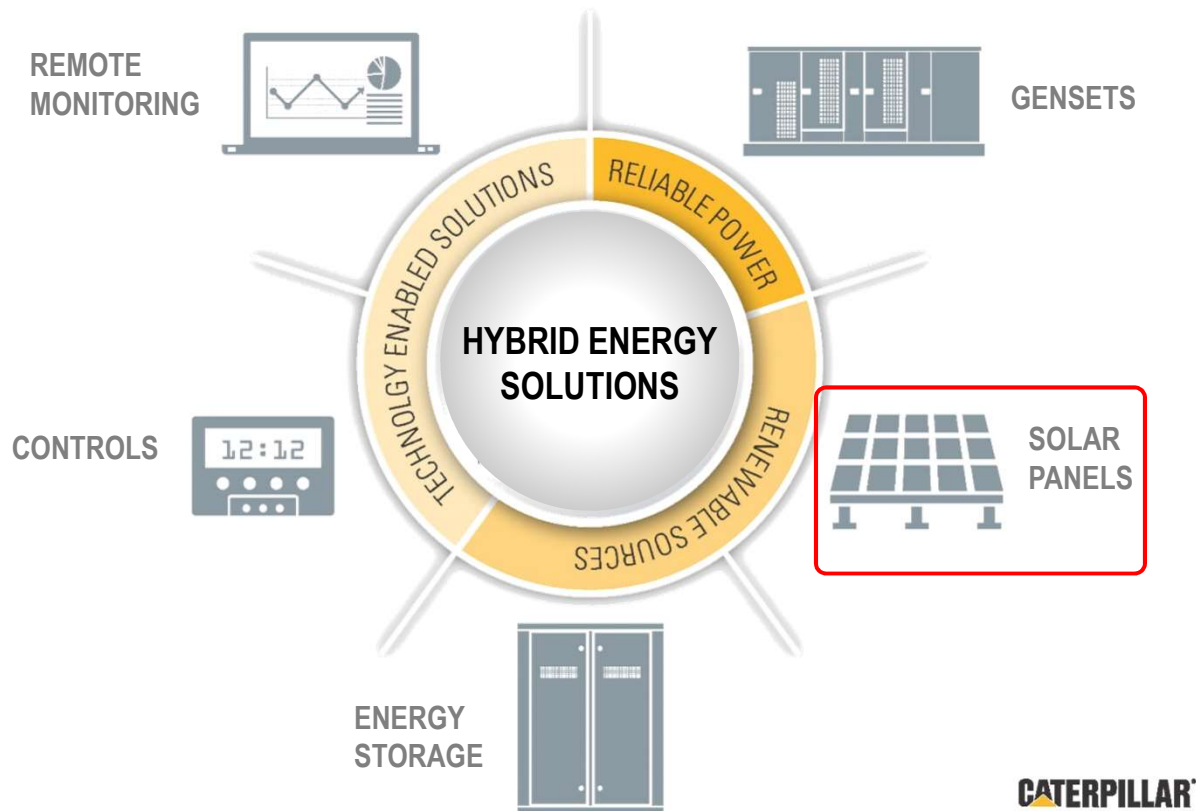
Reduces Genset Maintenance & Repair Cost 25%

Project IRR: 15% at diesel fuel price \$2.98/gallon

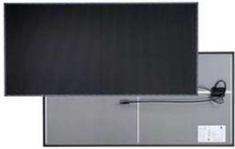


Microgrid Products



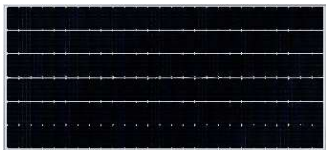


Cat Solar Photovoltaic (PV)



**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

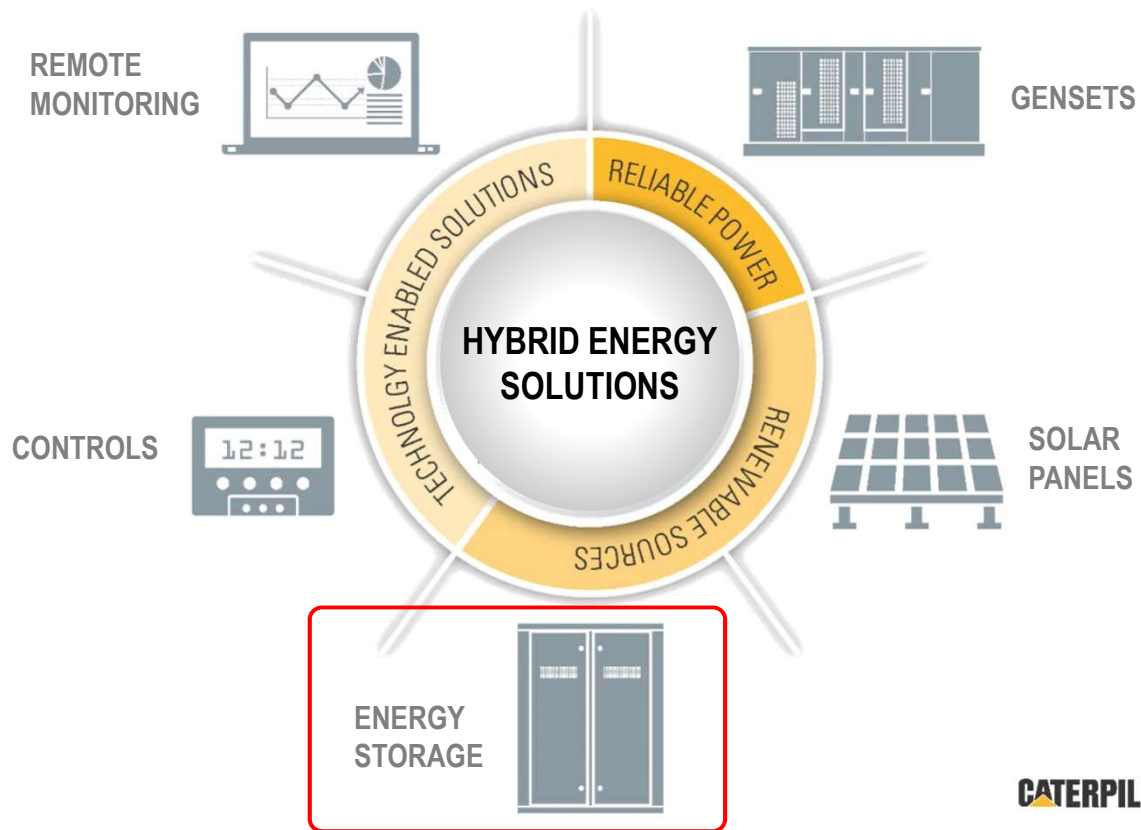
**Optimizing
the Solution**



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

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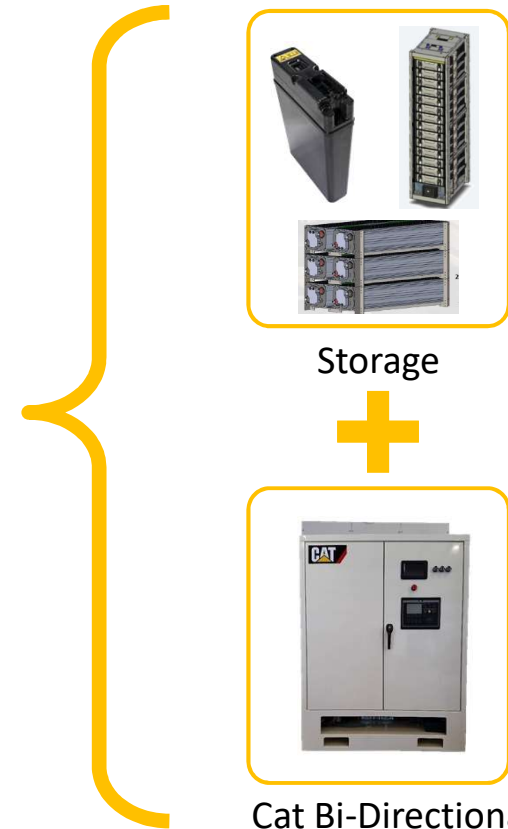
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Cat Energy Storage Packaged Solutions



Factory Built and Tested (Plug-n-play)

- Includes fire suppression equipment
- Options for Environmental Control (HVAC)



Cat Bi-Directional Inverter (BDP)

Energy Storage Solutions



BDP250 Based Energy Storage

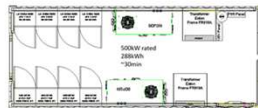
Grid Stabilization

Energy (time shift)

10'



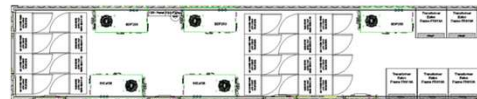
20'



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

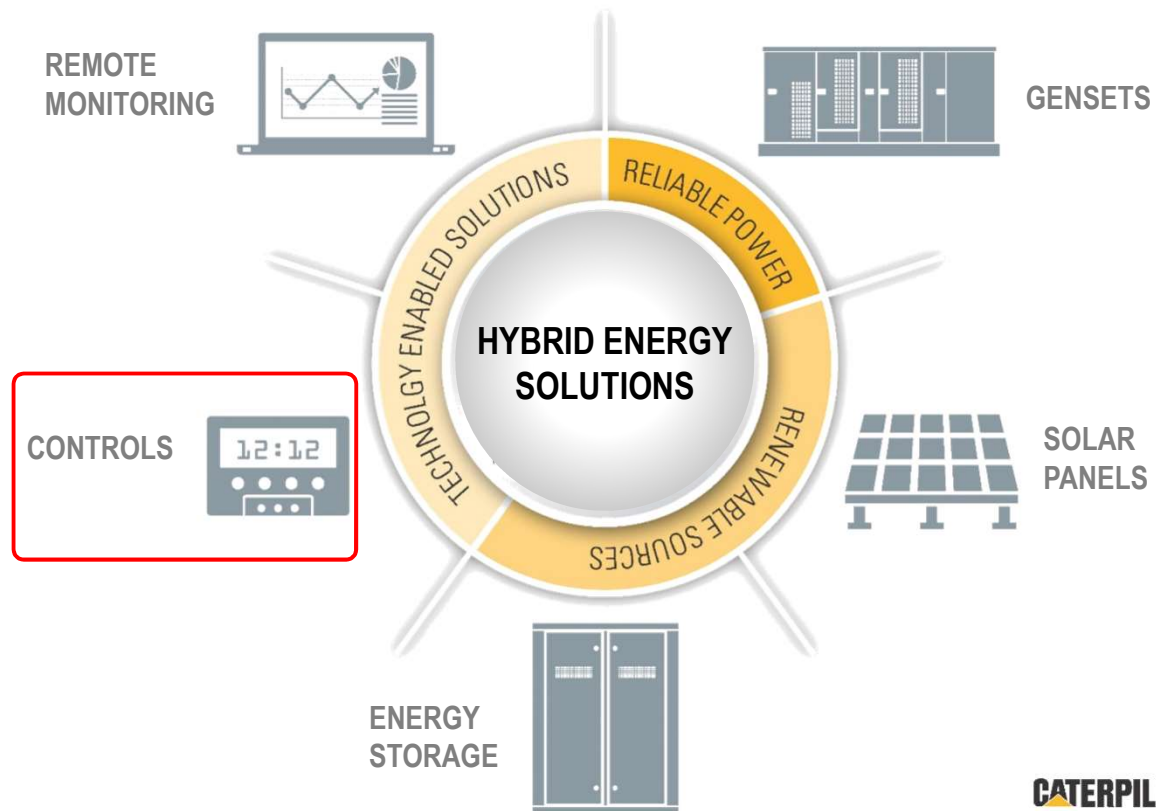
Energy Storage Systems (ESS) Product Options

- 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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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

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Cat MMC Features



Feature	MMC-S	MMC-M
PV Dispatch	Std.	Std.
Genset Dispatch	Std.	Std.
ESS Dispatch	Std.	Std.
Grid Import/Export Power control	Std.	Std.
Black Start	-	Std.
Load Management	-	Std.
MicroGrid V/f Regulation for distributed assets	-	Std.
Grid-tie and Islanding Transition	-	Std.
Energy Market Participation	-	Std.
Weather-based system dispatch	-	Std.
Adaptive Protection	-	Std.
SCADA	Std.	Std.
Enterprise Data Integration	Option	Std.

Controller Options for Every Situation

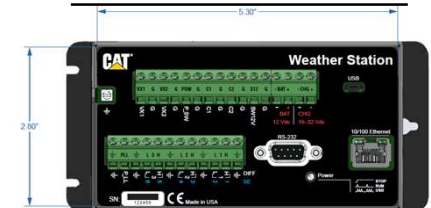
Power Metering



Comms Solutions



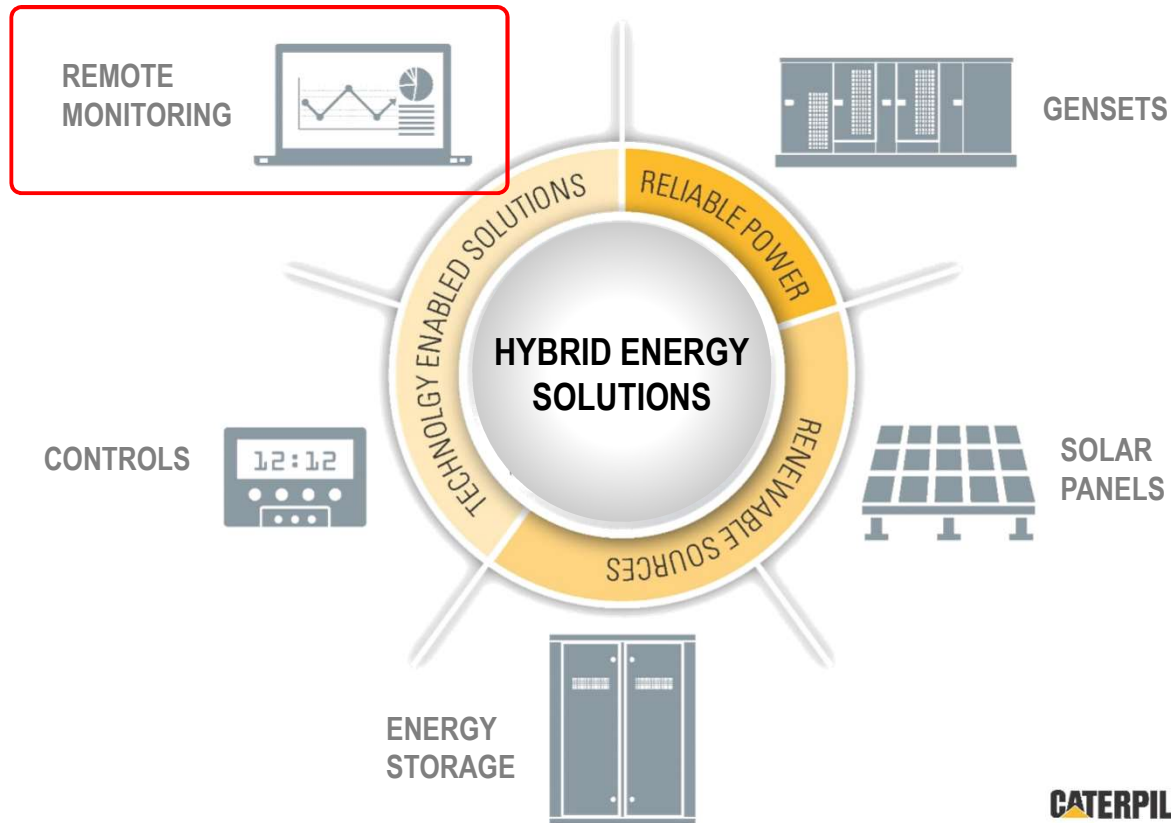
Weather Stations



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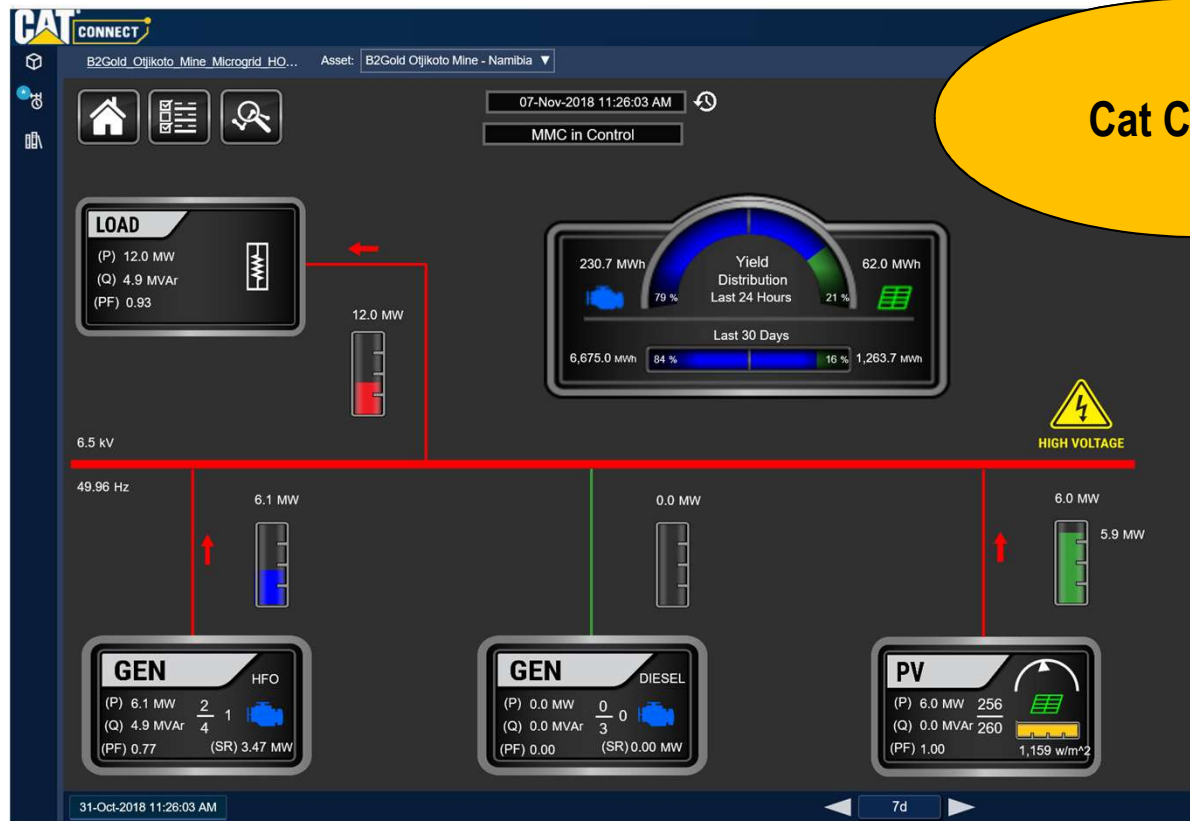
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Cat Master Microgrid Controller (MMC) User Interface

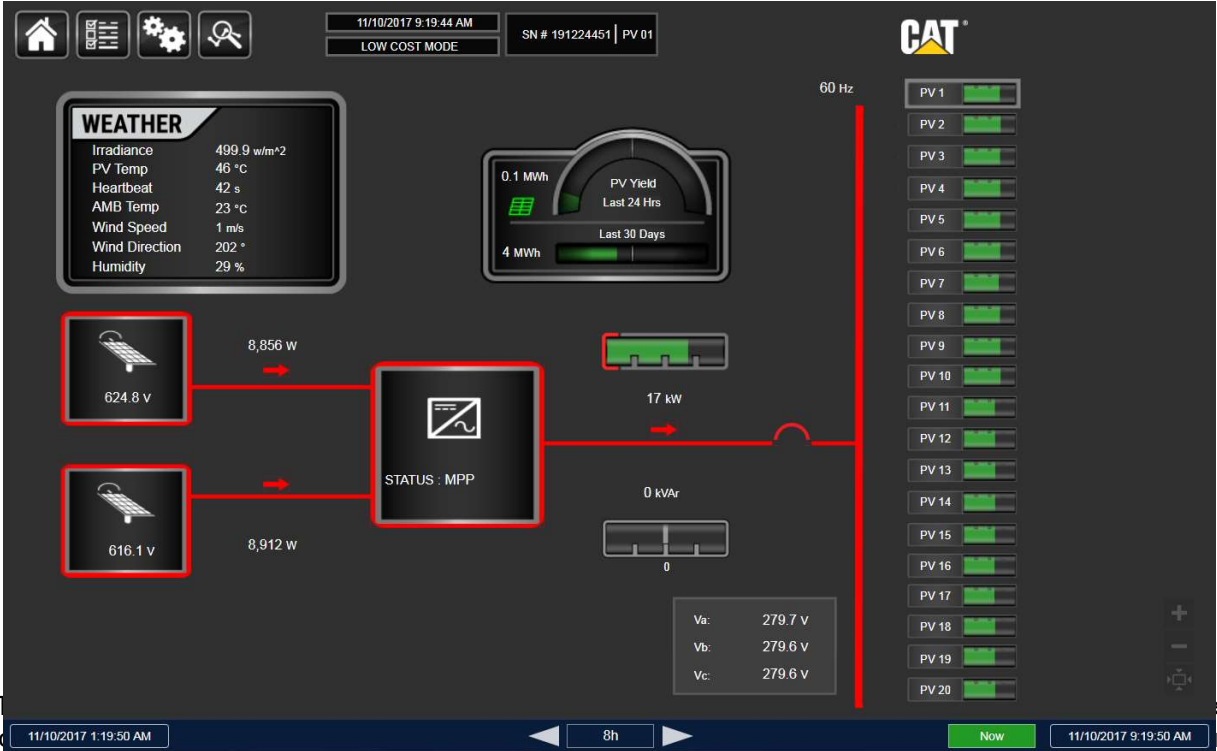


Cat Connect

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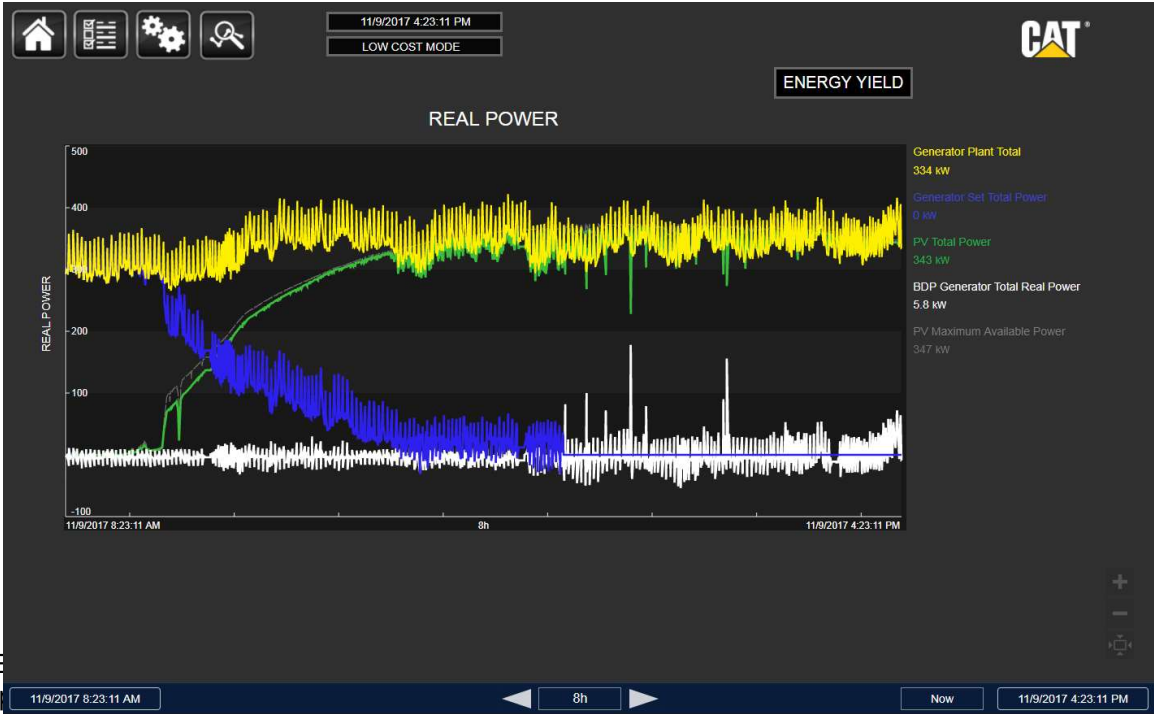
Remote Monitoring – Detailed Status



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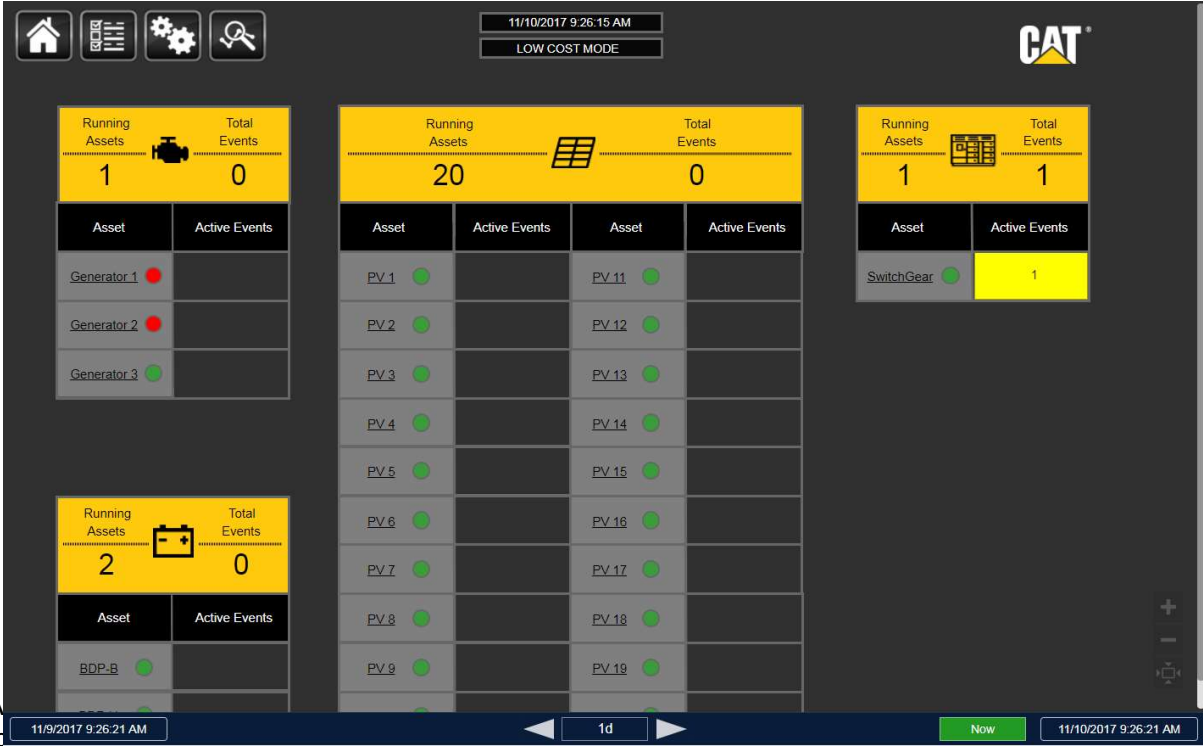
Remote Monitoring – Reports & Trending



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Remote Monitoring – System Health



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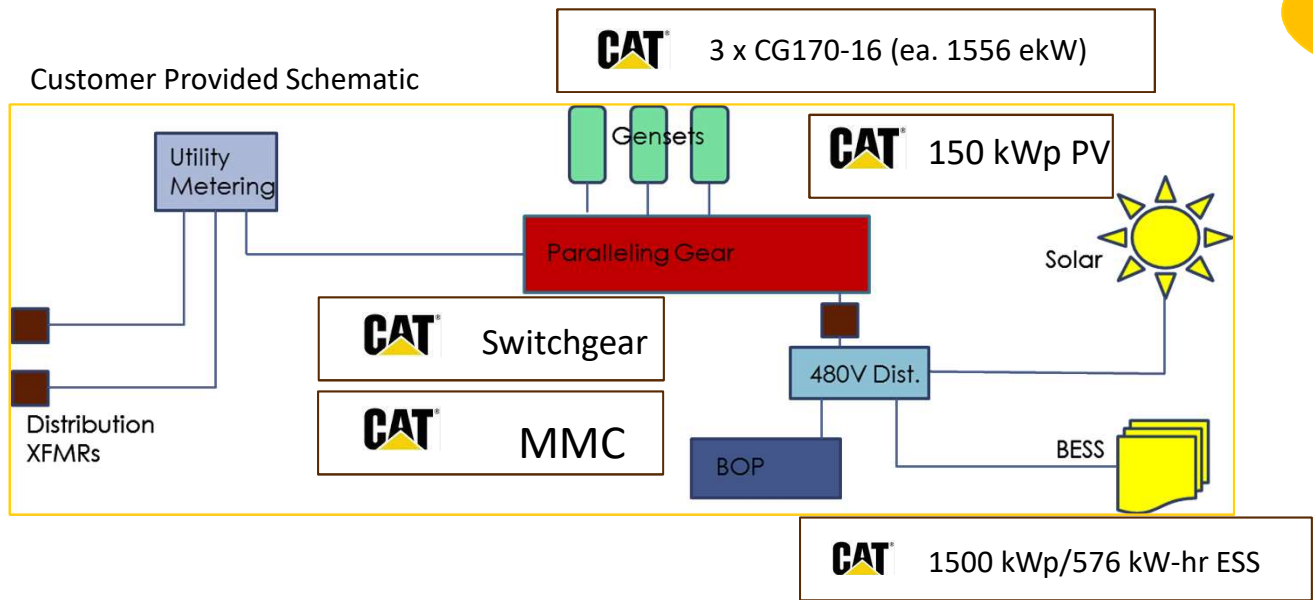


Project Examples



Industrial / Manufacturing – Hybrid Energy System Example

Grid Connected





Questions?

