CATERPILLAR®

Energy Storage System for Mine Sites and Land Drilling

ADVANCED POWER

Dr. Dachuan Yu

March 24, 2022

Dachuan Yu

Dachuan Yu is an Engineering Manager at Caterpillar Inc. His team's focus is on providing power conversion solutions for advanced power sources such as energy storage, fuel cell, and charging solutions for all Caterpillar electrified machines and power applications. He has been with Caterpillar for 17 years.

Dachuan received his Ph.D. in Power Electronics and Controls from North Dakota State University in 2005. His primary focus is power converters and control. Dachuan also holds an MBA with Technology Management concentration, and M.Sc. and B.Sc. in Power System and its Automation.

Prior to joining Caterpillar, Dachuan worked for four years as a substation control engineer in a utility company. He holds 10 US patents on various subjects including inverter control, battery management, and variable speed genset controls. Dachuan has published over 12 conference and journal papers on energy storage system and inverter technologies for renewable and power system protection.

Caterpillar: Non-Confidential

COMMITTED TO BUILDING A BETTER WORLD

Sustainability is one of Our Values in Action and something we do every single day.

We contribute to a reduced-carbon future by:

- Supporting global efforts to mitigate the impact of climate change
- Reducing GHG emissions from our operations
- Helping our customers achieve their climate-related goals by continuing to invest in new products, technologies and services that help them build a better, more sustainable world.

Renewable Fuels

Enable increased use of reduced-carbon options and hydrogen blends.

Fuel Cells

Use renewable hydrogen fuel as a scalable source of electric power.

Electric & Hybrid Powertrains

Employ an electric drive transmission with power components.

Batteries

Power the work with stored electrical energy.

Microgrids

Integrate renewable energy sources into electric power systems.

ADVANCED POWER

Multiple Solutions Made to Match the Work

- Making **established power** sources even more efficient and fuel-flexible
- Pairing established power sources with new technologies in a **hybrid format**
- Replacing established power sources with **stand-alone new technologies**
- Delivering **reman, repair, rebuild, retrofit and repower** services

CATERPILLAR®

Caterpillar: Non-Confidential

Energy Storage Solution for Mine Sites

Power the work with stored electrical energy.

7.5 MW Energy Storage Capacity

Integrates hydroelectric power stations, diesel generator sets, energy storage, power inverters, controls, and remote monitoring

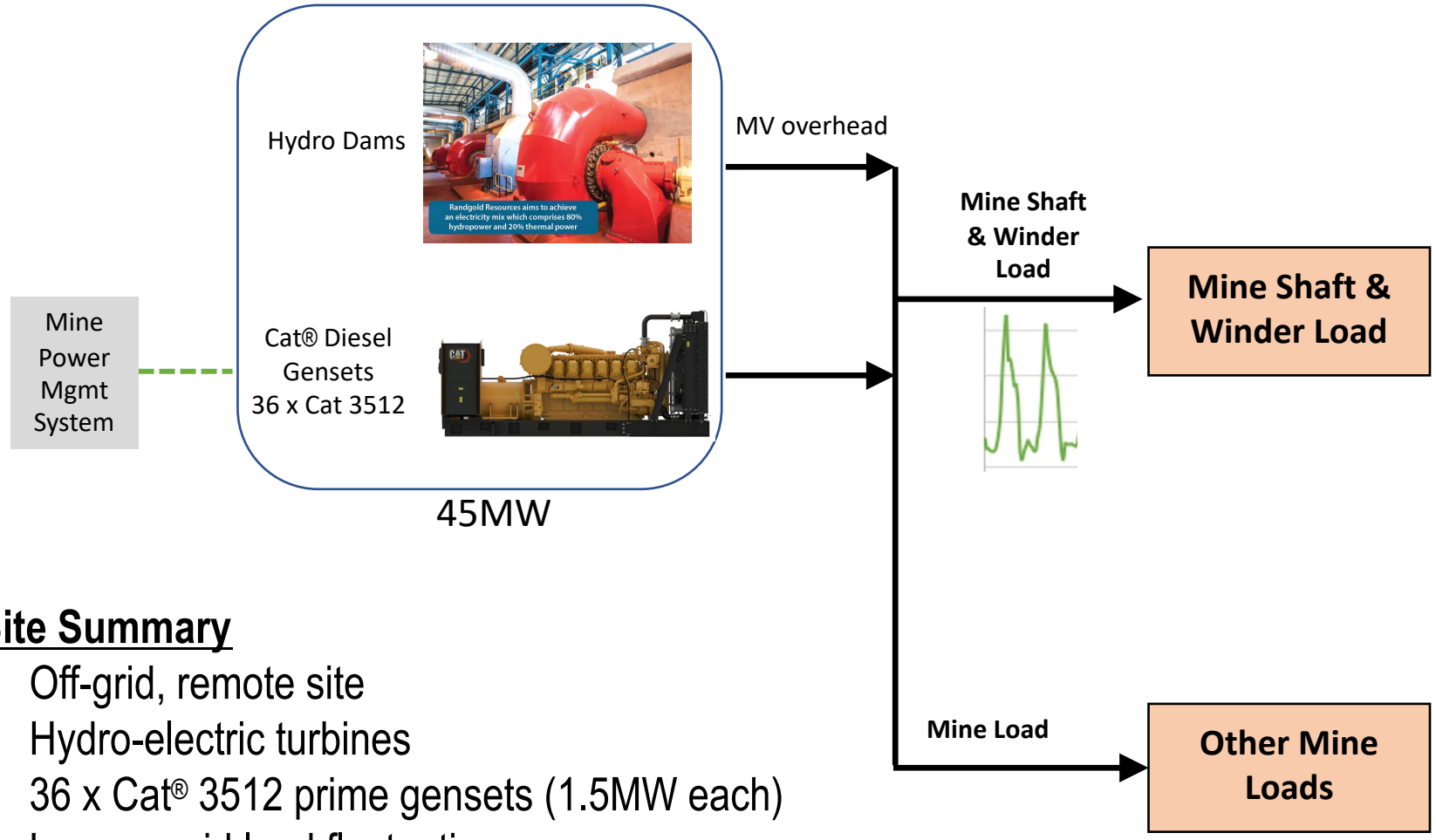
Offsets cyclical loading, decreases diesel consumption and associated emissions

Supplies cleaner and more stable power to customers while reducing costs

ADVANCED POWER

CATERPILLAR®

Example Mine Site: Existing Electrical System

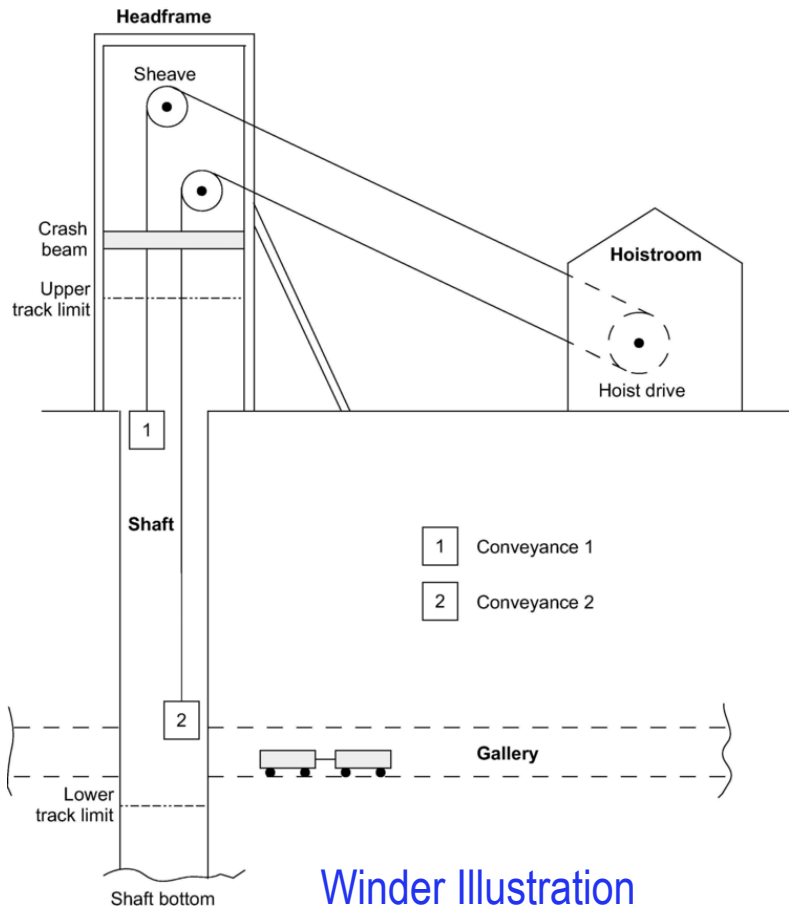


Site Summary

- Off-grid, remote site
- Hydro-electric turbines
- 36 x Cat® 3512 prime gensets (1.5MW each)
- Large, rapid load fluctuations

Caterpillar: Non-Confidential

Mine Regenerative Load



Winder Illustration

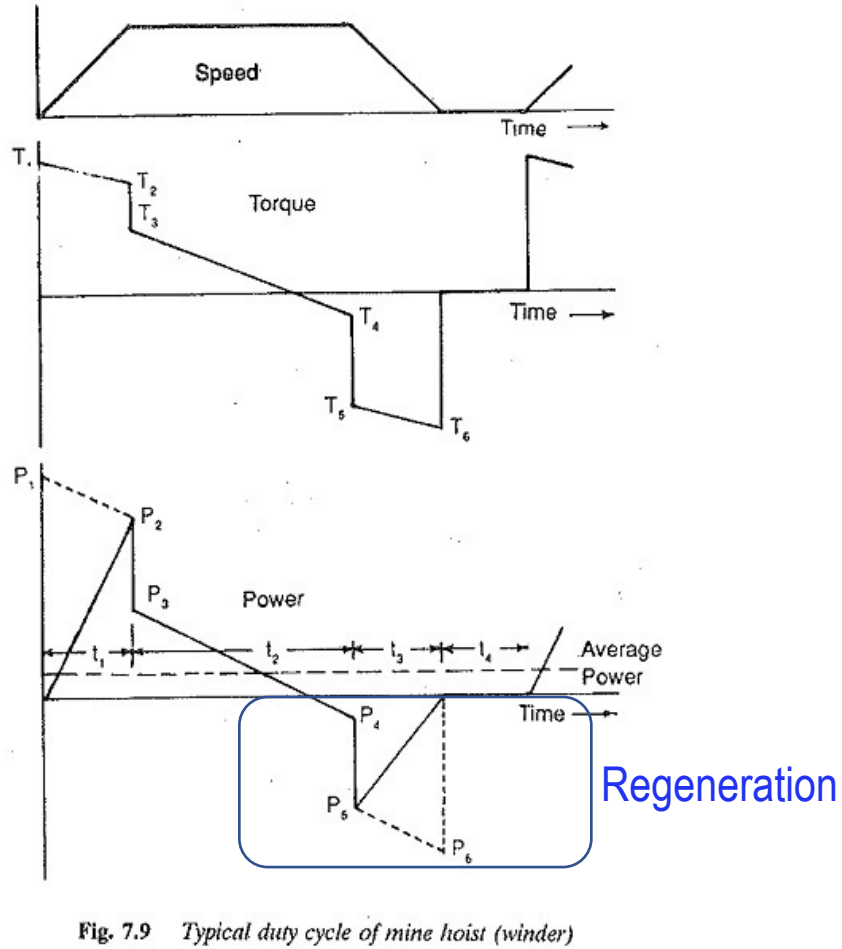


Fig. 7.9 *Typical duty cycle of mine hoist (winder)*

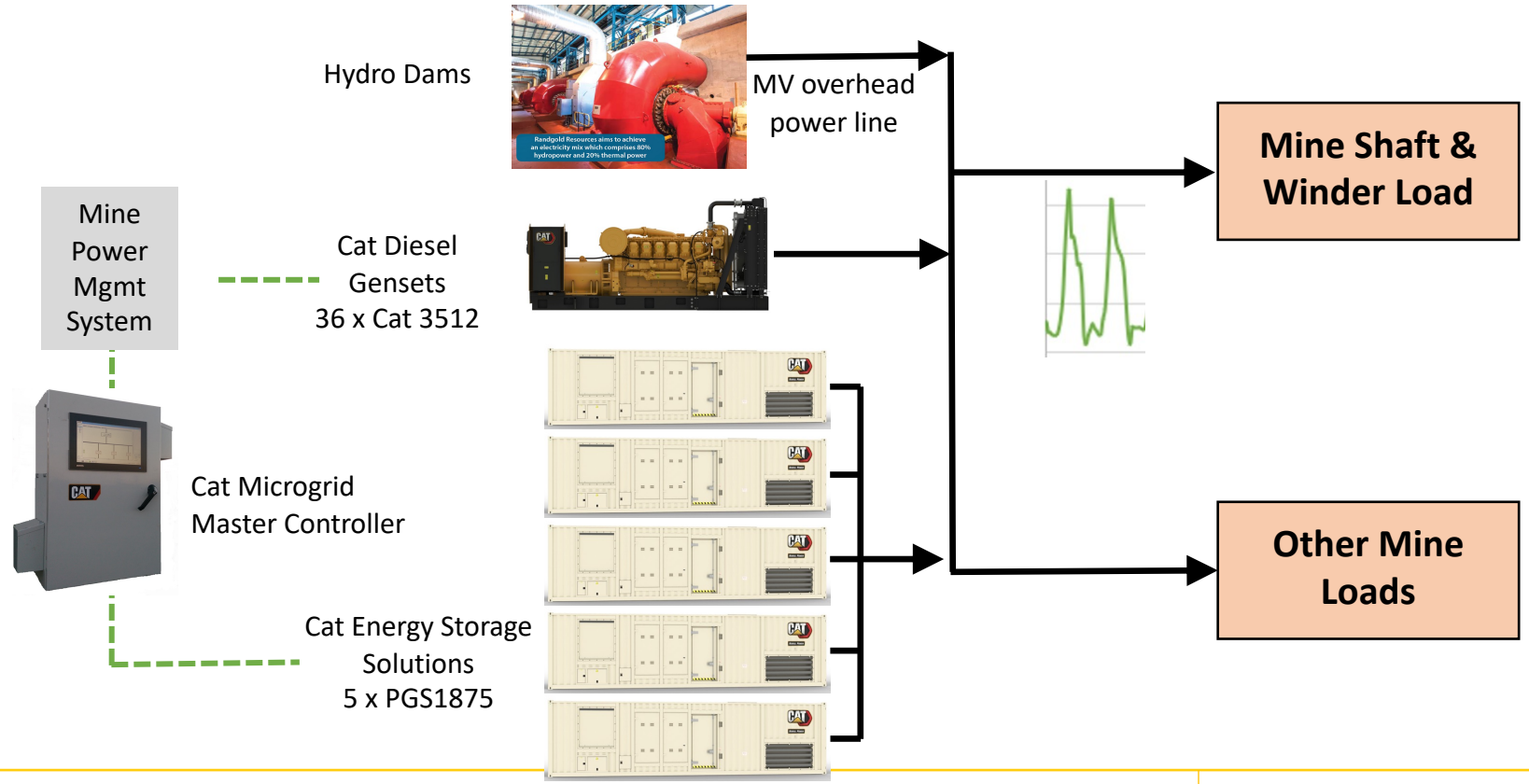
Source: https://www.quora.com/How-does-the-mine-hoist-winder-work https://www.eeeguide.com/coal-mining-process-diagram/

Caterpillar: Non-Confidential

Example Mine Site: With New Cat Hybrid Power

Cat Hybrid Solution

- Added 7.5MW Energy Storage
- Added Microgrid Master Controller and Cat Connect
  - Keeps loads continuously energized with high-quality power at the lowest cost
  - Remote Asset Monitoring provides data visualization, reporting, and alerts through an easy-to-use web interface



Caterpillar: Non-Confidential

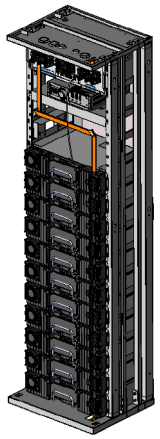
Cat Energy Storage Systems (ESS)

ESS-PGS1875

Power Grid Stabilizer

BDP250

Battery



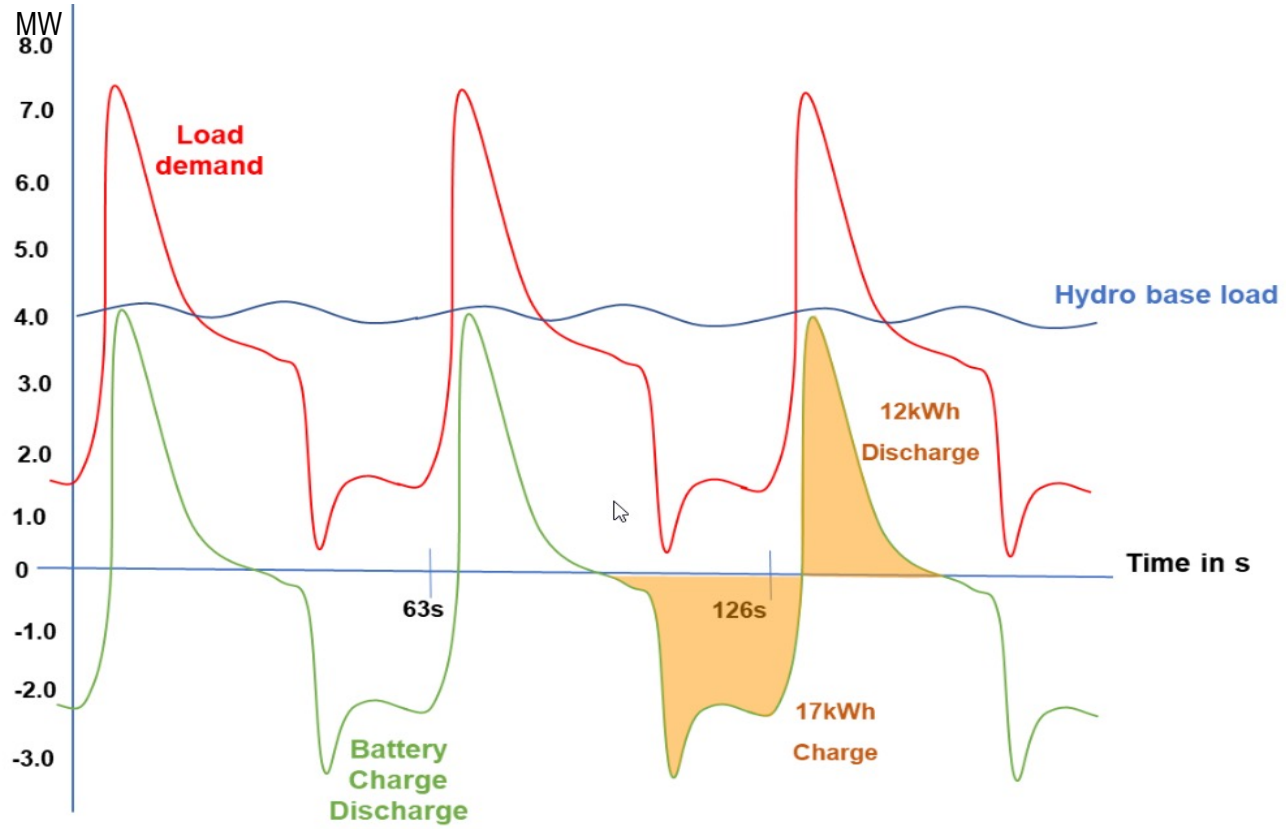
Cat Energy Storage System Benefits

- Fully integrated and factory tested
- Uses advanced lithium-ion batteries with superior energy density, high discharge/recharge efficiency, and high cycle life to compensate for fluctuations in output from renewable energy sources
- State of the art Cat Bi-Directional Power (BDP) inverter with a patented control algorithm
- Provides power stabilization - transient support (f/V), virtual spinning reserve (VSR), Power Factor correction (Full 4 Quadrant PF Control), Fault Current capability of 2 P.U.
- Supplies real and reactive power with Grid Following mode and with a seamless transfer to Grid Forming mode
- Enables ‘genset off’ mode
- Easily re-deployable to other sites

Caterpillar: Non-Confidential

Mine Hybrid Project Results

- Decreased annual diesel consumption by approximately 3 million liters
- Decreased emissions by an estimated 8 kilotons
- Improved power quality



Shaft Power 63 sec profile with 5x PGS1875

Caterpillar: Non-Confidential

LAND DRILLING ENERGY STORAGE SYSTEMS

Power the work with stored electrical energy.

G3512 Natural Gas Generator + Energy Storage System

- Allows use of available natural gas vs. trucked-in diesel
- Lowers carbon intensity of operation
- Reduces fuel consumption per rig per year for current rig operator

ADVANCED POWER

CATERPILLAR®

Land Drilling Rig Introduction

Ensign Rig 162

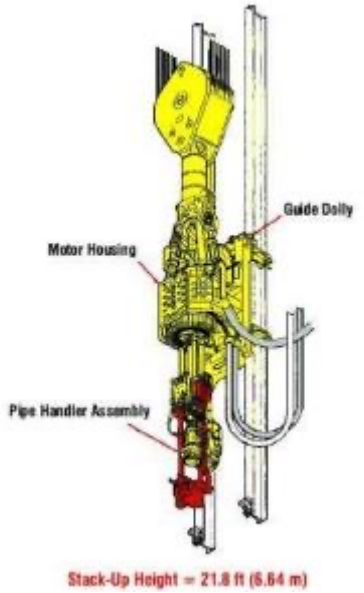
- Top drive
- Draw works
- Hydraulics

- 3 or 4 Gensets
- 1.1MW / 1.3MW

- Shakers, Mixers
- Mud pumps

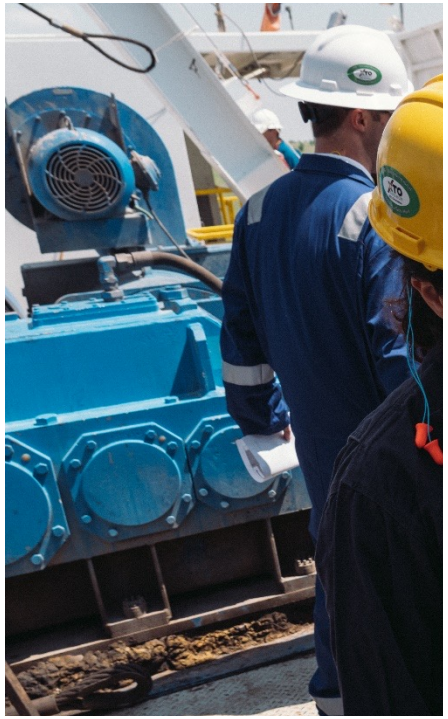
Caterpillar: Non-Confidential

Typical Large Power Consumers Used in Drilling

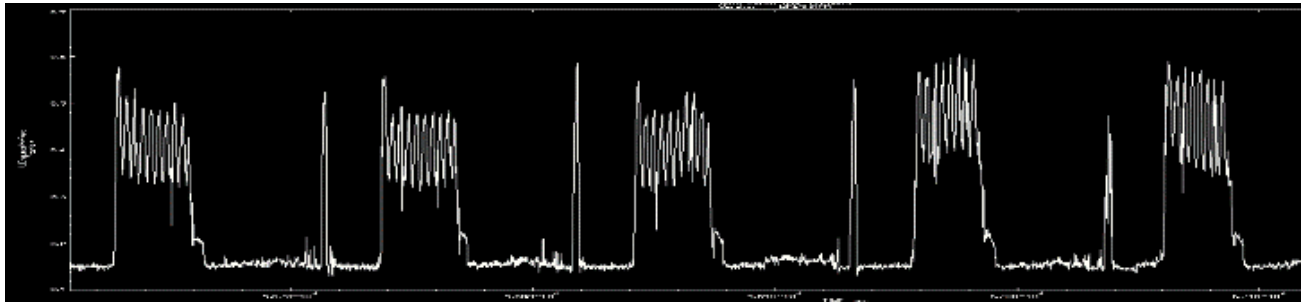


Top Drive: 1000-2000 BHP

Mud Pumps: 500-3000HP



Draw works: 500-2000BHP



Tripping Out of Hole

Caterpillar: Non-Confidential

Caterpillar Hybrid Land Drilling Solution

- **Solution**
  - 4 X 1MW Natural Gas or Dynamic Gas Blending (DGB™) Genset
  - PGS1260HD
    - 1MW Bi-directional Energy Storage Inverter (BDP1000)
    - 672 kWh Li-Ion Battery

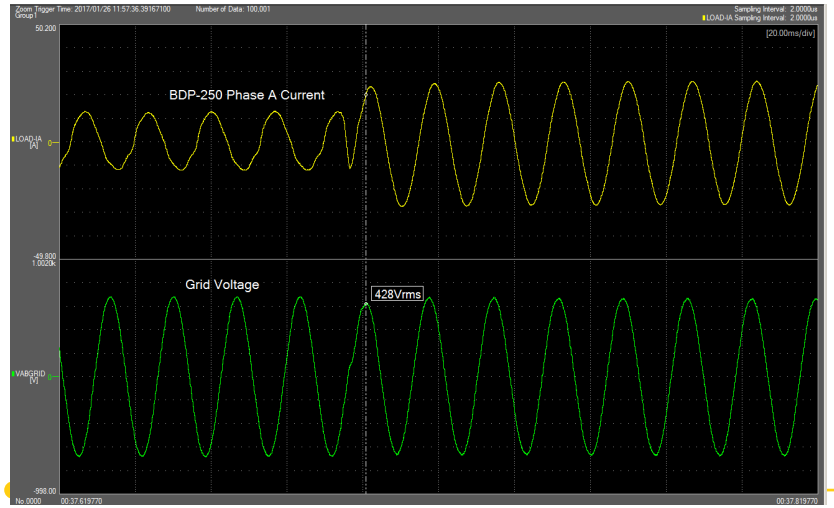
BDP1000

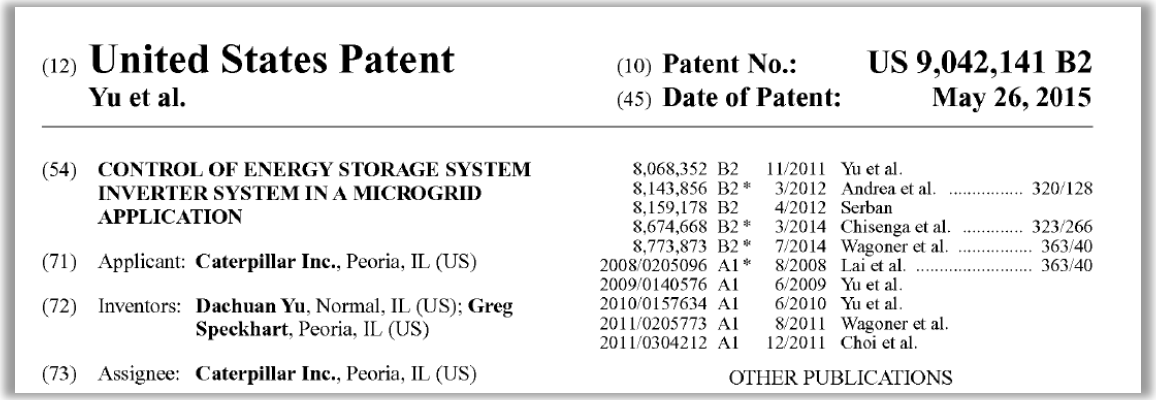
- **Customer Benefit**
  - Fuel Saving
  - Improved Power Quality

Caterpillar: Non-Confidential

Key Enabling Technologies

- **Non-Linear Droop Based Grid Forming Inverter**
  - Patent #: 9,042,141: Control of Energy Storage System Inverter System in Microgrid Application, 2015
  - Patent #: 9,722,445: Control of Hybrid Energy Storage System for High Pulse Load, 2017
  - Patent #: 8, 068,352: Power Inverter Control for Grid-tie Transition, 2011
- **Seamless Mode Transfer**





(12) **United States Patent**
Yu et al.

(10) **Patent No.: US 9,042,141 B2**
(45) **Date of Patent: May 26, 2015**

(54) **CONTROL OF ENERGY STORAGE SYSTEM INVERTER SYSTEM IN A MICROGRID APPLICATION**

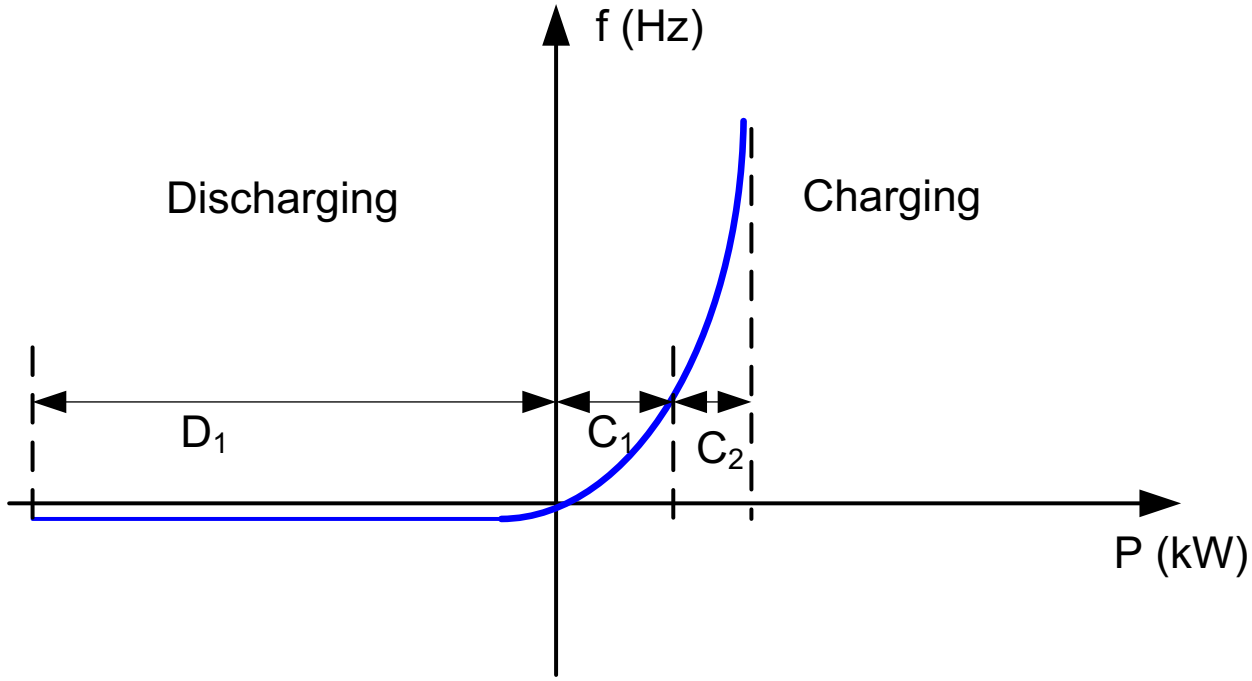
(71) Applicant: **Caterpillar Inc.**, Peoria, IL (US)

(72) Inventors: **Dachuan Yu**, Normal, IL (US); **Greg Speckhart**, Peoria, IL (US)

(73) Assignee: **Caterpillar Inc.**, Peoria, IL (US)

8,068,352	B2	11/2011	Yu et al.	
8,143,856	B2 *	3/2012	Andrea et al.	320/128
8,159,178	B2	4/2012	Serban	
8,674,668	B2 *	3/2014	Chisenga et al.	323/266
8,773,873	B2 *	7/2014	Wagoner et al.	363/40
2008/0205096	A1 *	8/2008	Lai et al.	363/40
2009/0140576	A1	6/2009	Yu et al.	
2010/0157634	A1	6/2010	Yu et al.	
2011/0205773	A1	8/2011	Wagoner et al.	
2011/0304212	A1	12/2011	Choi et al.	

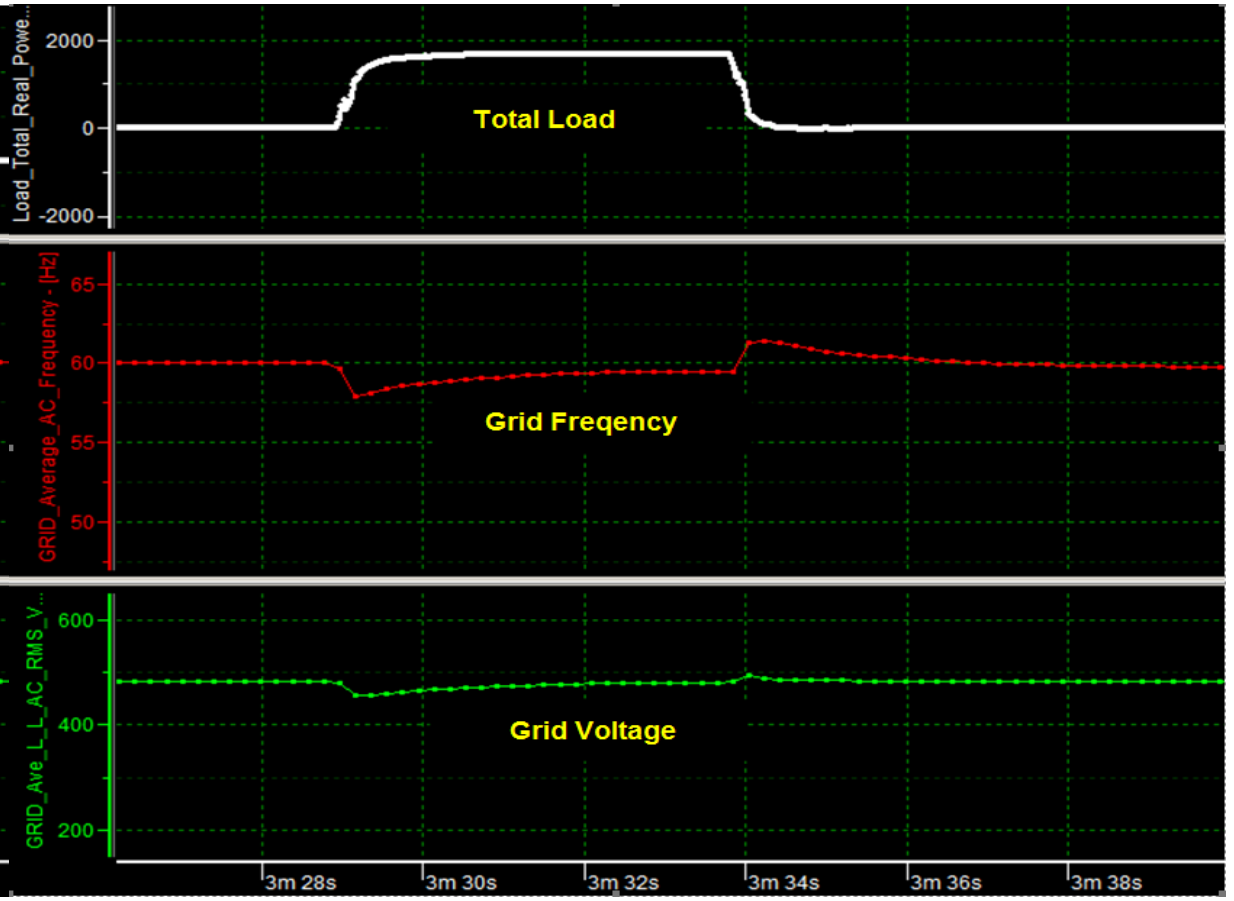
OTHER PUBLICATIONS



Caterpillar: Non-Confidential

ESS Feature: Grid Stabilization

520kW load step on 500kW Genset

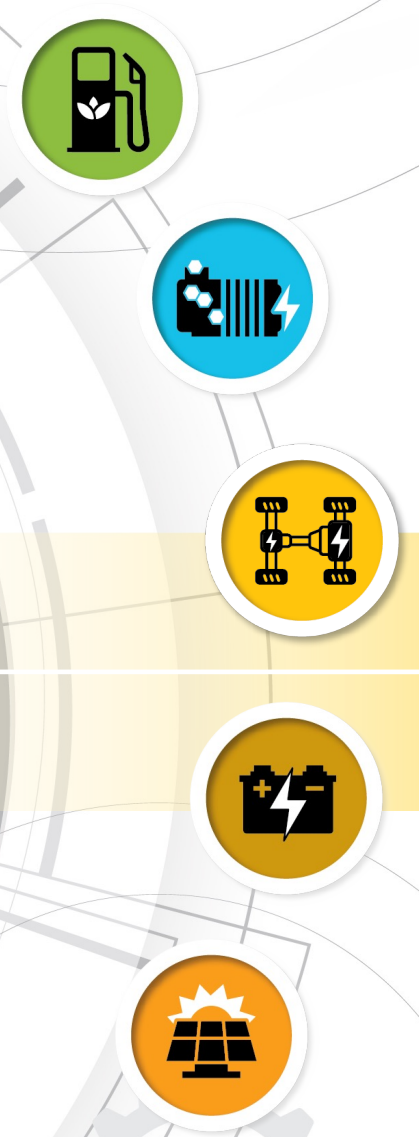


1.5MW load step on 750kW ESS + 500kW Genset

Caterpillar: Non-Confidential

CATERPILLAR®

OUR CUSTOMERS' GOALS.
OUR COMMITMENT.



ADVANCED POWER

© 2022 Caterpillar. All Rights Reserved. CAT, CATERPILLAR, LET'S DO THE WORK, their respective logos, "Caterpillar Corporate Yellow", the "Power Edge" and Cat "Modern Hex" trade dress as well as corporate and product identity used herein, are trademarks of Caterpillar and may not be used without permission.

Thank you for your interest.

Dr. Dachuan Yu
Email: Yu_Dachuan@Cat.com

Phone: 309-578-0103
PSMA Energy Management Committee/IS18

Caterpillar: Non-Confidential