Enabling Sustainable and Reliable Energy Options for Mining Operations

- With Advanced Controls using a PI Data Platform

Presented by:

Patrick Lee – President

Andy Miller – Finance & Bus. Dev. Advisor

PXiSE Energy Solutions LLC

April 25th, 2018

Conference Theme & Keywords

Outline

- Introduction
- Energy & Electricity in the Mining Industry
- Global Trends in Energy Production, Delivery and Use
- The Clean Energy Transition
- Challenges to Adopting Cleaner and More Distributed Resources
- Mining Business and Operational Challenges
- Advantages of GPS-based Technology
- New Energy Technologies Applicable for Mining and Metal
- Energy Options for Connected and Remote Mining Sites

Who is PXiSE Energy Solutions

- **PXiSE is a wholly owned Indirect subsidiary of Sempra Energy**

- **Technology joint-developed by Sempra and OSIsoft, advantaged by an OSIsoft OEM partnership**

Sempra Energy®

- Fortune 300 company
- 2017 revenues of approximately $11B
- 20,000 employees worldwide
- 43 million customers served worldwide

UTILITIES

SDGE connected
San Diego Gas & Electric
- 3.5 million consumers
- 4,100 sq. mile service territory

Southern California Gas Company
Southern California Gas Co
- Largest U.S. gas utility
- 20 million customers
- 20,000 sq. mile service territory

ONCOR
Oncor
- Largest electric transmission & distribution provider in Texas
- 10 million consumers

CHILQUINTA energia **LUZ DEL SUR**
Latin America Utilities
- Electric utilities in Chile and Peru

INFRASTRUCTURE

Sempra® LNG & Midstream
Sempra LNG & Midstream
- U.S. natural gas infrastructure
- LNG terminals

Sempra® Renewables
Sempra Renewables
- Renewable energy generation
- Energy storage
- Distributed generation

IEnova®
IEnova (Mexico)
- Gas Pipelines and Distribution
- Power Generation

PXiSE
PXiSE Energy Solutions

Introduction to Speaker

- **Patrick Lee**
- President - PXiSE Energy Solutions LLC
- Vice President - Sempra Infrastructure
- Patrick.lee@pxise.com

"Over 30 years of hand-on experience in electric generation, transmission, distribution, and end-use technologies"

https://www.linkedin.com/in/patrick-t-lee-53547415/

Introduction to Speaker

- **Andy Miller**
- Finance and Bus. Dev. Advisor
- Andy.miller@pxise.com

What is PXiSE Energy Solutions

P≡SE
Energy Solutions, LLC

PXiSE offers software-based intelligent energy and electric grid solutions to integrate and control any type and size of energy resource. Beyond the use of only traditional electric measurement data, PXiSE adopts high-speed synchro-phasor measurement data into its solutions, thereby enabling a high percentage of renewables integration and differentiated intelligence to improve asset and grid-wide efficiency and reliability.

CHALLENGE

Traditional control technology is slow, coordinates resources poorly, and involves longer more complex integration & maintenance

- System instability under more dynamic grid conditions
- Cap on amount of renewables that can be reliably integrated
- Increased fuel consumption for fossil generations
- Increased system Capex & Opex

SOLUTION

PXiSE ACT: A new GPS-based advanced control solution with built-in PI data platform

- Standardized & distributed high-speed sensors with new insights (PMUs)
- Real-time advanced feedback control, predicative models, and optimization
- Proven data platform (OSIsoft PI)
- Hardware agnostic, fast & simple integration & maintenance

RESULTS

PXiSE ACT: coordinates any mix of resources precisely & simultaneously at high-speed, enabling optimal electric system efficiency & reliability
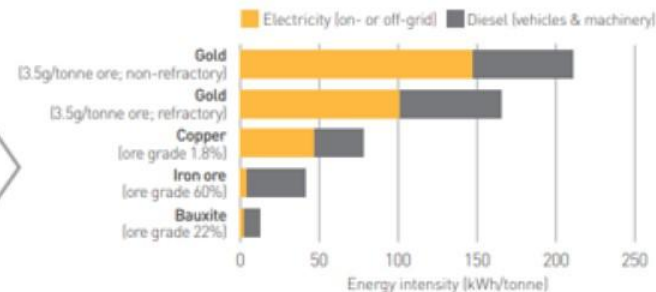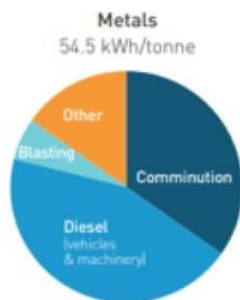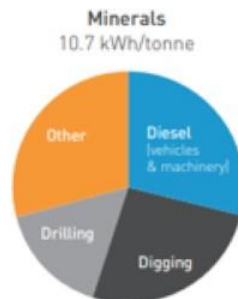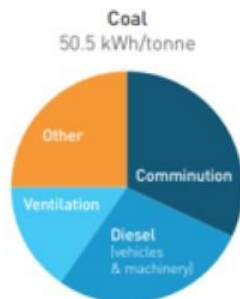
- Enhanced grid stability
- Remove cap on renewables production
- Decreased fuel consumption for fossil generations
- Decreased system Capex & Opex

Energy and electricity is a big cost driver for the mining industry

Mining Electric Consumption

Mining Electric Price Range

- <$0.10/kWh for grid electricity

- $0.15/kWh–$0.30/kWh (after rebates) for electricity derived from off-grid diesel or gas

Coal
50.5 kWh/tonne

- Other
- Comminution
- Ventilation
- Diesel (vehicles & machinery)

Minerals
10.7 kWh/tonne

- Other
- Diesel (vehicles & machinery)
- Drilling
- Digging

Metals
54.5 kWh/tonne

- Other
- Blasting
- Comminution
- Diesel (vehicles & machinery)

■ Electricity (on- or off-grid)   ■ Diesel (vehicles & machinery)

- Gold (3.5g/tonne ore; non-refractory)
- Gold (3.5g/tonne ore; refractory)
- Copper (ore grade 1.8%)
- Iron ore (ore grade 60%)
- Bauxite (ore grade 22%)

Energy intensity (kWh/tonne)
0   50   100   150   200   250

Global Trends in Energy Production Significantly Impact Delivery and Use

Adoption of more renewable resources

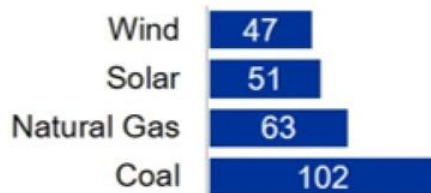- Solar PV
- Wind
- Bio-Fuel
- Geo-Thermal

Shift from centralized to distributed resources

- Rooftop Solar
- Energy Storage
- Fuel Cell
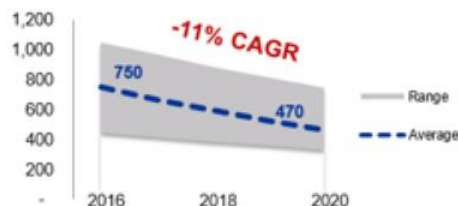- Micro-turbines

The Clean Energy Transition is Progressing

Renewables Pricing

Unsubsidized Levelized Cost ($/MWh)[1]

Wind	47
Solar	51
Natural Gas	63
Coal	102

Battery Cost Trends

Lithium-ion battery install cost ($/kWh)[2]

Distributed Generation

- Centralized generation economies-of-scale cost advantage threatened by distributed energy resources (DERs) mass-production economies-of-scale
- Increasingly competitive pricing at point of consumption
- Consumer choice advocacy towards self-generation

Policy Drivers

- Governments pursuing aggressive RPS standards & renewable targets
- Germany 80% by 2050; CA & Hawaii 100% by 2045; India 175 GW renewable energy target by 2022

Challenges to Adopting Cleaner & More Distributed Resources

- Limited capabilities of legacy power controls
- Designed for centralized fossil generation, not keeping pace, and inadequate to integrate distributed and renewable resources

Unnecessary High Cost for Asset Owners   **Poor System Reliability Performance**

1. Slow and **poor utilization & coordination** of energy assets due to limitations of legacy sensor & control technology **leaves value trapped**

2. Traditional control methods **cannot integrate high % of renewables** effectively, forcing a **reliance on fossil fuel** generation and oversizing of assets

Mining Operations Challenged to Achieve Sustainable and Reliable Energy Use

- Building an energy delivery system to mine sites could be costly , difficult, and take a long time. This impacts project economics in constructing green field and/or expanding existing mines
  - Environmental concerns and long permitting process
  - High cost of construction and reliance on utility supply
- Choices of on-site generation could be limiting
  - Fossil fuel price volatility and logistics have a significant impact on mining viability but are outside the control of most miners
  - Renewables integration and control technology limitations
- No clear alternatives to meet sustainability and green requirements of projects

Current Energy Solutions Are Inadequate

- Most solutions focus on solving narrowly defined problems associated
  - Aggregating energy resource using virtual power plant concept
  - Addressing voltage problems with specific hardware equipment
- A new system thinking and comprehensive solution is needed to address the complex and dynamic changes in a modern grid

Other Industries Have Adopted GPS-based Solutions
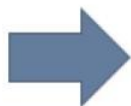
MILITARY
From Morse Code communication

To a coordinated system with time-synchronized operation of air, land, and sea resources
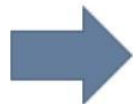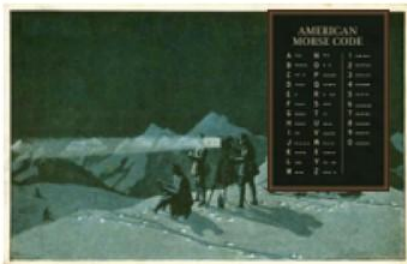
GPS with Enabling Technologies

TRANSPORTATION
From 1x1 local taxi solution

To a system solution for network transportation

GPS with Enabling Technologies

A Magnitude Measurement Has Limited Information
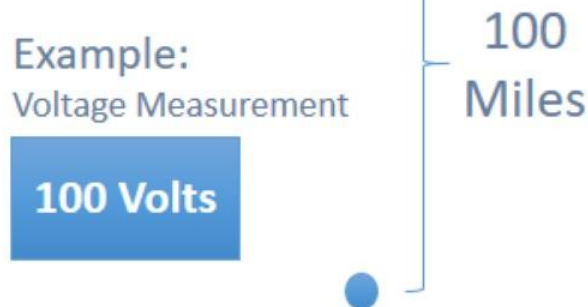
A GPS-based Vector Measurement Offers More Insights

N

Example:
Voltage Measurement

100 Miles

| 100 Volts |

Example:
Voltage Phasor

100 Miles

| 100 Volts At 90° |
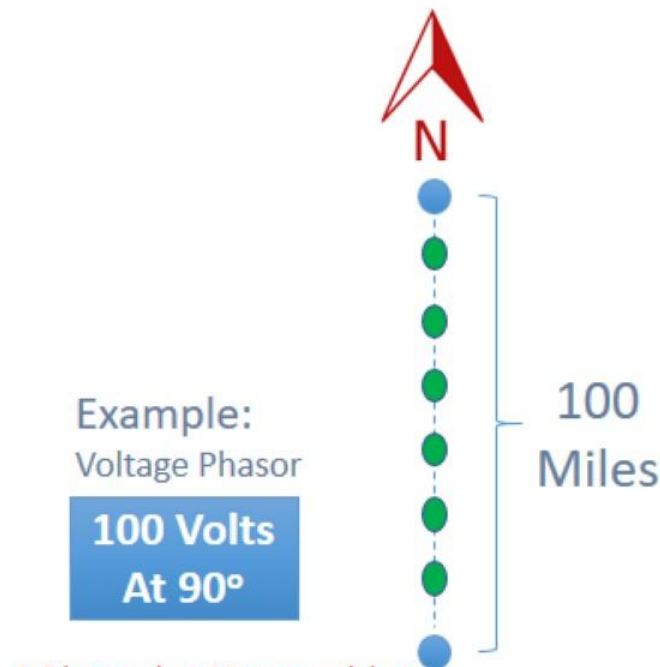
A Phasor is a Vector with a magnitude & direction
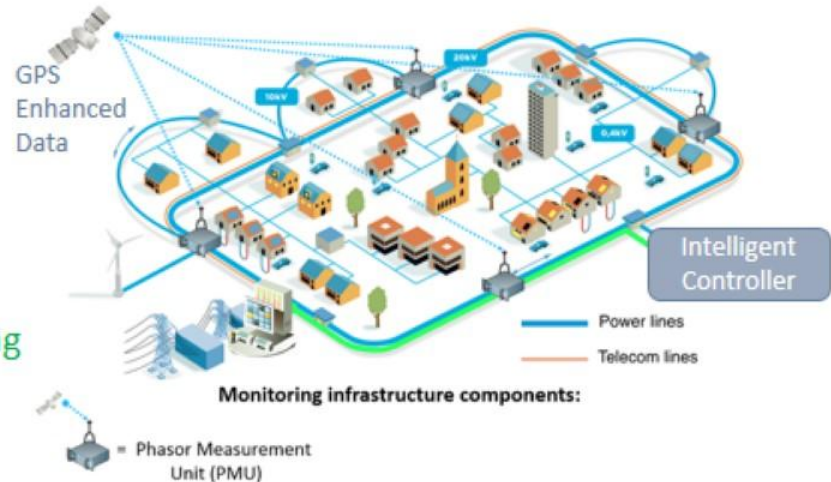
Electric Grids Can Benefit from GPS-based Solutions

From sub-optimally coordinated generation resources

To a system solution optimized for any mix of renewables, storage, and conventional resources

GPS Enhanced Data

GPS with Enabling Technologies

Intelligent Controller

Power lines

Telecom lines

Monitoring infrastructure components:
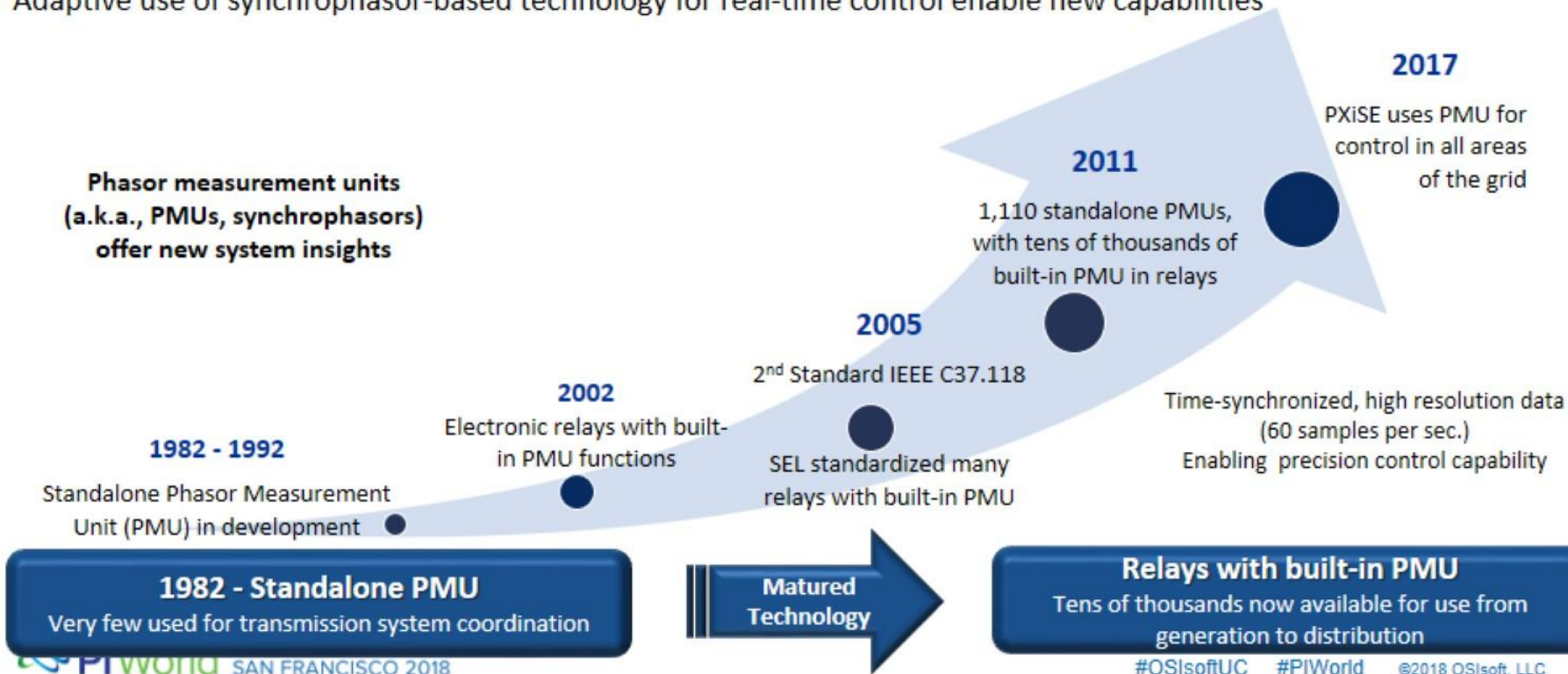
= Phasor Measurement Unit (PMU)

Invented in 1980s

Why Is GPS-based Electric Grid Technology Possible Now?

Previously un-tapped data is now available

Adaptive use of synchrophasor-based technology for real-time control enable new capabilities

Phasor measurement units (a.k.a., PMUs, synchrophasors) offer new system insights

2017

PXiSE uses PMU for control in all areas of the grid

2011

1,110 standalone PMUs, with tens of thousands of built-in PMU in relays

2005

2nd Standard IEEE C37.118

2002

Electronic relays with built-in PMU functions

SEL standardized many relays with built-in PMU

Time-synchronized, high resolution data (60 samples per sec.) Enabling precision control capability

1982 - 1992

Standalone Phasor Measurement Unit (PMU) in development

1982 - Standalone PMU
Very few used for transmission system coordination

Matured Technology

Relays with built-in PMU
Tens of thousands now available for use from generation to distribution

Taking Advantages of GPS-based Technology

The solution: Combining Relevant Enabling Technologies

Innovations

Standardized & Distributed High-Speed Sensors with New Insights (Phasor Measurements)

Advanced Feedback Control , Predictive Models, & Optimization Tools

New Capabilities

Solved intermittency problem with high % renewables integration

Addressed Coordination of many DERs with time-synchronized control

Creating The Advanced Control Technology (ACT)

Multiple enabling technologies integrated to create new control capabilities not possible before

Application of Modern, Broadly Available PMU Data

Time-synchronized, high resolution, and high-speed data management

+

Provides New Capabilities Not Possible Before
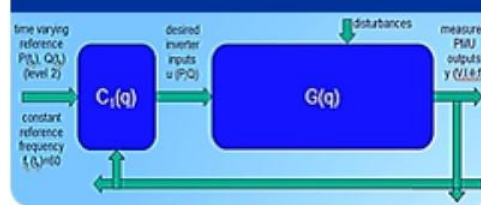
Provides New Capabilities Not Possible Before

+

Provides New Insights Not Available Before

Provides New Insights Not Available Before

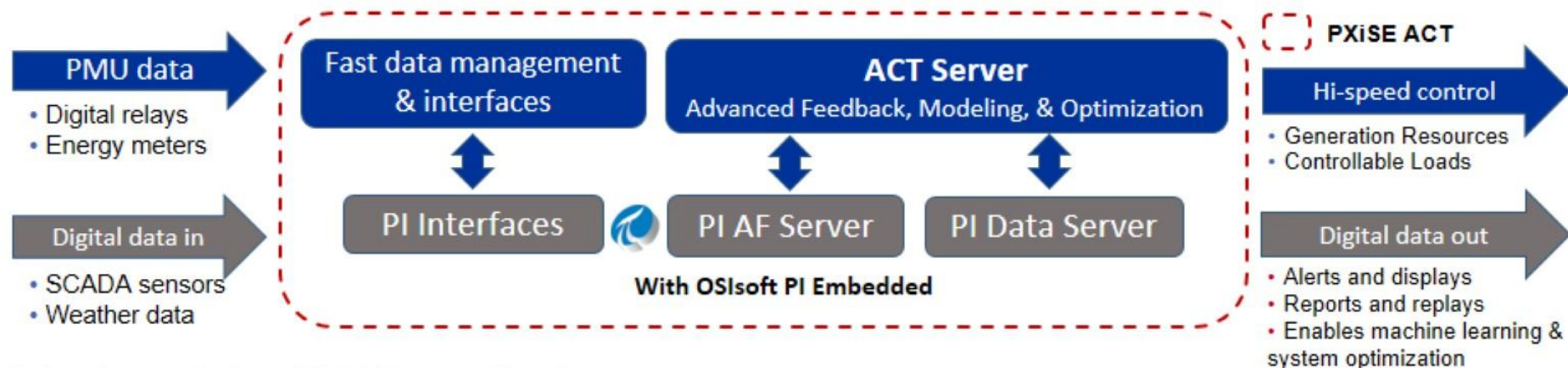**+** **Embedded OSIsoft PI Data Historian** **=** **Advanced Control Technology (ACT)**

* High-speed data function available in existing substation equipment; phasor measurement units (PMUs) are broadly available today

Inside the Advanced Control Technology (ACT)

1. Integrated on a Proven Data Platform (Function Like an Intelligent High-speed (SCADA)

PMU data
- Digital relays
- Energy meters

Digital data in
- SCADA sensors
- Weather data

Fast data management & interfaces

ACT Server
Advanced Feedback, Modeling, & Optimization

PXiSE ACT

Hi-speed control
- Generation Resources
- Controllable Loads

PI Interfaces   **PI AF Server**   **PI Data Server**

With OSIsoft PI Embedded

Digital data out
- Alerts and displays
- Reports and replays
- Enables machine learning & system optimization

2. Implemented on Field Proven Hardware

Example hardware:
- Industrial computer (SEL 3355)
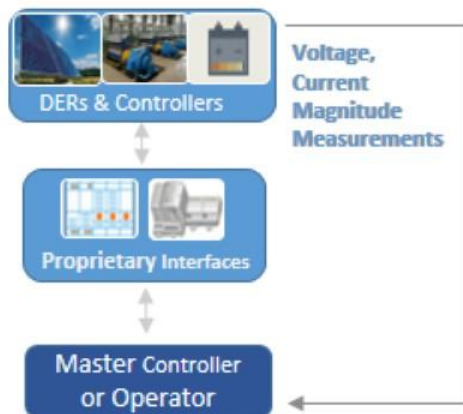- Dell / HP Server

3. Software Designed for Fast Field Implementation
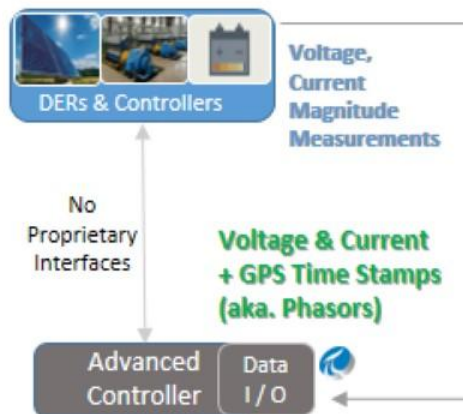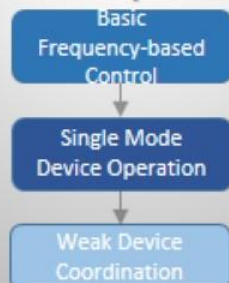
GPS-based Control Technology Offers Superior Capabilities
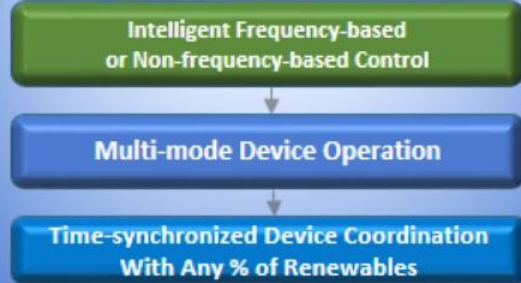

Others Use
Magnitude-based Control

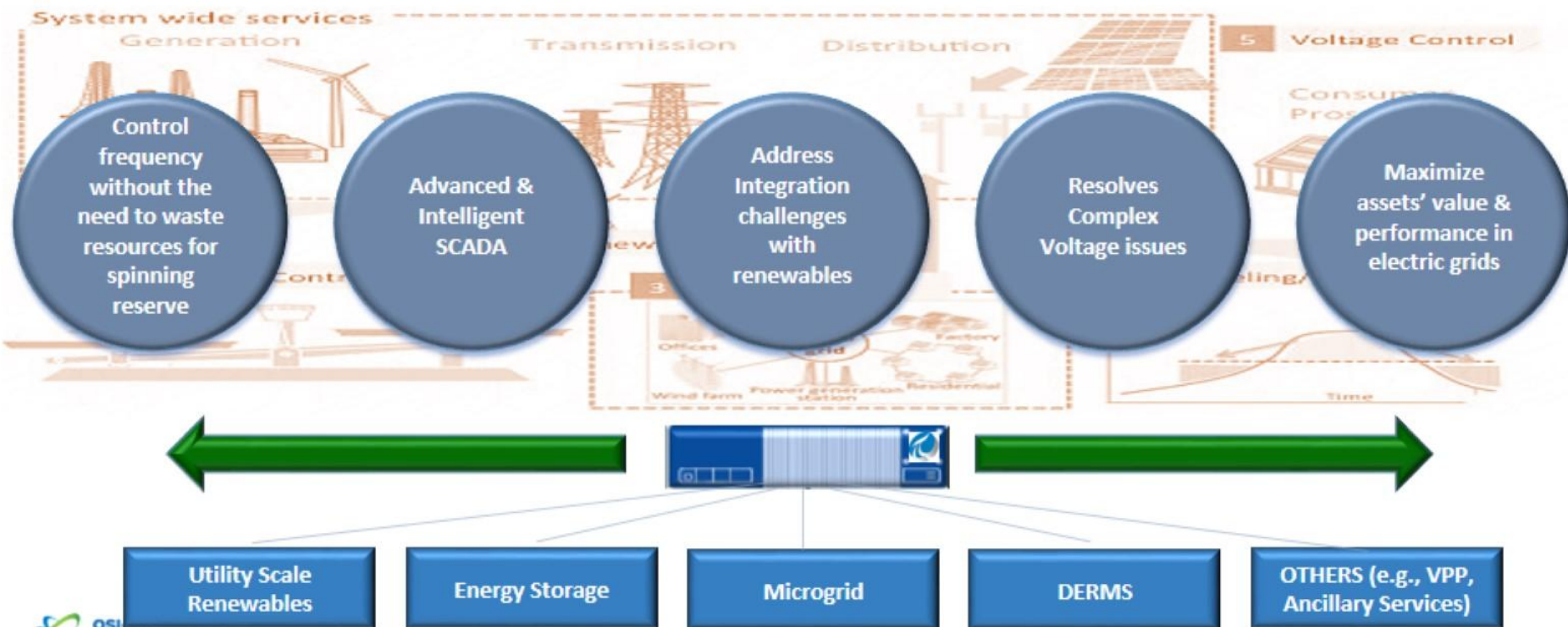**PXiSE Offers**
Vector-based Control

key Differentiating Capabilities of ACT

Combines standardized, distributed, high-speed sensors with proprietary power system intelligence to enable precise multi-objective control of energy resources to extract maximum asset value & attain high % renewables penetration

	Advanced Control Technology	Legacy Control
CONTROL CAPABILITIES	• Frequency-based to operate current grid with large inertia • Non-Frequency-based to operate dynamic grids with up to 100% renewables • Simultaneously precision control of Real & Reactive Power maximizing benefits of an energy asset	• Frequency-based to operate current grid with large inertia • Control of Real Power and Reactive Power separately resulting in higher capital and O&M costs in owning additional energy assets
MIXED ASSETS OPTIMIZATION & OPERATIONS	• Time-synchronized coordination of a dynamic mix of energy assets to achieve an optimal system level performance • Tailored control of energy assets according to its speed and capacity	• Poor coordination of a dynamic mix of energy assets resulting in lower operational efficiency

Broad Applications in the Electric Grid

Precisely coordinates and synchronizes the control of many energy assets from utility system to end-use

Control frequency without the need to waste resources for spinning reserve

Advanced & Intelligent SCADA

Address Integration challenges with renewables

Resolves Complex Voltage issues

Maximize assets' value & performance in electric grids

Utility Scale Renewables

Energy Storage

Microgrid

DERMS

OTHERS (e.g., VPP, Ancillary Services)

ACT-Enabled Energy Storage Has Differentiation Capabilities

Real & Reactive Power Optimization

- Power Balancing and Ancillary Services
- Mitigate Volatility of Renewable Energy
- High-power Output Shaping

Real & Reactive Energy Optimization

- Bulk Storage / Energy Shifting
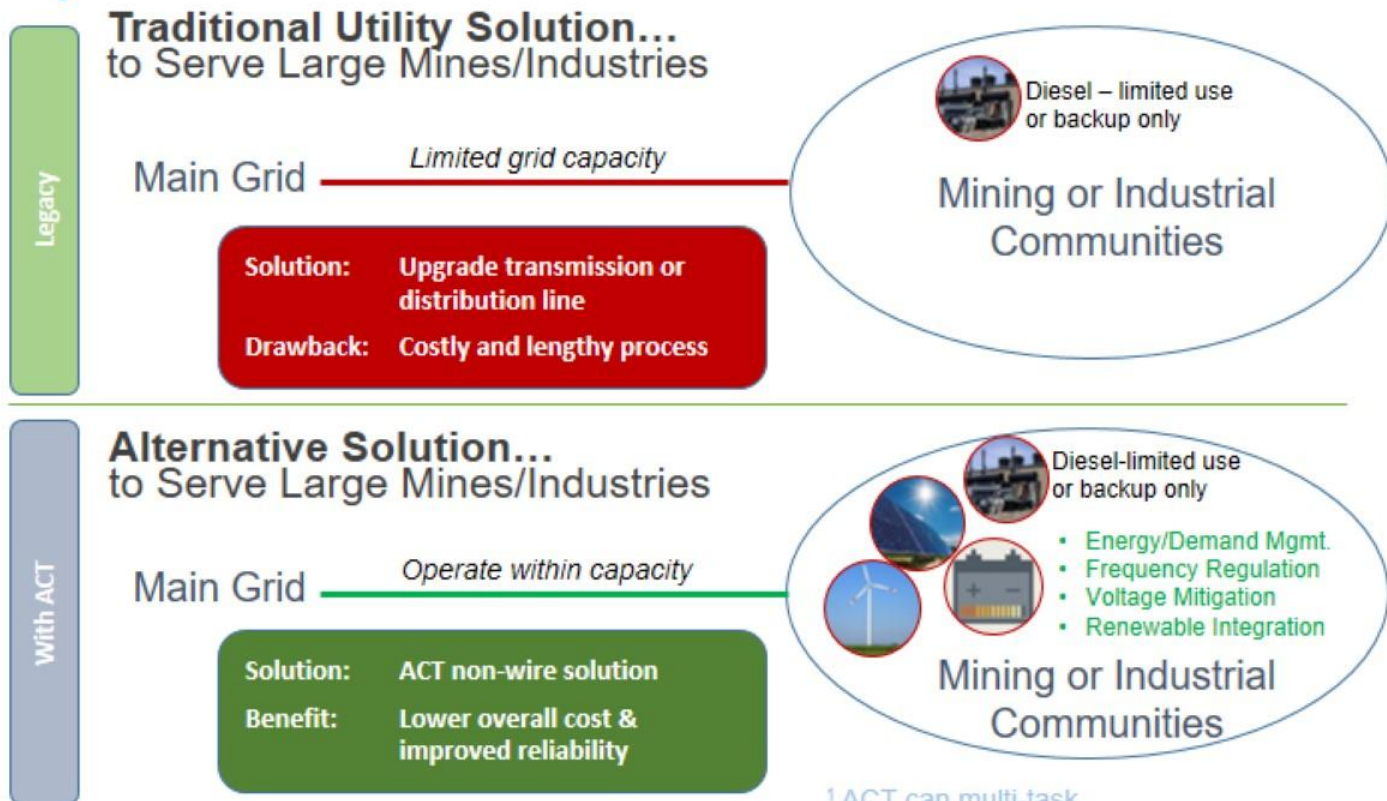- Power Factor Management
- Predicted Energy Schedule

ACT- enabled storage has full-time Multi-mode Optimization and Operation

ACT Enables Maximum Value of Energy Storage in Mining & Metal Operations

DER electricity sales	DER energy market participation (aggregation)
Demand response	Demand response participation
Energy market services	Access regulation and frequency markets
Surplus sales	Revenue from excess green electricity

INCOME OPPORTUNITY

Demand reduction	Reduce demand charge and energy cost through real-time optimization of energy storage to lower energy bill
TOU energy shifting	
PF Penalty Avoidance	Manage Power Factor to avoid penalties
Power Quality	Mitigate intermittency from renewables & operations
Service Reliability	Seamless islanding and reconnection to main grid to enhance reliability

COST AND RELIABILITY BENEFITS

An Alternative Solution to Serve a **Connected** Mining or Industrial Community

Legacy

Traditional Utility Solution…
to Serve Large Mines/Industries

Main Grid —— *Limited grid capacity* ——

Solution:	Upgrade transmission or distribution line
Drawback:	Costly and lengthy process

Diesel – limited use or backup only

Mining or Industrial Communities

With ACT

Alternative Solution…
to Serve Large Mines/Industries

Main Grid —— *Operate within capacity* ——

Solution:	ACT non-wire solution
Benefit:	Lower overall cost & improved reliability

Diesel-limited use or backup only

- Energy/Demand Mgmt.
- Frequency Regulation
- Voltage Mitigation
- Renewable Integration

Mining or Industrial Communities

[1] ACT can multi-task

An Alternative Solution to Serve a **Remote** Mining or Industrial Community

Traditional

Traditional Solution…
to Serve Remote Mines/Industries

Solution:	Fossil fuel electric generation with small % of renewables
Drawback:	Costly and limited reliability due to poor control performance

Integrate up to 30% of renewable generations

Diesel – many operating and backup units to provide electric supply

Remote Mining or Industrial Communities

With ACT

Alternative Solution…
to Serve Remote Mines/Industries

|	
Solution:	ACT microgrid solution
Benefit:	Achieve lowest cost of energy production, maximize low-cost renewables, minimize fossil fuel and emission; high reliability with fast battery to regulate grid

Diesel – limited use or backup only

- Maximize low cost renewables
- Improve reliability

Remote Mining or Industrial Communities

[1] ACT can multi-task

ACT Enables Mining Microgrids with 4 Levels of Control to Achieve Maximum Assets Value
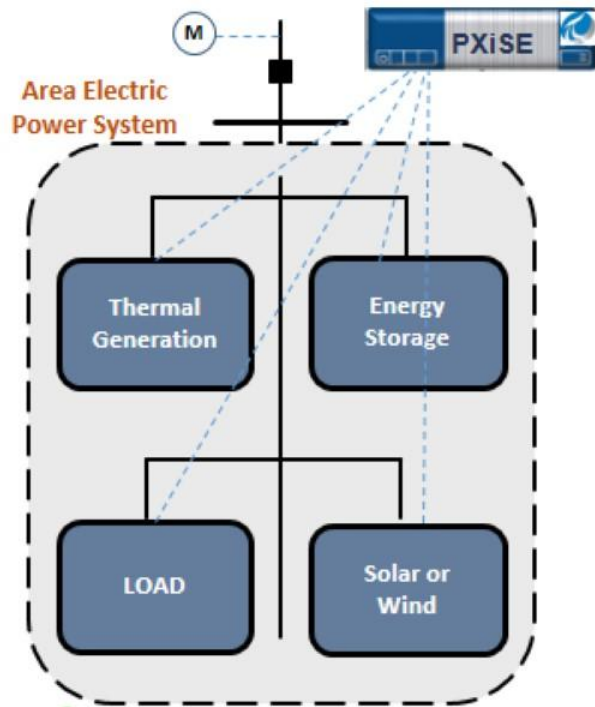
Level	Description
Grid-Interactive	Area Electric Power System Control, Electricity Markets, DMS Interaction, Distribution System Interaction, SCADA Functions
Supervisory EMS	Generation and Load Dispatch, Optimization (Voltage Profile, Economic), Spinning Reserve, Reconfiguration, Black Start, Protection Coordination, Forecasting, Data Management and Visualization
Local Area	Load Management, Energy Management, Automatic Generation Control, Fast Load Shedding, Disconnection, Resynchronization
Device Level	Voltage/Frequency Control, Current/Power Control, Reactive Power Control, Generation Control, Load Control, Energy Storage Control, Islanding Detection, Fault Detection and Protection

Demonstrated Operational Value with ACT + Battery
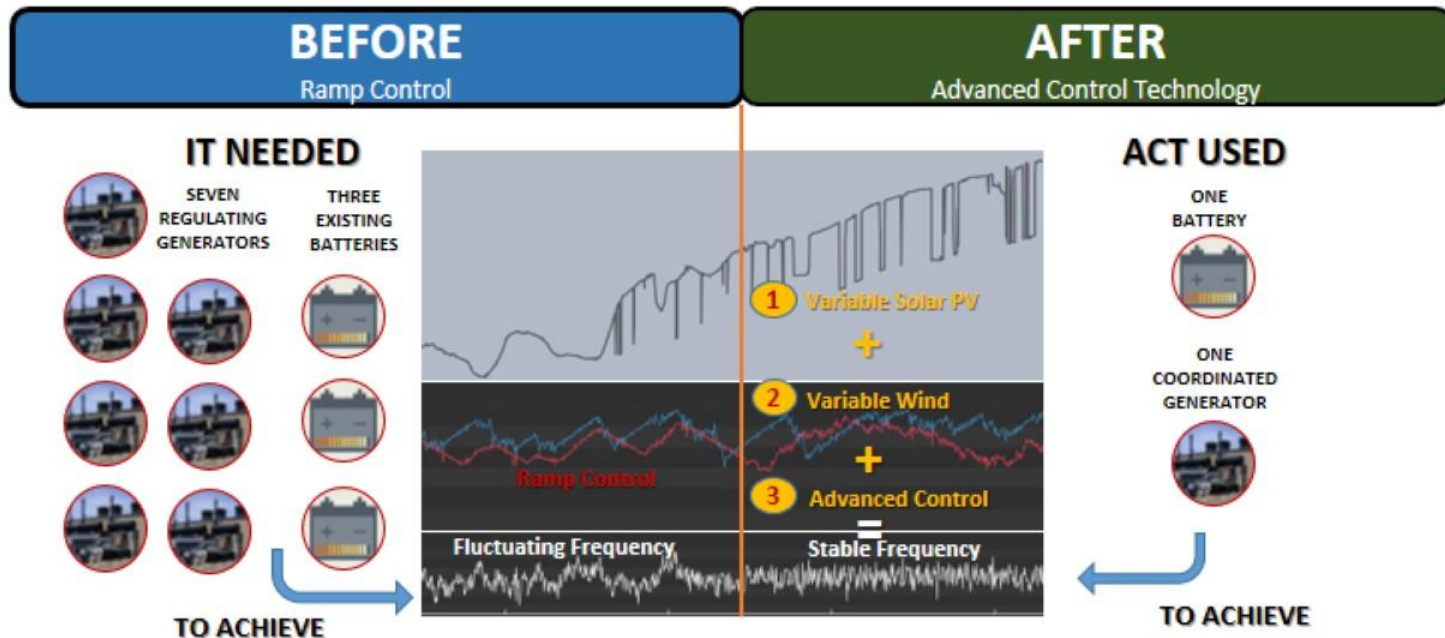
Value to a Remote Grid:

1. Reduce generator capital, O&M, and fuel costs
2. Enable an increase of renewable mix to lower energy cost

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Remote Mine Sites Opportunities with ACT + Battery to Optimize Power Generation

BEFORE
Traditional Control

➤ A mix of generators at a remote mine site running with a spinning reserve
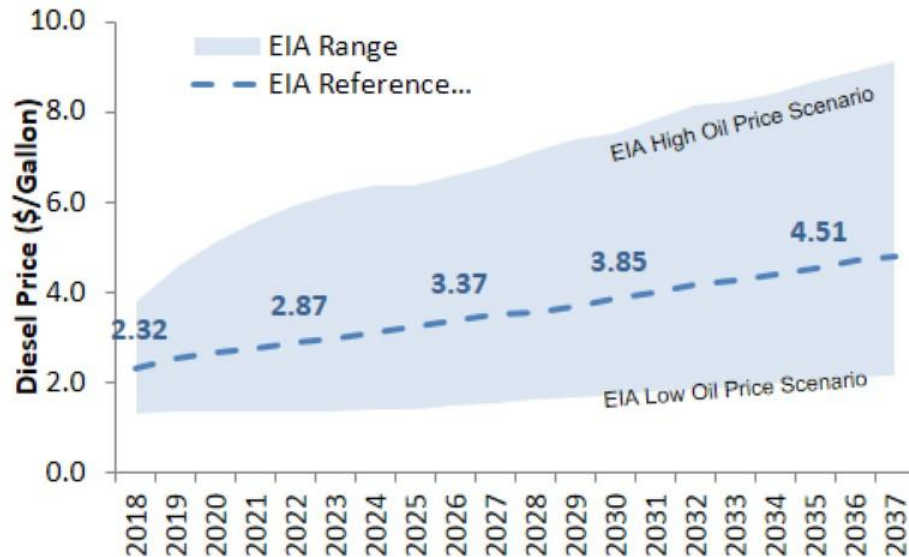
AFTER
Advanced Frequency Control

ACT

➤ ACT+Battery enable lower performance generators on-site to be on stand-by
➤ Maximize generators loading with higher operating efficiency
➤ Lower fuel use overall
➤ Lower O&M costs of generators

Diesel Fuel Price

Fuel prices increasing and becoming more volatile[1]

EIA Range
EIA Reference...

EIA High Oil Price Scenario

2.32   2.87   3.37   3.85   4.51

EIA Low Oil Price Scenario

Diesel Price ($/Gallon)

2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037

Electricity Cost =
$0.25 – $0.35 per KWh

Fuel price volatility leads to electric rate volatility which is a significant pain point for isolated electric grids

1) EIA Annual Energy Outlook 2017

Case Study of a 25MW Peak Load Isolated Grid Depended Primarily on Diesel Generation

ACT + Small Battery Value Streams

- Peak shaving
- Grid balancing
  - Frequency Regulation
  - Spinning reserve
- Power quality management
- Optimal resource dispatch

Grid Operating Performance

- 5% heat rate improvement = ~535,000 gallons of fuel saved a year
- 15% reduction in run hours on diesel generation units = ~10,000 less run hours a year
- Enhanced grid stability

Economic Benefits

Reduced fuel cost
- Year 1 = ~$1.25M
- 15yr Avg = ~$1.7M/yr
- Decrease exposure to fuel price volatility

O&M Savings
- ~$0.2M/yr

More efficient capital allocation

Advanced GPS-base Control Offers Sustainable and Reliable Energy Options for Mining Operations

Achieve Corporate Sustainability and Green Objectives

Implement cost effective energy solutions in urban & remote sites

Balance project site selection, energy choices, & time to market objectives

Questions

Please wait for the **microphone** before asking your questions

State your **name & company**

Please remember to…

Complete the Online Survey for this session

Merci

谢谢

Спасибо

Danke

Gracias

Thank You

감사합니다

ありがとう

Grazie

Obrigado

PXiSE Energy Solutions, Patrick Lee