Sempra Energy®

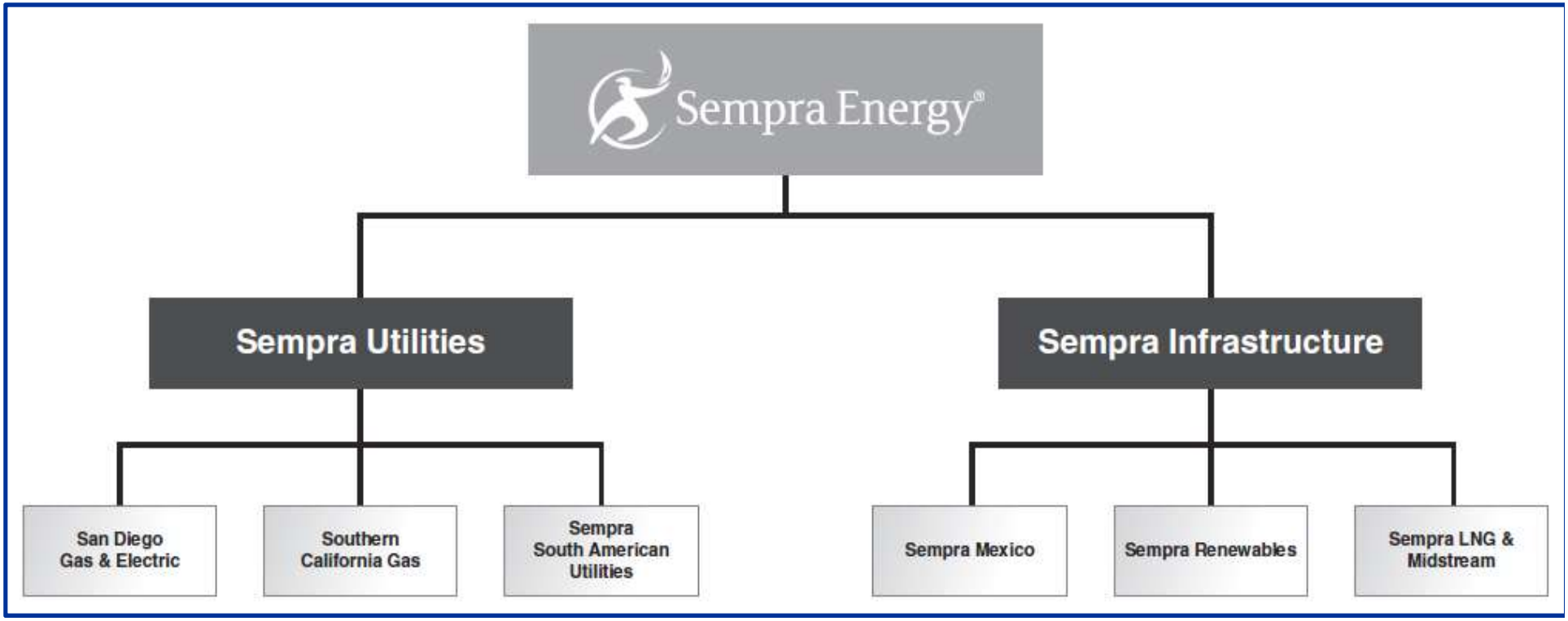
PXiSE Energy Solutions

Advanced Control Technology: Enabling the Electric Grid of the Future

August 2017

PXiSE Energy Solutions, LLC is not the same company as the California utilities, San Diego Gas & Electric Company (SDG&E) or Southern California Gas Company (SoCalGas), and PXiSE Energy Solutions , LLC is not regulated by the California Public Utilities Commission.

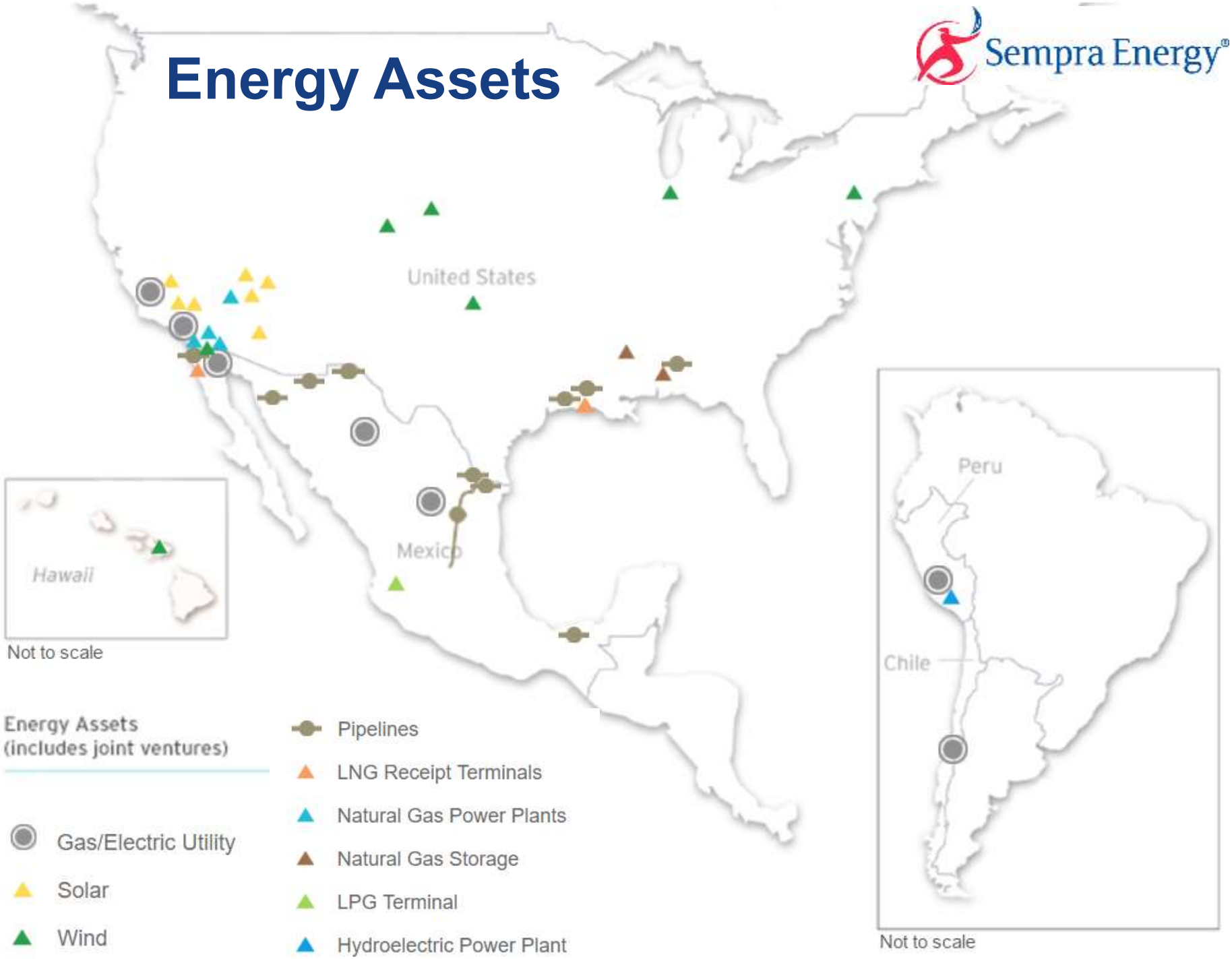
Who we are



- Fortune 500 company – based in San Diego
- 2016 revenues of more than $10 billion
- 17,000 employees worldwide
- 32 million consumers served worldwide

2

Energy Assets



Utility industry is transforming

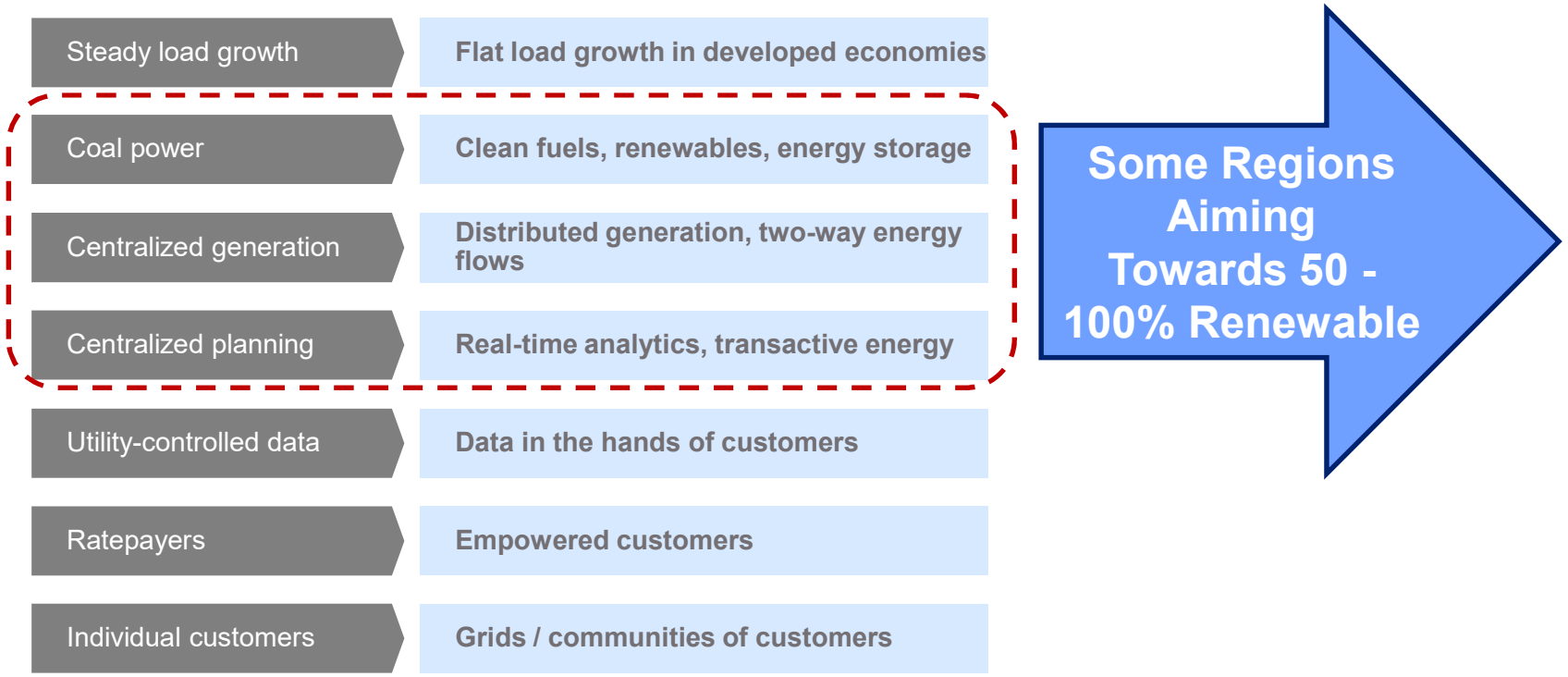
Operational challenges requiring new solutions

What will be required in a new control solution to solve these challenges?

Combining key advanced control technologies as new tools to enable electric grid of the future

Demonstrated benefits for a wide range of applications in an electric grid

Utility industry is transforming



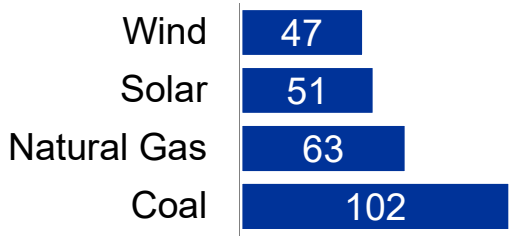
Worldwide increases in renewables and distributed energy resources are changing the electric grid *(economical & social aspects)*

The electric grid is changing…

Significant Growth in Renewables

- **Unsubsidized grid-scale renewables becoming lowest energy cost generation resources**
- Consumers putting significant political pressure on governments to address CO_2 emissions; governments responding with aggressive RPS standards (Germany 80% by 2050; CA 50% by 2030)

Unsubsidized Levelized Cost ($/MWh)[1]



Distributed Electric Grid

- **Centralized generation economies-of-scale cost advantage being threatened by distributed energy resources (DERs) mass-production economies-of-scale**
- Utility planning horizons shrinking from multi-year to semi-annual
- Distributed generation growing 3x of central generation in U.S.
- 60% CAGR for storage capacity expected globally over the next 3 years
- 35% CAGR for microgrid deployments expected globally over the next 8 years

1) Midpoint of levelized cost range per Lazard Research

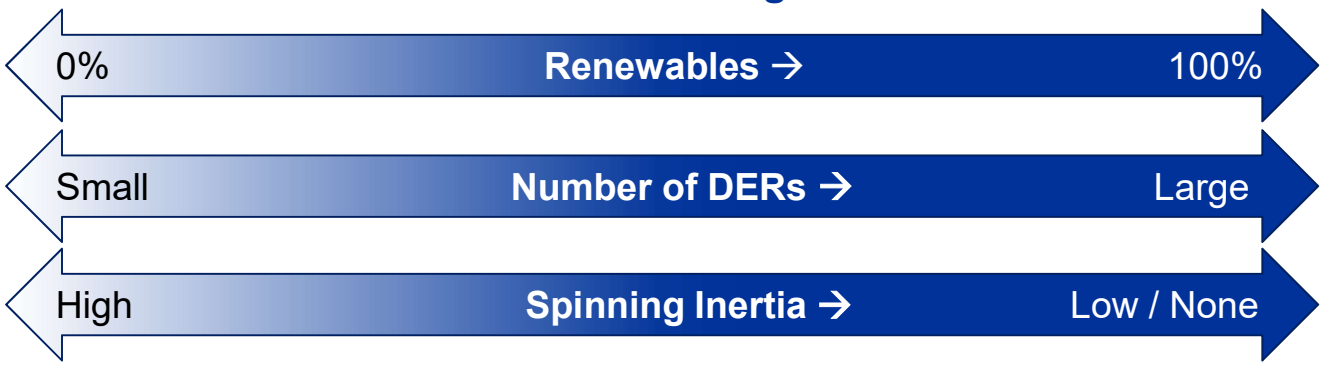
Sources : Lazard Research, Navigant

Worldwide increases in renewables and distributed energy resources are changing the electric grid *(operational aspects)*

…thereby creating new grid challenges

- Low cost but highly intermittent renewables are displacing conventional generation resources, **leaving less available spinning inertia**[1] thus yielding tradition controls less effective
- Proliferation of DERs creating **exponential electric system complexity**, necessitating faster and better system coordination to cost effectively manage grid reliability and power quality

All are trending →→→



1) Traditional generation provides spinning inertia which serves as a shock absorber for the electric grid to maintain stability

Utility industry is transforming

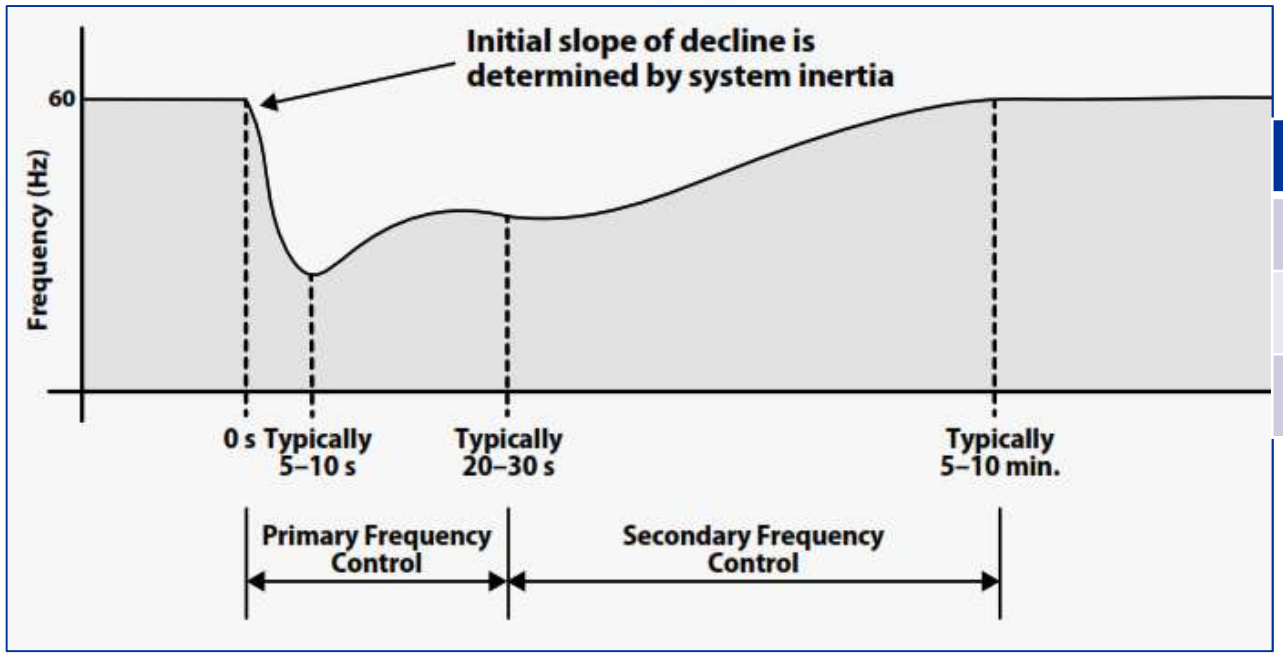
Operational challenges requiring new solutions

What will be required in a new control solution to solve these challenges?

Combining key advanced control technologies as new tools to enable electric grid of the future

Demonstrated benefits for a wide range of applications in an electric grid

Traditional controls use power frequency as the reference signal - System inertia is a key factor for how fast frequency can change



	CAISO	MAUI
Peak Load	40,000MW	200MW
Frequency Response	200MW per 0.1Hz	2.3MW per 0.1Hz
Largest Contingency	~2400 MW	~30 MW

Values approximated for illustration only

Why is timely frequency response important?

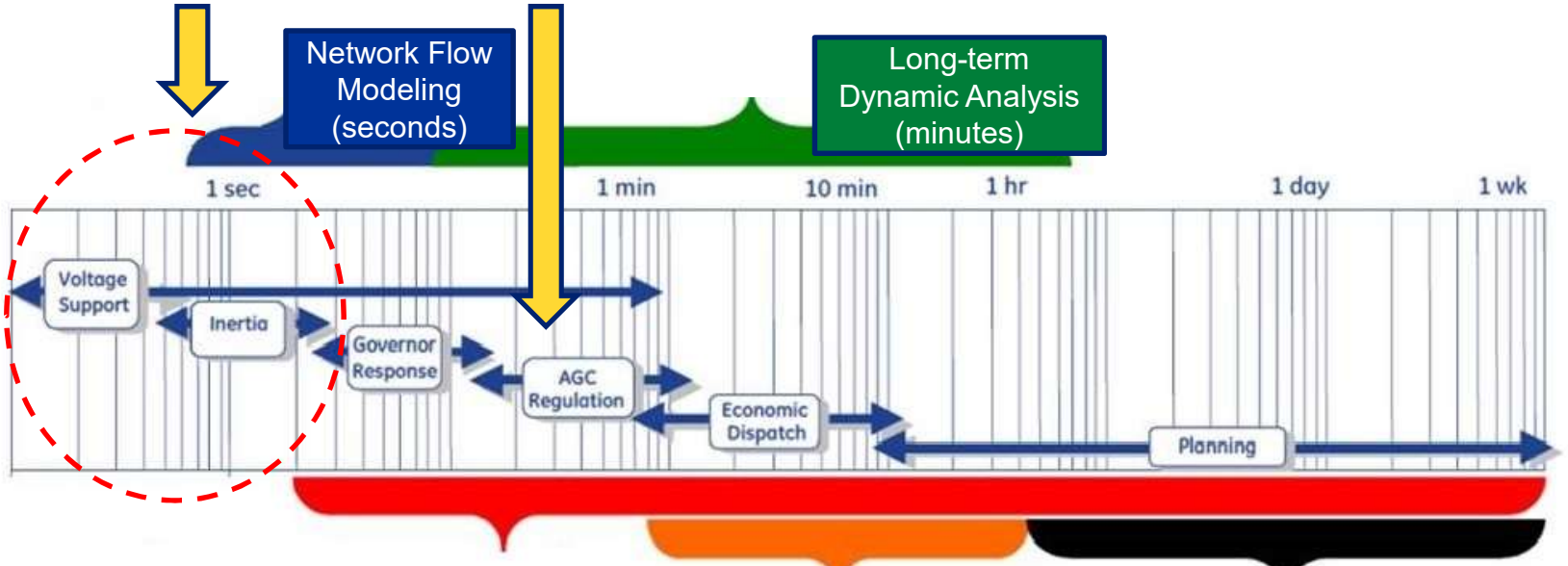
- When a disturbance occurs, the frequency of the electric power system deviates from its scheduled level.
- The frequency must be stabilized and returned to its scheduled level to avoid further reliability issues.

Traditional frequency-based control technology cannot keep up with the fast and dynamic electric grid challenges

Uncoordinated energy storages with fast droop control assumed to be the solution at the moment

Relied on inertia today (no active control)

Generators with droop control are too slow to respond to fast grid changes (worsen as inertia decreases)



Statistical Renewable Variability Assessment (minutes - days)

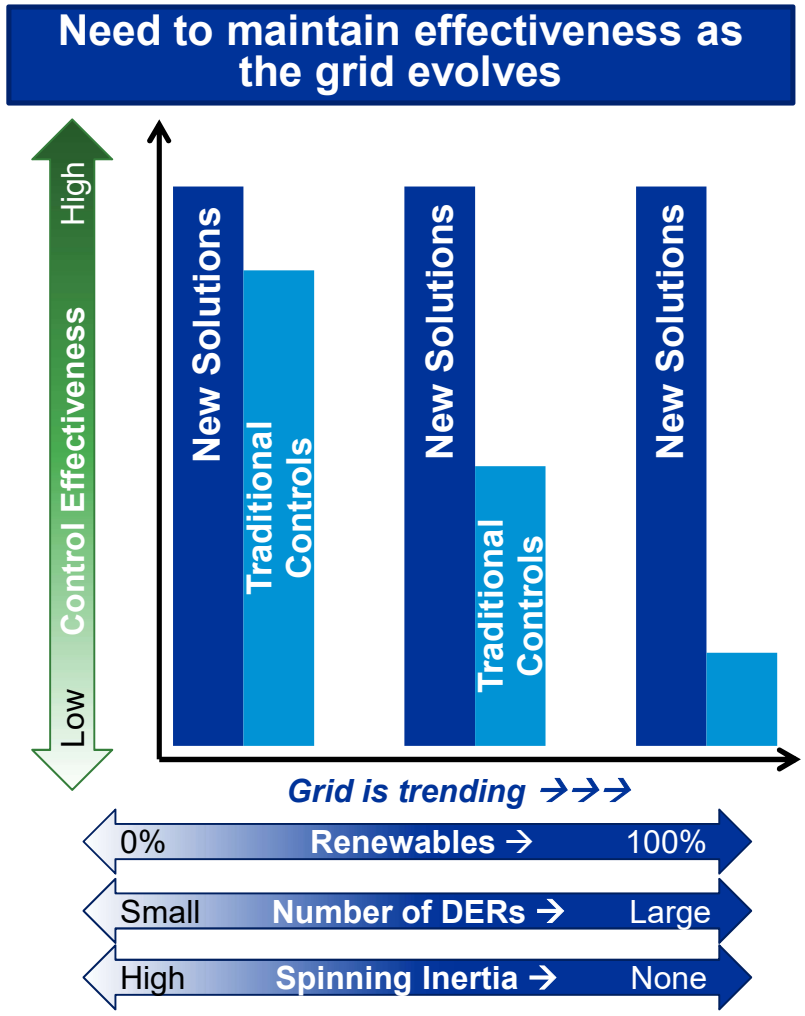
Short-term Renewable Forecast (hours)

Integrated Resources Simulations (days)

Industry needs an advanced control technology to mitigate the major challenges facing the today's electric system

New Solutions to effectively:

1. Manage fast changes of electric supply and demand
2. Address intermittency issues from renewables
3. Actively and precisely control bi-direction energy flow
4. Optimize the utilization of a diverse mix of resources to meet environmental objectives
5. Minimize infrastructure capital and O&M costs in the transition



Utility industry is transforming

Operational challenges requiring new solutions

What will be required in a new control solution to solve these challenges?

Combining key advanced control technologies as new tools to enable electric grid of the future

Demonstrated benefits for a wide range of applications in an electric grid

A well-designed electric control system solution must have specific “desirable characteristics”

Use standards

An advanced control

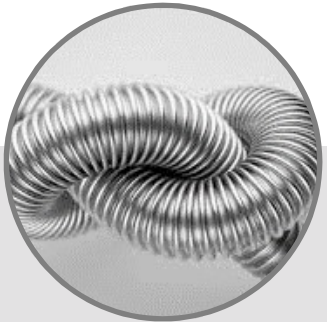
Intelligent

Common hardware

Systematic & robust

Familiar software

Flexible design

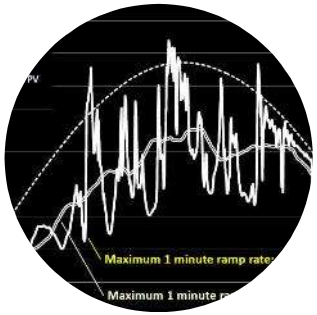


Ease of use

Scalable

A well-designed electric control system solution must have "desirable performance capabilities"

Mitigate disturbances



Address intermittencies

Precision control

Multi-objectives resource optimization

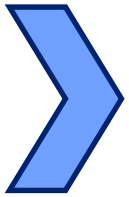
Lower Cost

An efficient and reliable electric grid

Utility industry is transforming

Operational challenges requiring new solutions

What will be required in a new control solution to solve these challenges?



Combining key advanced control technologies as new tools to enable electric grid of the future

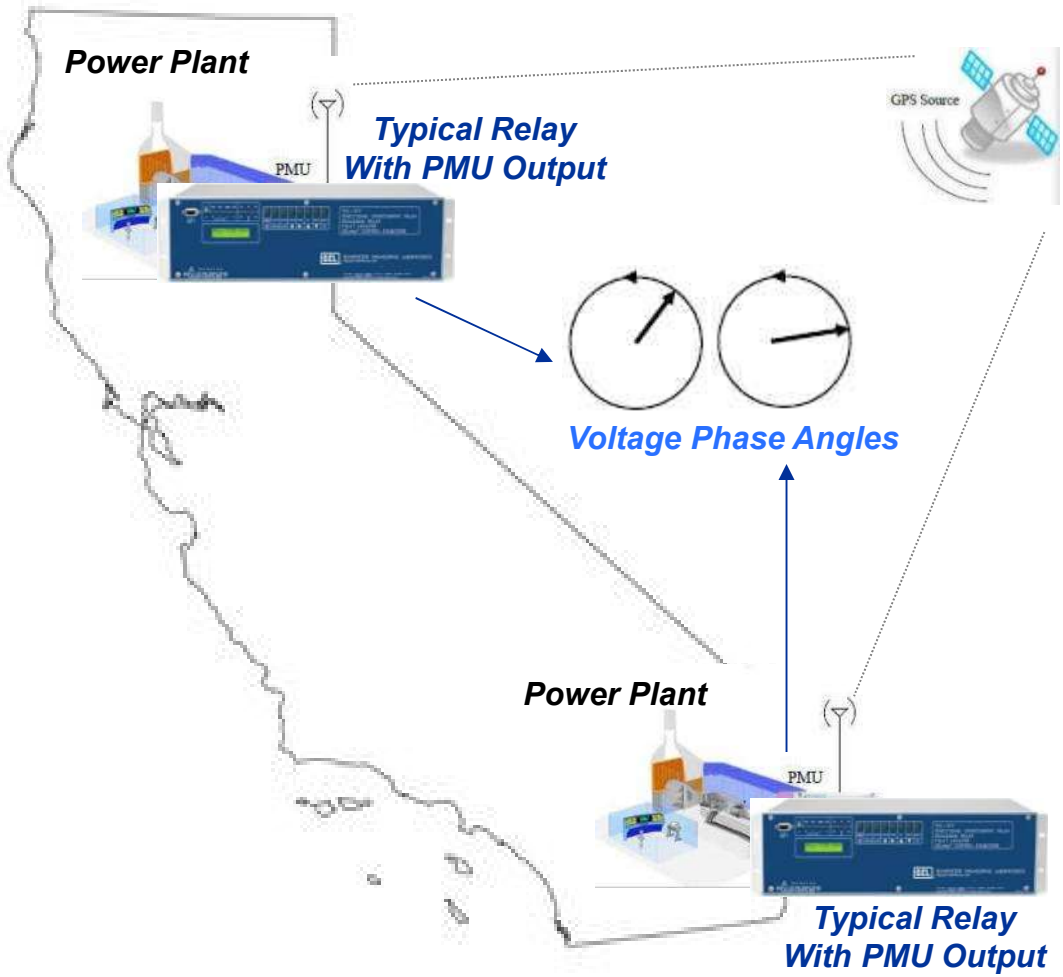
Demonstrated benefits for a wide range of applications in an electric grid

An advanced control technology with a simple concept

Higher resolution data allows for more effective and faster control of responsive resources to coordinate with slower resources

Time-synchronized high-speed input data from Phasor Measurement Units (PMU) offer the foundation for advanced controls

IEEE Standard C37.118



Properties of a voltage phasor:

A. Magnitude

B. Phase Angle

C. Time Reference

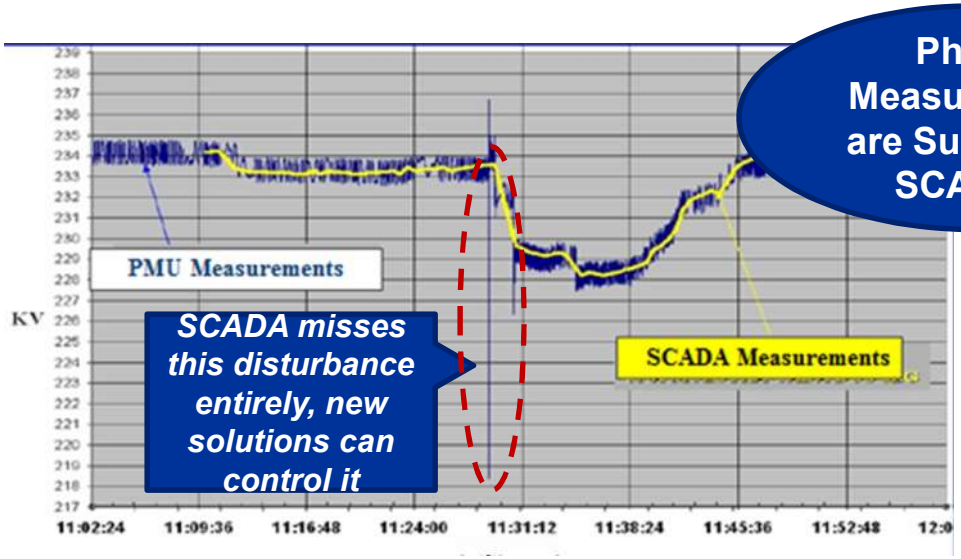
D. Frequency

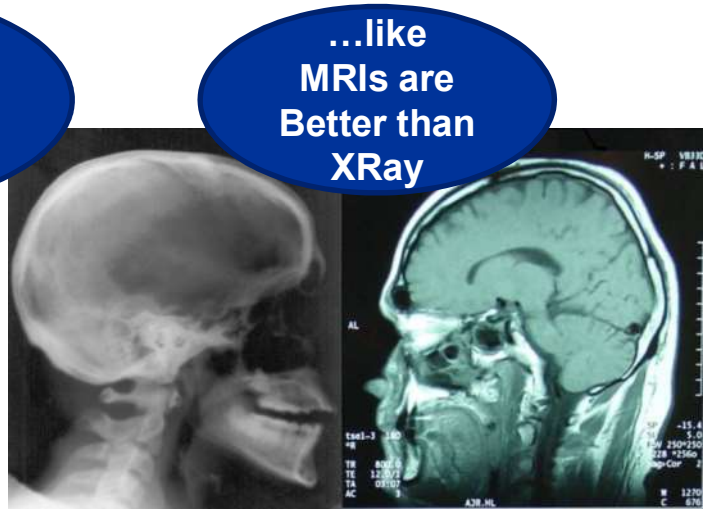
E. Location of the Measurement

Voltage Phasors provide new insights of electric power transfer and system topology

1. High Resolution – 30-60 measurements/second
2. Time Synchronized– GPS based UTC time stamped
3. Vector (Angle + Magnitude)

A high-speed data enabled control technology can enhance the current technology that is slow and limited in data resolution





ATTRIBUTE	SCADA	PMU
Resolution	1 sample every 2-4 seconds *(Steady State Observability)*	10-60 samples per second *(Dynamic/Transient Observability)*
Measured Quantities	Magnitude Only	Magnitude & Phase Angle
Time Synchronization	No	Yes
Total Input/ Output Channels	100+ Analog & Digital	~10 Phasors 16+ Digital 16+ Analog
Focus	Local monitoring & control	Wide area monitoring & control

You can't control what you can't measure

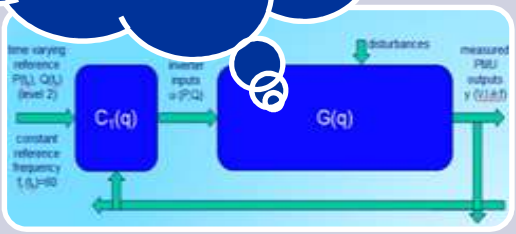
- Take advantage of broadly available high-speed data from substation equipment (i.e., phasor measurement unit, PMU*)
- Combine advanced control methods to offer new operational capabilities not possible before

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

Integrate key enabling technologies into a solution to address the complex grid challenges

Unique Application of Modern, Broadly Available Data

Provides New Capabilities Not Possible Before



Provides New Insights Not Available Before

1 **Time-synchronized high-speed data from PMUs*** **(60 samples/sec.)**

2 **Advanced feedback control technology**

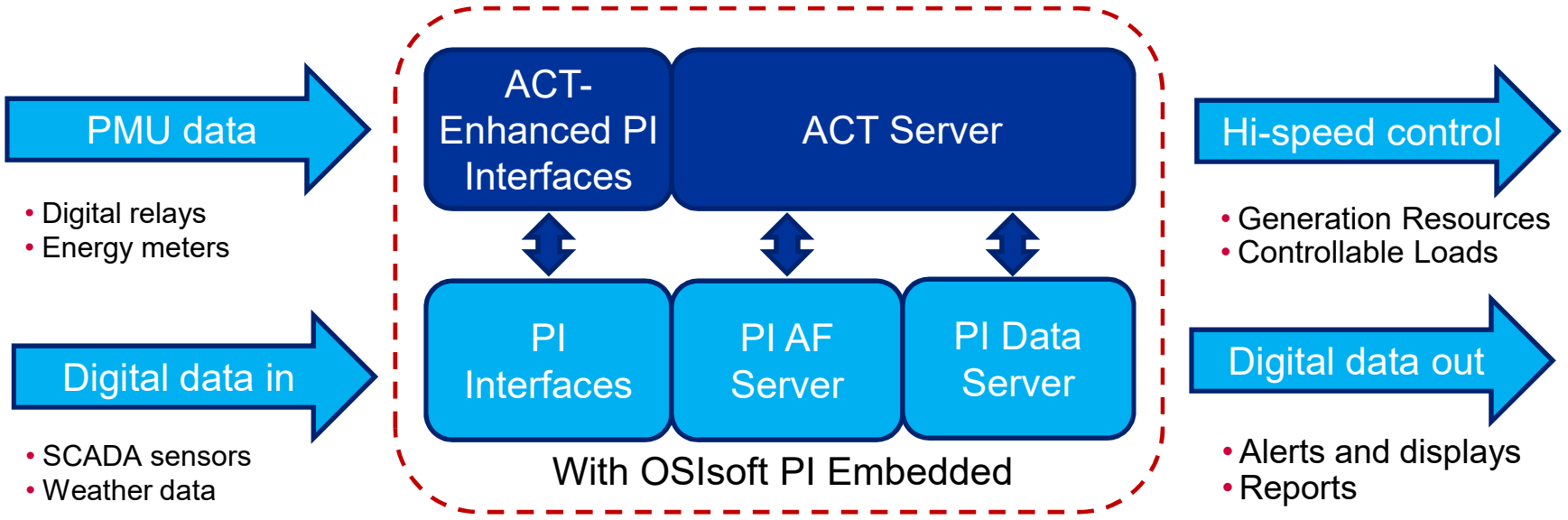
3 **System modeling, optimization, and data analytics**

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

Accomplished: An integrated software solution functions like a fast and intelligent SCADA / a system stabilizer

PXiSE ACT Solution

1. Integrated on a Proven Data Platform



2. Implemented on Field Proven Hardware

3. Software Designed for Fast Field Implementation

PXiSE ACT is a well-designed electric control system solution with "desirable characteristics"

IEEE 37.118

Use standards

Common hardware

PXiSE ACT

ACT-Enhanced PI Interfaces

ACT Server

PI Interfaces

PI AF Server

PI Data Server

With OSIsoft PI Embedded

Eliminate Network flow analysis

Intelligent

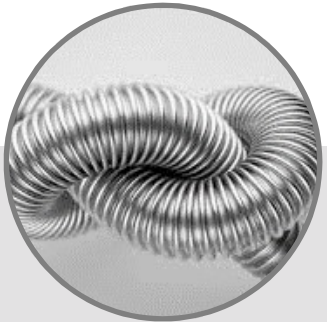
Systematic & robust

Scalable

Nested multi-level controls

Ease of use

Flexible design



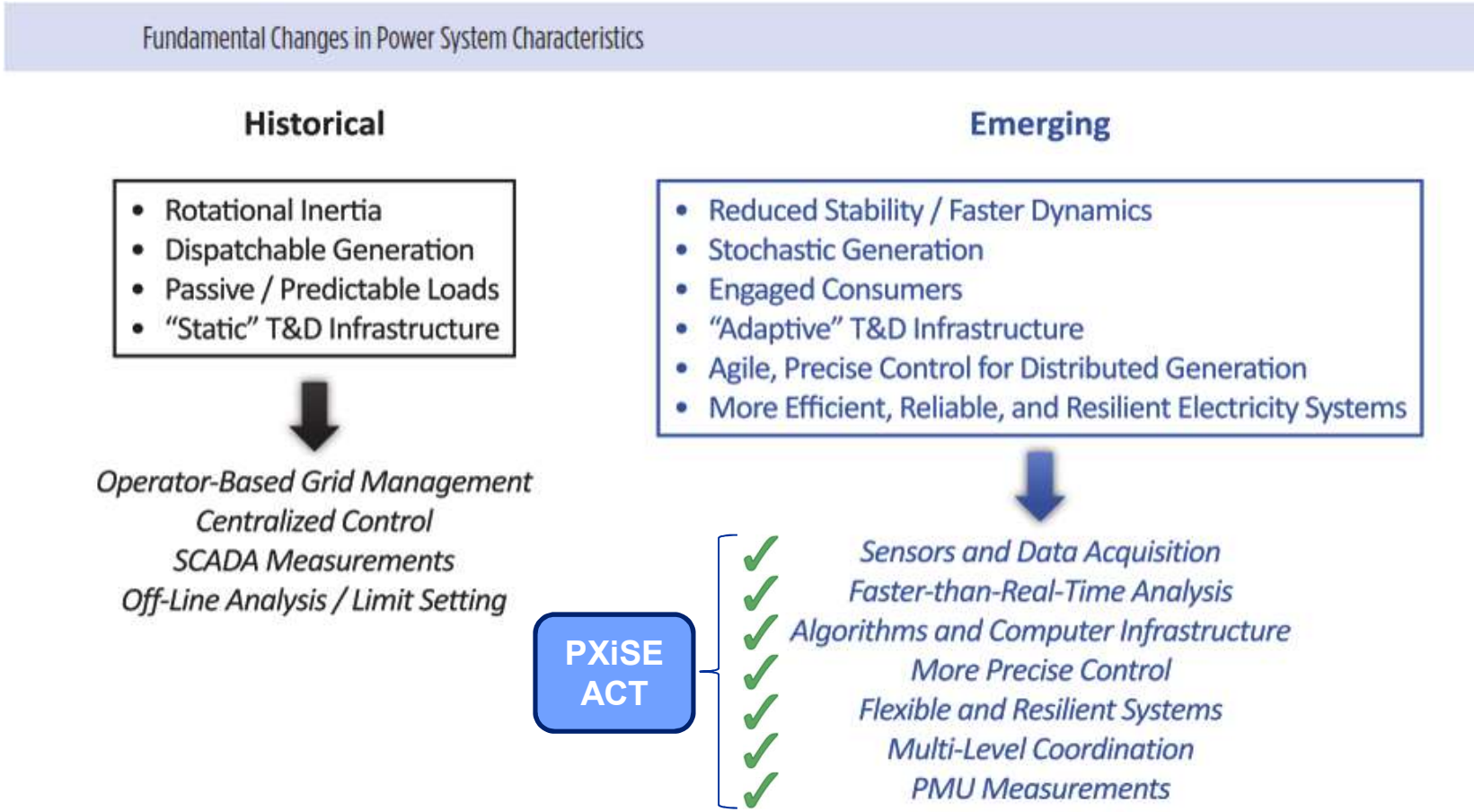
Familiar software

Proven OSIsoft Data Platform

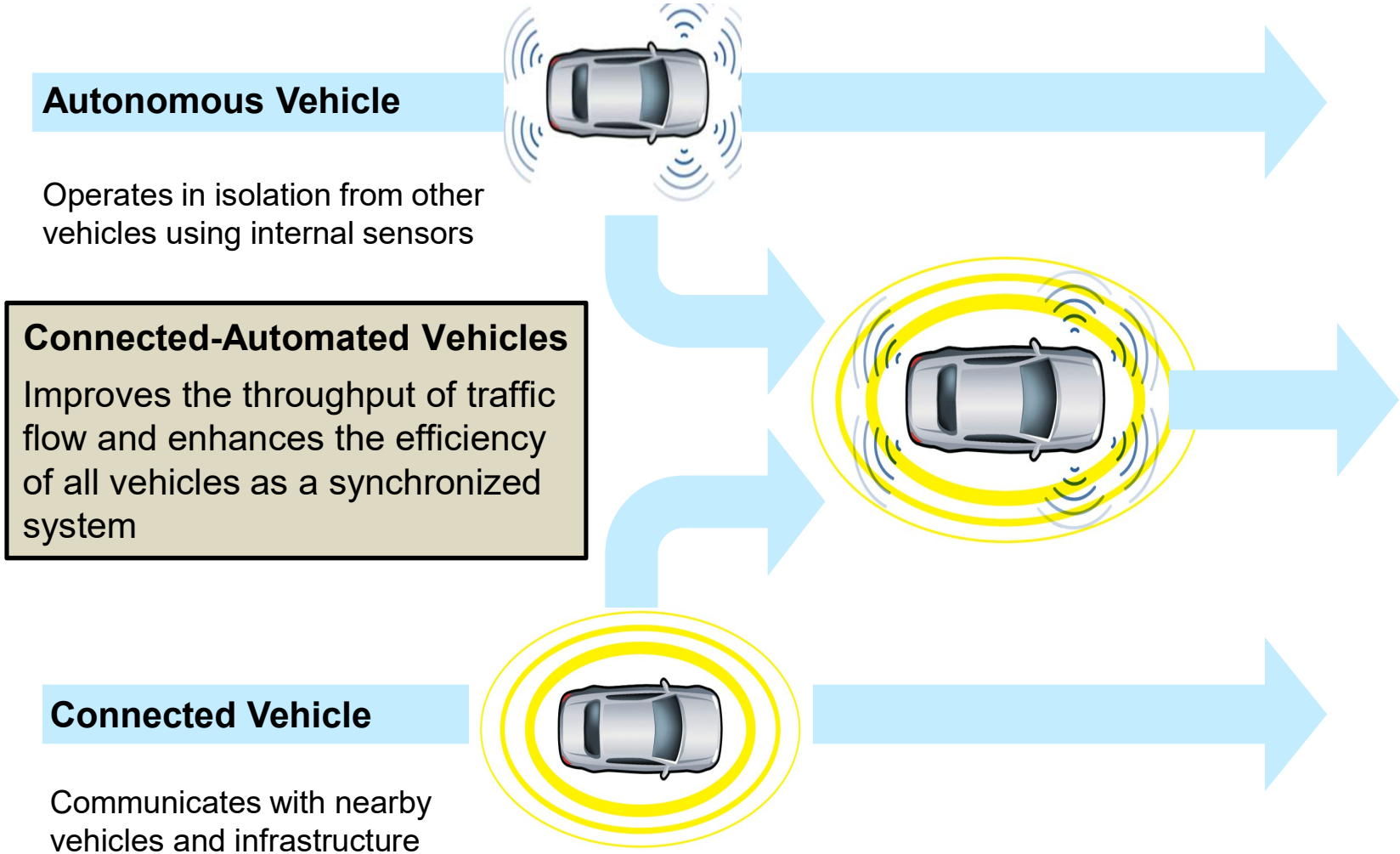
How do we know PXiSE ACT is the right solution?

"DOE Quadrennial Technology Review Report "

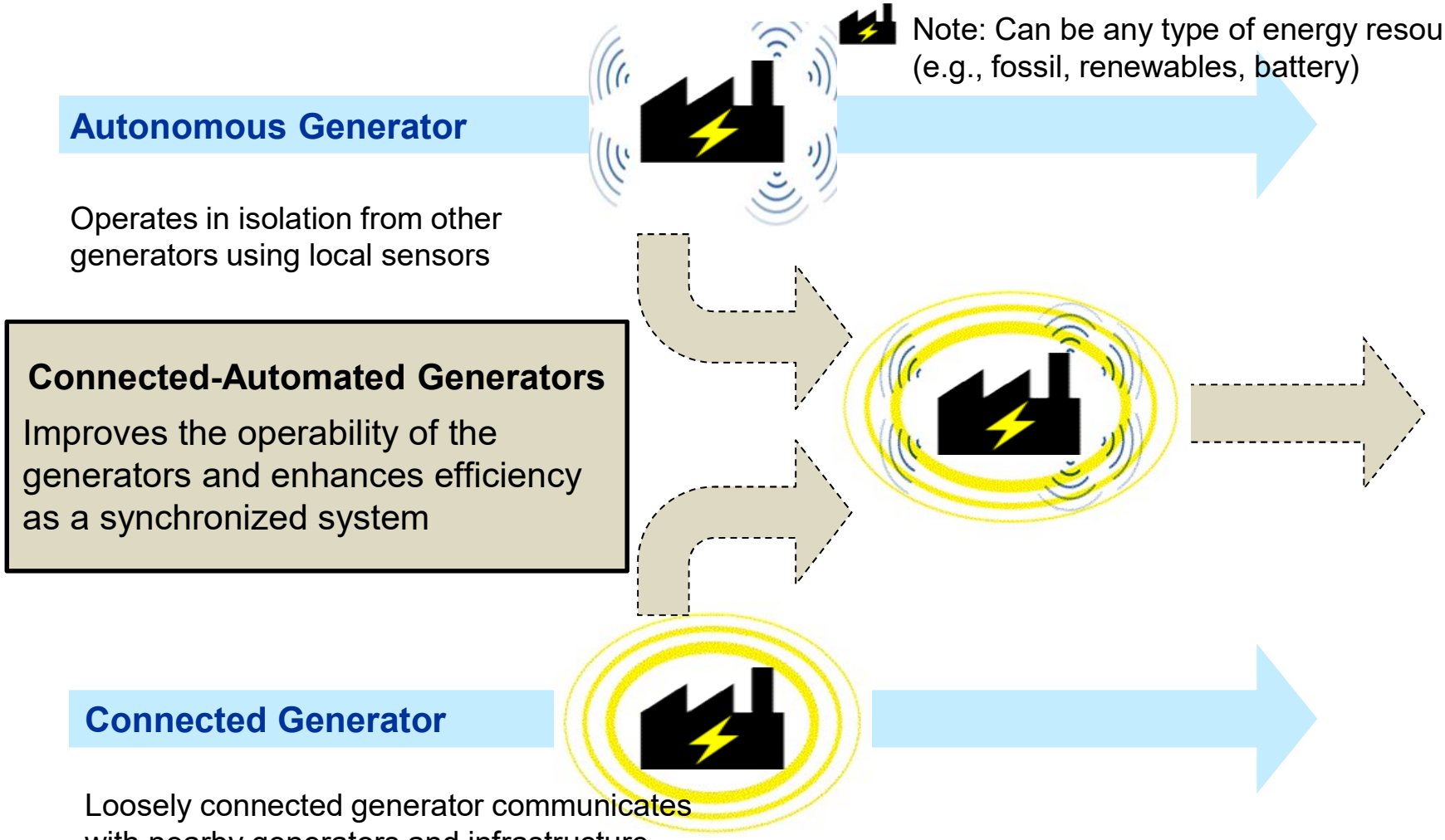
Enabling Modernization of the Electric Power System September 2015



An analogy to show new capability: Consider connected and autonomous capabilities, as is imagined for transportation in the future



Such new technology enables energy resources to function like connected-automated generators



Through connected, automated control, PXiSE ACT enhances performance of many DERs *as a whole system**

Wind Resources

Solar Resources

PXiSE Advanced Controller

Energy Storage

Thermal Generation

Features that improve operability and efficiency of a connected-automated system

- Time-synchronized, and precise coordination and control of DERs
- Optimized power scheduling according to characteristics of DERs
- Fast and precise frequency regulation
- Coordinated reactive power management
- Fast disturbance mitigation to ensure reliability and service quality

* All applicable from microgrids to macrogrids

Utility industry is transforming

Operational challenges requiring new solutions

What will be required in a new control solution to solve these challenges?

Combining key advanced control technologies as new tools to enable electric grid of the future

Demonstrated benefits for a wide range of applications in an electric grid

New capabilities offer grid solutions not possible until now

New grid control capabilities	Traditional electric control limitations
1 **High-speed** grid visibility and **direct control** enabled by PMUs sampling at 60 times/sec.	**200x slower** grid visibility and **dispatch only** commands using legacy SCADA systems
2 **Closed-loop feedback** of real & reactive power[1] enables **precision control** able to account for system dynamics in real-time	**Reactive open-loop** "droop" control that doesn't adjust for changing system dynamics yielding inexact real power **dispatch**
3 **Time-synchronized coordinated total control** of multiple energy resources	**Poorly coordinated** power **dispatch** commands to energy resources

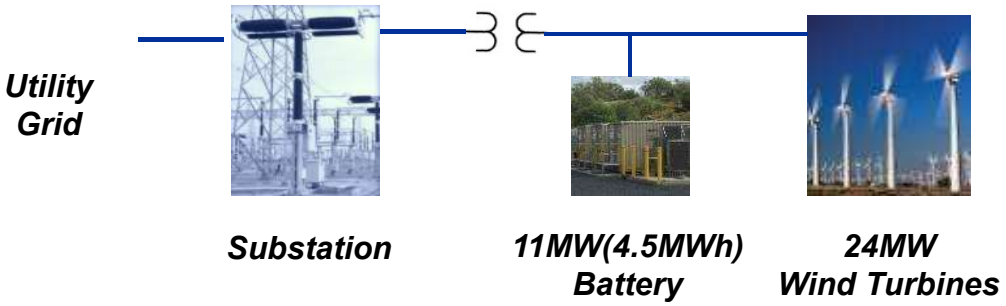
- The grid of today needs to detect and mitigate dynamic changes to ensure grid reliability while balancing supply and demand by direct control of inverter with minimal latency, and
- To optimize the utilization of energy resources according to their characteristics, creating better, more efficient resource planning & scheduling

1) Remember Ohm's Law and decouple real & reactive power - enable real power to directly influence system frequency and reactive power to directly influence system voltage, both of which are critical to reliably operating an electric system

EXAMPLE: Wind farm deployment with battery storage validates value proposition of new grid control

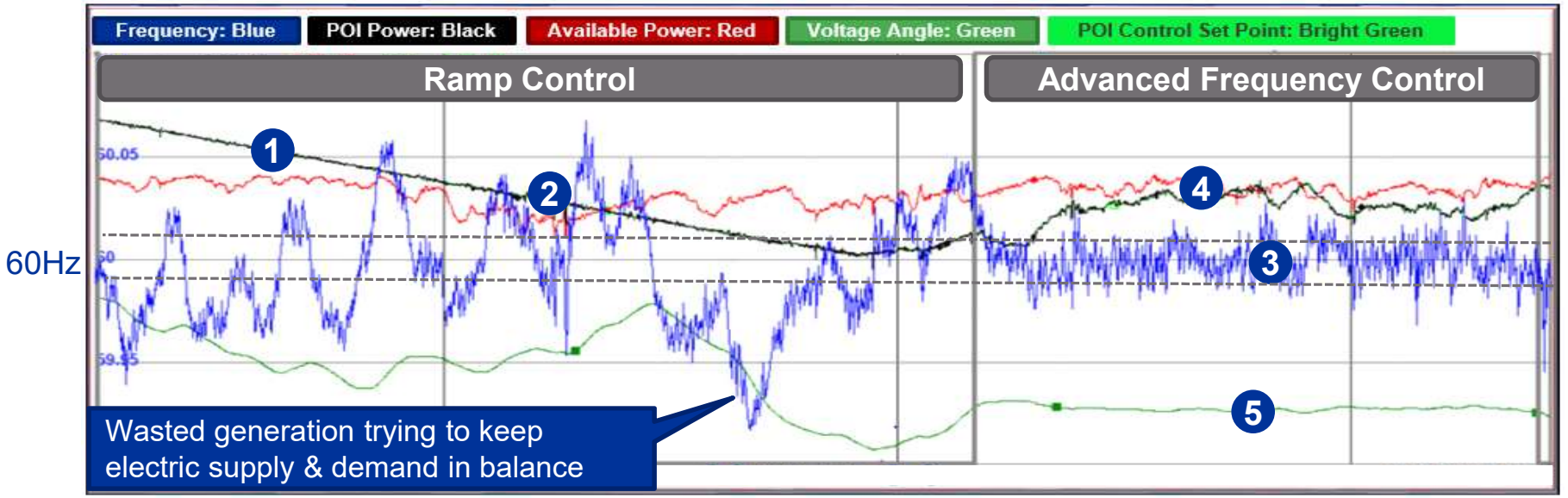
Validated frequency control capabilities of new technology solution in an unstable grid

Demonstrated control from San Diego to a wind farm over 2,500 miles away



1. **Precise Power Set Point Attainment**
2. **Simultaneous Intermittency & Energy Management**
3. **Efficient Frequency Regulation**
4. **Reduced Curtailment**
5. **Maximum Real Power Delivery**

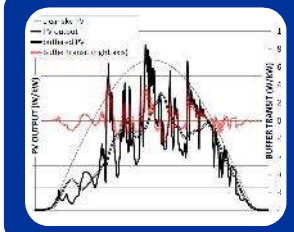
Significant benefits with advanced frequency control



1. **Precise Power Set Point Attainment:** Actual power delivered exactly matches control set points
2. **Simultaneous Intermittency & Energy Management:** Constant power at the point of interconnect regardless of resource(s) intermittency/variability (scheduled output and ramp control)
3. **Efficient Frequency Regulation:** Lowered frequency variation 10x with minimal battery capacity[1]
4. **Reduced curtailment:** More direct to grid power[2] enabled by minimal throttling of battery capacity[3] to stabilize frequency allowing more renewable power to be injected into the grid
5. **Maximum Real Power Delivery:** Prices control of the voltage angle enabling power to be directed to specific locations in an electric system decreasing line loses

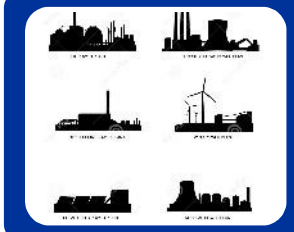
1) ~140MW island
2) Additional efficiencies achieved through reducing round trip efficiency loses of ~13% from charging and discharging battery
3) Shallow battery discharging supports a longer useful life of the asset over deep discharging

Deployment at wind farm with a large battery storage validated significant value proposition of the ACT



Stabilized frequency of island

- Addressed solar PV intermittency issues
- Support more renewables adoption
- Achieved high power quality



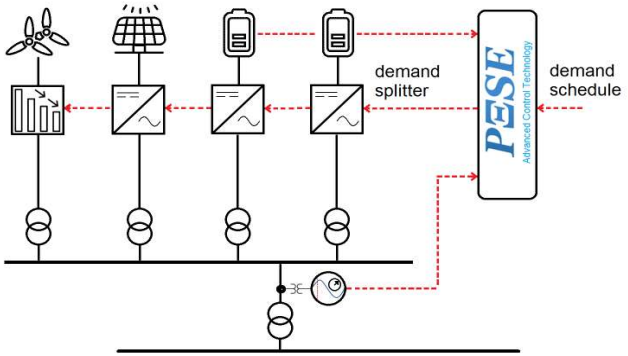
Improve thermal generator efficiency

- Less cycling of generators with stable frequency
- More operational flexibility of thermal generators with battery providing regulation service

Maximize renewable energy delivery

- More energy delivered from wind turbines with more effective use of battery
- Less operational wind curtailments

Many Applications for Reliable and Cost-effective Integration of Diverse Renewable Resources in the Electric Grid of the Future



Control Microgrids and Integrate in Power Systems

PSE
PXiSE Advanced Controller

Energy Storage

Multi-objectives Energy Dispatch – Timed Demand & Flow Control

PSE
PXiSE Advanced Controller

Energy Storage Gas Turbine

Enhanced Hybrid Turbine – Ramp & Frequency Control

PSE
PXiSE Advanced Controller

Energy Storage

Intermittencies and Power Schedule Management

Wind Resources

Solar Resources

PSE
PXiSE Advanced Controller

Energy Storage

Thermal Generation

Optimal Control of All Resources – Improve Efficiency and Reliability

ACT has a differentiated gateway solution approach to offer all markets creating internal and external synergies

1. Utility-scale Renewables
2. Energy Storage
3. Microgrid
4. Utility (DERMS)
5. RTO/ISO (VPP)

PXiSE ACT

Most competitors operate in a range of 2-3 of the market categories above

PXiSE's ACT horizontal technology applies across all market categories, thereby opening up opportunities for strategic partnerships to enable the electric grid of the future

PXiSE Energy Solutions

For Further Information

Call us at +1 (619) 696 2744
Email us at info@pxise.com
Visit us at www.pxise.com

PXiSE Energy Solutions, LLC is not the same company as the California utilities, San Diego Gas & Electric Company (SDG&E) or Southern California Gas Company (SoCalGas), and PXiSE Energy Solutions , LLC is not regulated by the California Public Utilities Commission.