

Welcome to the

 **ENERU 2026**

THE CONFERENCE FOR BETTER ENERGY

March 16<sup>th</sup> – 17<sup>th</sup>, 2026

# High Performance Power Quality Monitoring with PMU in Australia

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2026.03.17

# Agenda

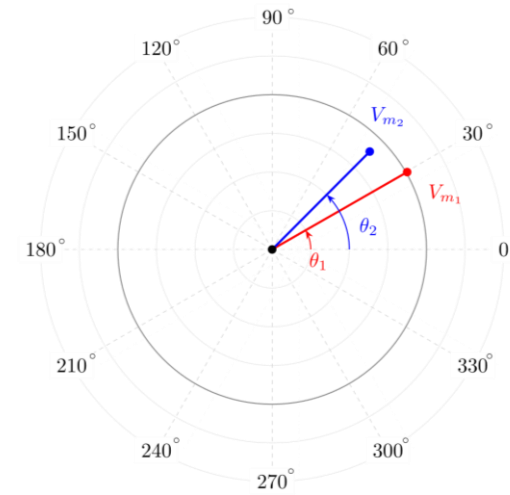
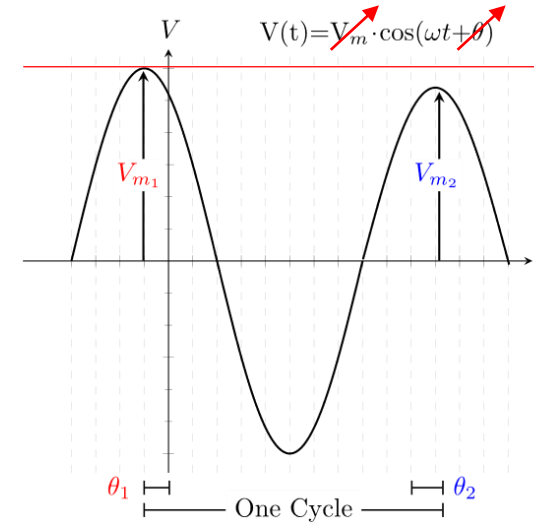
1. What are Phasor Measurement Units?
2. New and advanced solution: PQA8000H-RM
3. Applications of Phasor Measurement Units
4. Wide Area Monitoring Systems - Software Solution
5. Overview on general use cases

# Phasor Measurement Unit

- **IEC/IEEE 60255-118.1 Standard Definition:** Phasor Measurement Unit (PMU): “a device or function in a multifunction device that produces synchronized phasor, frequency, and rate of change of frequency (ROCOF) estimates from voltage and/or current signals and a time synchronizing signal.”
- Definition from IEC/IEEE 60255-118.1: A **Synchrophasor** is a phasor representing the fundamental of an AC signal whose magnitude is the RMS value of the fundamental amplitude and angle is the **difference between the signal fundamental angle and the phase angle of a cosine** at the **nominal signal frequency** that is synchronized to **UTC time**.

$$f(t) = f_0 + \frac{d}{dt} \left[ \frac{\theta(t)}{2\pi} \right] = f_0 + \Delta f(t)$$

$$\Delta\theta \propto \Delta f$$



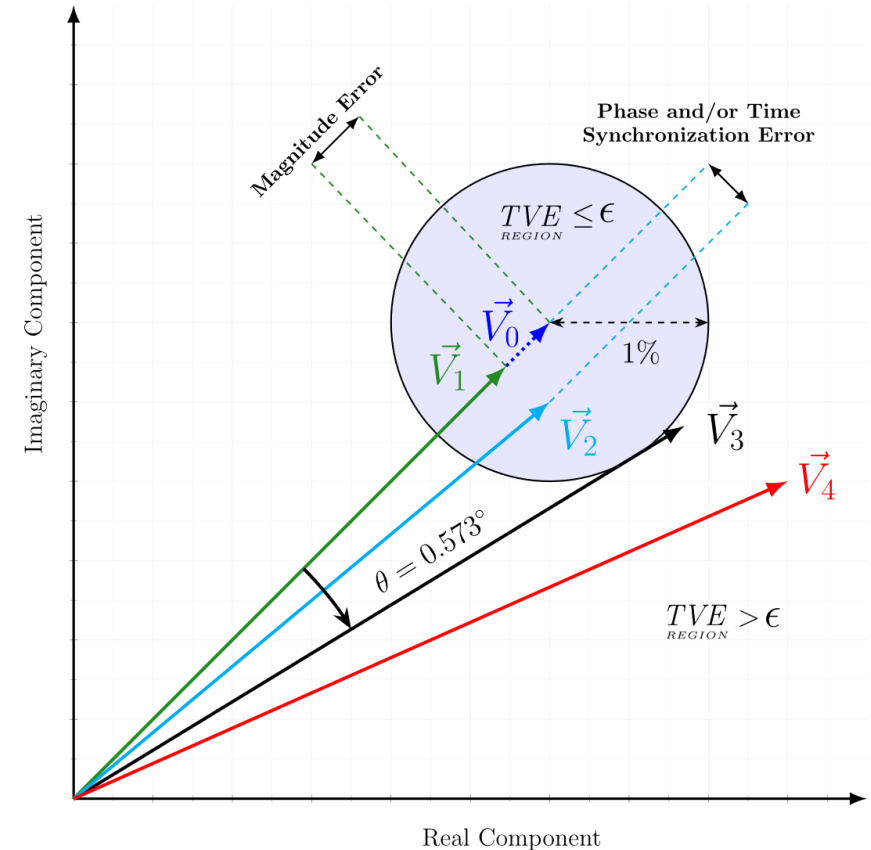
Absolute Time Reference is KEY, and fundamental to PMUs.

M. P. Anguswamy, "Power Quality Insights and Fault Analysis in Distribution Networks with Optimally Placed D-PMUs," **PhD Doctoral Thesis**, RMIT University, 2024.

# PMU Accuracy and Calibration

- **Total Vector Error (TVE)**
  - **Measured phasor** vs **actual phasor**
  - Considers magnitude errors, angle errors, and time-synchronization errors
  - Evaluates precision is a single metric
- IEEE C37.118.1a-2014 and IEC/IEEE 60255-118-1 **Standard for TVE is 1% for both Class M & P**
- But remember, this is at close to the fundamental frequency (50Hz or 60Hz)

$$TVE(n) = \sqrt{\frac{\left(\widehat{X}_r(n) - X_r(n)\right)^2 + \left(\widehat{X}_i(n) - X_i(n)\right)^2}{\left(X_r(n)\right)^2 + \left(X_i(n)\right)^2}}$$

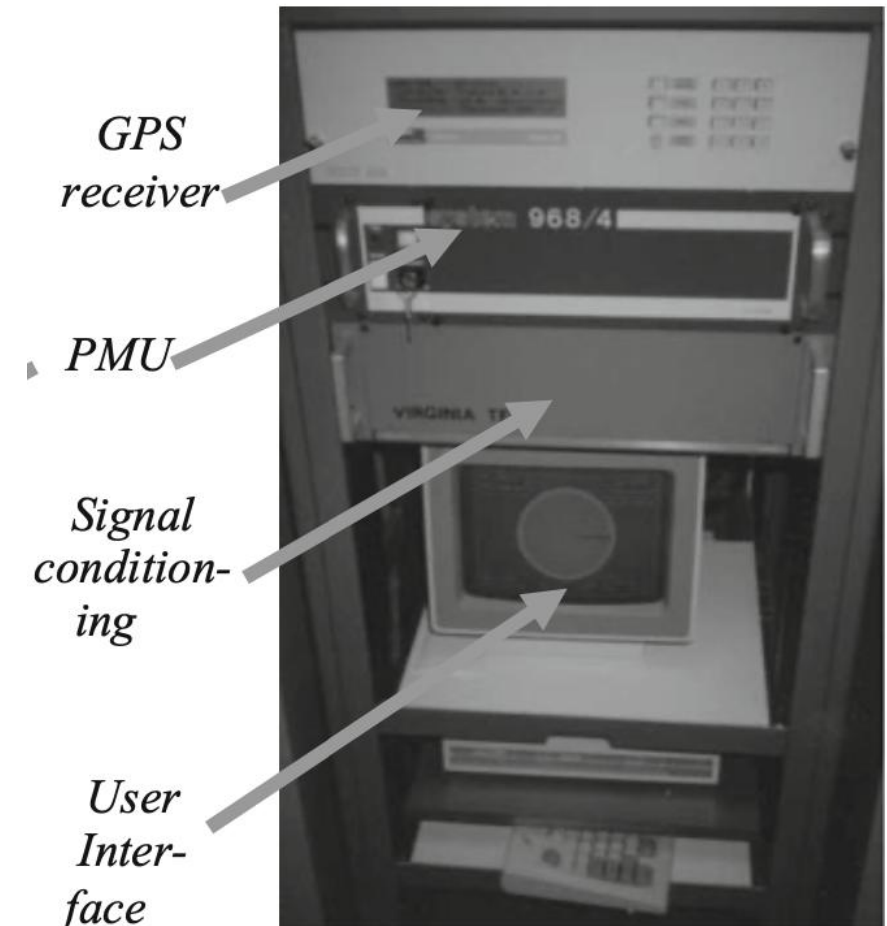


- Actual Phasor ( $\vec{V}_0$ )
- Measured Phasor ( $\vec{V}_1$ )
- TVE Compliant Region
- In-Compliance ( $\vec{V}_2$ )
- Edge-of-Compliance ( $\vec{V}_3$ )
- Out-of-Compliance ( $\vec{V}_4$ )

Manoj Anguswamy, "Power Quality Insights and Fault Analysis in Distribution Networks with Optimally Placed D-PMUs," **PhD Doctoral Thesis**, RMIT University, 2024.

# Phasor Measurement Unit

- Transmission or **Traditional PMUs** were **large, expensive, slow, and hardware limited.**
- Meeting Class M & P Standards are typically not good enough for the modern grid.
- GPS Time-Stamped to PDC.
- SCADA vs PMUs
  - SCADA: 1-2 samples/second
  - D-PMU: Up to 200/240 FPS
- **Modern D-PMUs** are **modular, faster, cost-effective,** with **increased accuracy** than traditional PMUs. D-PMUs (microPMU) are suitable for **active distribution networks**



A. G. Phadke and J. S. Thorp, Synchronized Phasor Measurements and Their Applications, Second ed. 2008.

# Introducing PQA8000H Rackmount



# PQA8000H Rackmount

- Accurate measurements and future proof design
- ENA Software powered by Avera
- AEMO Very Fast FCAS, GPS & Model Validation
- Includes up to 4 high accuracy IPCS 10A Zeroflux Sensors
- 1 MHz Continuous Waveform Sampling
- 0.01% Error margin: 100 times more accurate than IEC/IEEE Standards
- 500 kHz Supraharmonics (10k<sup>th</sup> Harmonic)
- Class A++ | Exceeds all standards
- Portable variant available (PQA8000H)



# ENA PMU Measurement

- ENA Software developed by Avera is employed
- Highly accurate synchrophasor and RoCoF measurements (IEC/IEEE 60255-118.1)
- Supporting TCP and UDP protocols for data transmission and storage

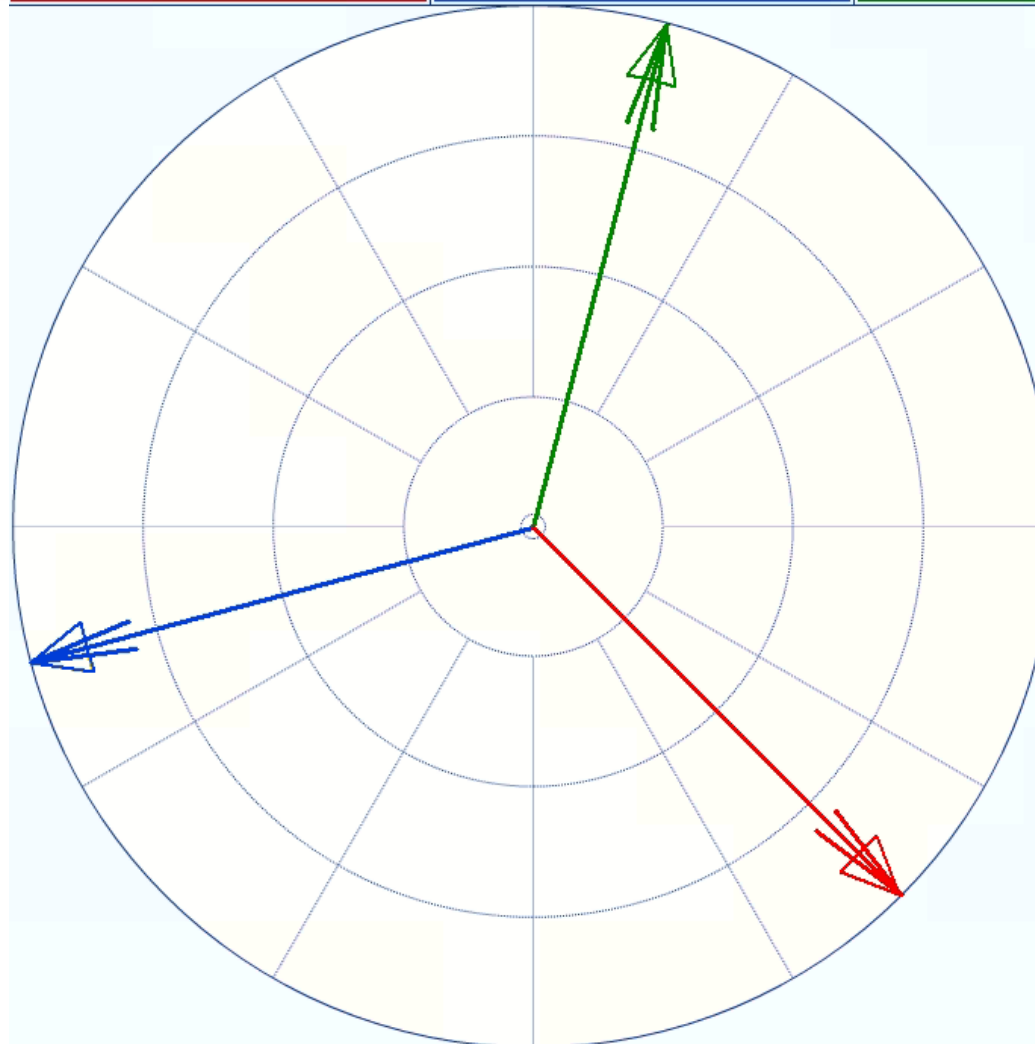
PMU ID:

PMU TCP Port:

PMU Station Name:

PMU Header:

Reporting Rate:



Channel	Amplitude	Angle
U Phase 1	299.99V	315.0°
U Phase 2	299.96V	195.0°
U Phase 3	299.96V	75.03°
I Phase 1	9.9924A	315.0°
I Phase 2	9.9952A	195.0°
I Phase 3	9.9955A	75.06°
U Phase N	300.00V	75.04°
I Phase N	9.9953A	195.0°

Time Stamp:

Time Status:

Digital Inputs:

Frequency:

# Frequency & ROCOF

**Frequency** refers to the **angular velocity in hertz (Hz)** of an AC power system signal and represents the **first derivative of the phase angle of the original signal with respect to time**.

It is also known as the instantaneous frequency.

$$f(t) = \frac{1}{2\pi} \cdot \frac{d\theta(t)}{dt} = f_0 + \frac{1}{2\pi} \cdot \frac{d\phi(t)}{dt}$$

**ROCOF** refers to the Rate of Change of Frequency, and is calculated by taking the **second derivative of angular velocity** which **yields the angular acceleration** of the original AC power system signal in **hertz per second (Hz/s)**.

$$ROCOF(t) = \frac{df(t)}{dt} = \frac{d}{dt} \left( \frac{1}{2\pi} \cdot \frac{d\theta(t)}{dt} \right) = \frac{1}{2\pi} \cdot \frac{d^2\theta(t)}{dt^2}$$

It is essentially a measure of how quickly the instantaneous frequency or angular velocity changes with respect to time.

**Not many PQ Meters can measure ROCOF.**

# Use Cases for ROCOF

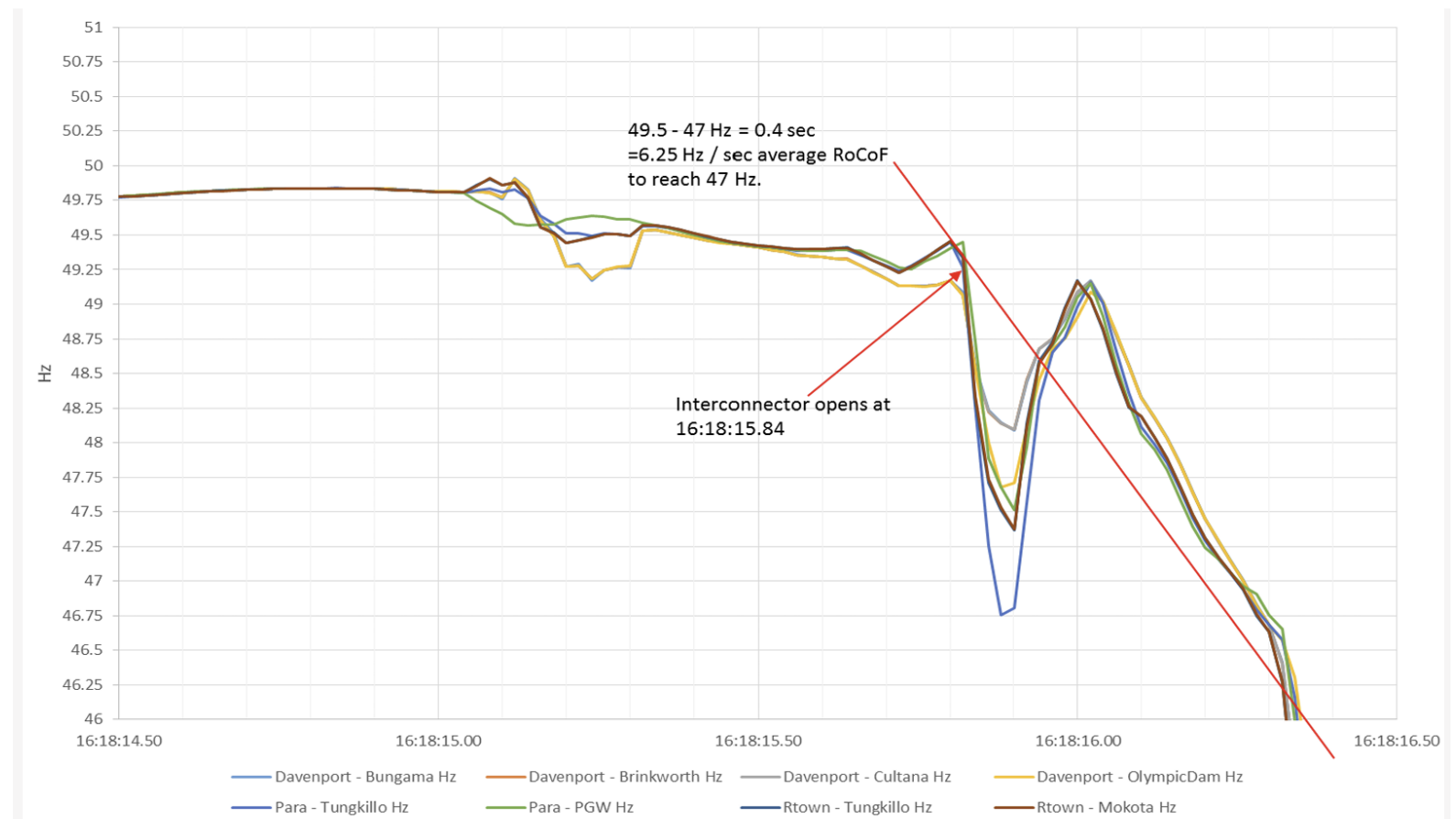
## ROCOF refers to Stability

### Used in many applications

- Grid Stability
  - Low Inertia as more renewables, no longer a large rotor to stabilize the grid from disturbances
  - UFLS (SA Blackout)
- Islanding
- Protection
- Ancillary Services (e.g. FCAS)
- DERs
  - EVs
  - Battery

## CASE STUDY: South Australia Frequency & ROCOF During BLACKOUT

Figure 6 Frequency and ROCOF in various SA nodes immediately before the system separation



A. E. M. O. (AEMO), "BLACK SYSTEM SOUTH AUSTRALIA 28 SEPTEMBER 2016,"  
01-03-17 2017.

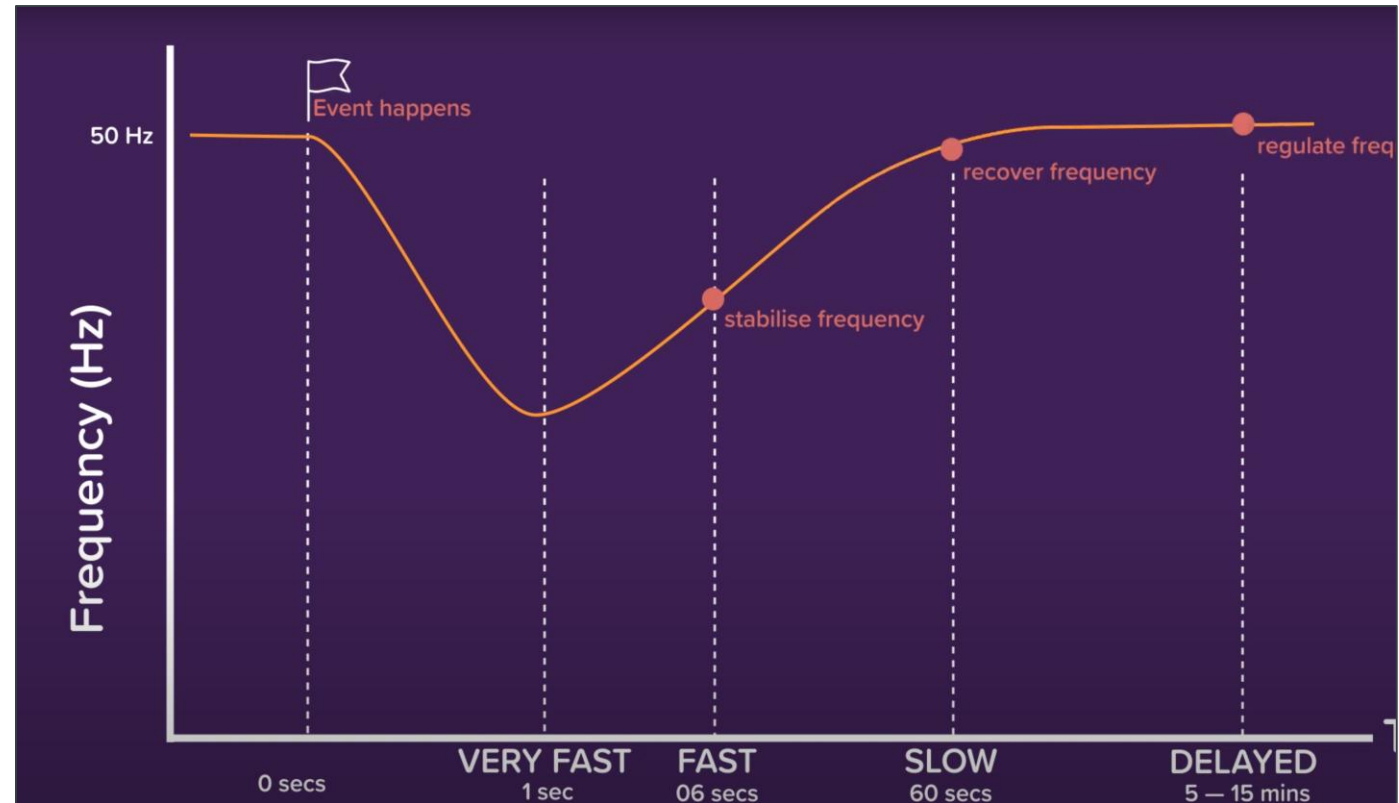
# Frequency Control Ancillary Services

## Challenge:

- Low inertia in grid as more renewables are Integrated
- Fewer large rotors to stabilize the grid during disturbances
- Has to maintain frequency stable at 50Hz

## Solution

- FCAS market using assets to reduce power consumption (industrial loads) or inject power into the grid (BESS) during frequency event
- BESS is popular because it can act as a load and generation
- Each time FCAS Asset Support the grid, market operator gives financial rewards. For example, \$100,000 for 1MW
- High accuracy measurement required in order to claim rewards and prove asset supported.



AEMO MASS v8.2 Specifications

# Frequency Control Ancillary Services

## Challenge:

- Metering Requirements are strict in Australia especially for FCAS Market. Only a few meters comply with FCAS Specification.

## Key Requirements:

### 1. Measurement Range of Power Flow Measurements

- $\leq 50\text{ms}$  Data
- Intrinsic Uncertainty  $\leq 2\%$
- Resolution of  $\leq 0.2\%$

### 2. Local Frequency Measurement

- Intrinsic Uncertainty  $< 0.010\text{ Hz}$  or  $10\text{ mHz}$
- Frequency Resolution  $0.0025\text{ Hz}$  or  $2.5\text{ mHz}$
- Cycle-by-Cycle Frequency Required

## Solution

- High Precision PMU (**NEO PQA-8000H**)
  - Deploying to large BESS systems
  - Example:  $750\text{MW} / 3000\text{MWh}$  BESS

### 5.3.2. Measurement requirements

The equipment used to measure and record the FCAS delivered must have the characteristics

Table 5 Measurement requirements for FCAS

Requirement	Applicable to...	Very Fast FCAS	Fast FCAS	Slow FCAS	Delayed FCAS	Regulation FCAS
Sampling rate of Local Frequency measurements	Aggregated FCAS Facilities comprised of $\geq 25$ FCAS Facilities with no Inertial Response and with an Initiation Delay of $\leq 500\text{ ms}$	$\leq 100\text{ ms}$				
	Aggregated FCAS Facilities comprised of $\geq 25$ FCAS Facilities with no Inertial Response and with an Initiation Delay of $> 500\text{ ms}$	$\leq 50\text{ ms}$				
	Aggregated FCAS Facilities with Inertial Response and those comprised of $< 25$ FCAS Facilities with no Inertial Response	$\leq 50\text{ ms}$				
	All other FCAS Facilities	$\leq 50\text{ ms}$				
Sampling rate of Generation Amount and Load Amount measurements	Aggregated FCAS Facilities comprised of $\geq 25$ FCAS Facilities with no Inertial Response and with an Initiation Delay of $\leq 500\text{ ms}$	$\leq 100\text{ ms}$				
	Aggregated FCAS Facilities comprised of $\geq 25$ FCAS Facilities with no Inertial Response and with an Initiation Delay of $> 500\text{ ms}$	$\leq 50\text{ ms}$				
	Aggregated FCAS Facilities with Inertial Response and those comprised of $< 25$ FCAS Facilities with no Inertial Response.	$\leq 50\text{ ms}$				
	All other FCAS Facilities	$\leq 50\text{ ms}$				
Measurement Range of Power Flow Measurements	Intrinsic Uncertainty of $\leq 2\%$ , and resolution of $\leq 0.2\%$					

Requirement	Applicable to...	Very Fast FCAS	Fast FCAS	Slow FCAS	Delayed FCAS	Regulation FCAS
Local Frequency Measurement Range	At least the range specified in the OFTB, with:					NR
	Intrinsic Uncertainty		$\leq 0.01\text{ Hz}$		$\leq 0.02\text{ Hz}$	
	Resolution		$\leq 0.0025\text{ Hz}$		$\leq 0.01\text{ Hz}$	
FDT	$< 10\text{ s}$					NR
Recording Period for Power & System Frequency Measurements	$\geq 5\text{ s}$ before FDT and $\geq 60\text{ s}$ after it			$\geq 20\text{ s}$ before FDT and $5\text{ min}$ after it	$\geq 20\text{ s}$ before FDT and $10\text{ min}$ after it	NR
Trigger for Recording Measurements	At least whenever Local Frequency changes $\geq$ Trigger Range.					NR

For **Wide Area Monitoring Systems (WAMs)**, all synchrophasor data from many different PMUs located throughout the grid needs to be gathered by the PDC.

**The PDC (Phasor Data Concentrator) serves key functions including:**

- **Data collection and storage:** Aggregation of data from many PMUs and storage of data. Can be in the cloud or on a local PDC Server.
- **Time Synchronization and Alignment:** Data needs to be perfectly synchronized based on UTC Time. Time Sync Errors need to be corrected.
- **Communication Health:** Bad data needs to be identified using algorithms and removed to maintain data quality.
- **Data resampling:** PMUs have a standardized protocol, but differ in accuracy, embedded filtering, streaming in Class M or P or both simultaneously, different reporting rates, different data frames etc.

**SmartGRID**  
 **EDGE**

by



SmartGRID | Power Quality  
Technologies | Solutions 

 **Averna**  
Powered by  SPHEREA

# SmartGRID EDGE - WAMS PDC

## WAMS PDC

- Compare Live or Historical Data from deployed PMUs on the same timescale.
- Live Tables
- Live Charts
- Live Phasors with Reference PMU
- Historical Data and more...

The screenshot displays the SmartGRID EDGE WAMS PDC interface. The left sidebar shows navigation options: QUICK ANALYSIS, GENERAL, SENSORS (Sensor Manager, Sensor Investigation), SMARTGRID PDC (PMUs: SUPREME-PMU, NEO PQA-8000H, SGT PQA-8000H-RM), WAMS (selected), HISTORICAL ANALYSIS (Server DB), and ACCOUNT (Profile, Settings, License). The main panel is titled 'SmartGRID WAMS' and 'WAMS INV 01'. It shows 'WAMS 2 PMU(s) available'. The 'Historical Analysis' tab is active, displaying a time range from 12/03/2026, 07:47:10 pm to 12/03/2026, 07:48:31 pm. A table lists parameters for 'SGT PQA-8000H-RM' and 'NEO PQA-8000H', including Frequency (2), Voltage (9), Current (6), Power (16), Unbalance (4), Sequence Components (6), and Energy (7). Below the table is a 'Frequency' chart comparing the two PMUs. The chart shows frequency in Hz over time, with a tooltip for 'Mar 12, 2026, 19:47:51.558' showing 'SGT PQA-8000H-RM | Frequency (Hz) : 49.9782 Hz' and 'NEO PQA-8000H | Frequency (Hz) : 49.9926 Hz'.

# SmartGRID EDGE - WAMS PDC

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Parameter	Count
All Parameters	86
Frequency	2
Voltage	11
Current	8
Power	16
Sequence Components	6
Unbalance	4
Energy	7

Parameter	Count
Active Power L1 (W)	1
Active Power L2 (W)	1
Active Power L3 (W)	1
Active Power Total (W)	1
Reactive Power L1 (VAr)	1
Reactive Power L2 (VAr)	1
Reactive Power L3 (VAr)	1
Reactive Power Total (VAr)	1
Apparent Power L1 (VA)	1

# SmartGRID EDGE - WAMS PDC

## WAMS PDC

- Compare Live or Historical Data from deployed PMUs on the same timescale.
- Live Tables
- Live Charts
- **Live Phasors with Reference PMU**
- Historical Data and more...

**SGT SmartGRID EDGE**  
PROFESSIONAL EDITION

QUICK ANALYSIS >

GENERAL >

SENSORS

(-+) Sensor Manager ^

○ No sensors

🔍 Sensor Investigation v

SMARTGRID PDC

🏠 PMUs ^

● SUPREME-PMU

● NEO PQA-8000H

● SGT PQA-8000H-RM

**🌐 WAMS**

HISTORICAL ANALYSIS

☰ Server DB

ACCOUNT

👤 Profile

⚙️ Settings

🛡️ License

**NM** NEO MESSTECHNIK  
SmartGRID EDGE x NEO

SmartGRID WAMS (←) All Devices (2) **WAMS INV 01** +

**WAMS INV 01** WAMS 2 PMU(s) available Close

Main Phasor Analysis Live Charts Historical Analysis

+ Add PMU Phasors

**Voltage Phasors (Select Reference PMU)** Ref: NEO PQA-8000H

PMU SITE	PHASOR	MAG	ANGLE	ΔMAG	ΔANGLE
SGT PQA-8000H-RM	V1	12702.889 V	359.87°	1.053 V	0.00°
SGT PQA-8000H-RM	V2	12700.599 V	239.88°	-0.996 V	0.00°
SGT PQA-8000H-RM	V3	12701.951 V	119.87°	0.207 V	0.00°
NEO PQA-8000H REF	V1	12701.836 V	359.87°	0.000 V	0.00°
NEO PQA-8000H REF	V2	12701.595 V	239.88°	0.000 V	0.00°
NEO PQA-8000H REF	V3	12701.744 V	119.87°	0.000 V	0.00°

**Current Phasors** Ref: SGT PQA-8000H-RM

# SmartGRID EDGE – PMU Analysis

## PMU Analysis

View Live or Historical Data from deployed PMU

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- Phasor Playback
- Events (Real-Time & Historical)
- Oscillation Detection
- Export
- Report
- Connect PQA Data to PMU
- Light/Dark Mode

**SGT SmartGRID EDGE**  
PROFESSIONAL EDITION

QUICK ANALYSIS

GENERAL

SENSORS

(+) Sensor Manager

No sensors

Sensor Investigation

SMARTGRID PDC

PMUs

SUPREME-PMU

**NEO PQA-8000H**

SGT PQA-8000H-RM

WAMS

HISTORICAL ANALYSIS

Server DB

ACCOUNT

Profile

Settings

License

NM **NEO MESSTECHNIK**  
SmartGRID EDGE x NEO

### NEO PQA-8000H

C37.118 NEO PQA-8000H

REC ⚙️ Config ^

Main Live Charts Historical Analysis Events Oscillation Configuration Phasor Map Storage

#### VOLTAGE PHASORS

#### CURRENT PHASORS

FREQUENCY ANALYSIS		VOLTAGE ANALYSIS VLN		CURRENT ANALYSIS		SEQUENCE COMPONENTS	
Frequency (Hz)	49.9966	VLN L1	12701.98 V < 358.03°	L1	129.925 A < 348.55°	V+ (pos)	12701.53 V
ROCOF (Hz/s)	-0.0053	VLN L2	12700.91 V < 238.04°	L2	130.346 A < 228.10°	V- (neg)	0.23 V
Nominal (Hz)	50	VLN L3	12701.70 V < 118.03°	L3	129.901 A < 108.21°	V0 (zero)	0.53 V

POWER L1		POWER L2		POWER L3		TOTAL POWER	
Active (W)	1627742.44	Active (W)	1638679.99	Active (W)	1625753.96	Active (W)	4884176.39
Reactive (VAr)	271932.17	Reactive (VAr)	285690.33	Reactive (VAr)	281599.66	Reactive (VAr)	839222.16
Apparent (VA)	1650300.75	Apparent (VA)	1655516.90	Apparent (VA)	1649961.91	Apparent (VA)	4955751.49
Power Factor	-0.9863	Power Factor	-0.9850	Power Factor	-0.9853	Power Factor	-0.9856

UNBALANCE		ACTIVE ENERGY		REACTIVE ENERGY		APPARENT ENERGY	
V Neg Seq %	0.002%	Total (kWh)	2910.3293	Total (kVArh)	513.1972	Total (kVAh)	2955.2799
V Zero Seq %	0.004%	Import (kWh)	2910.3293	Inductive (kVArh)	513.1972		
I Neg Seq %	0.330%	Export (kWh)	0.0000	Capacitive (kVArh)	0.0000		
I Zero Seq %	0.169%						

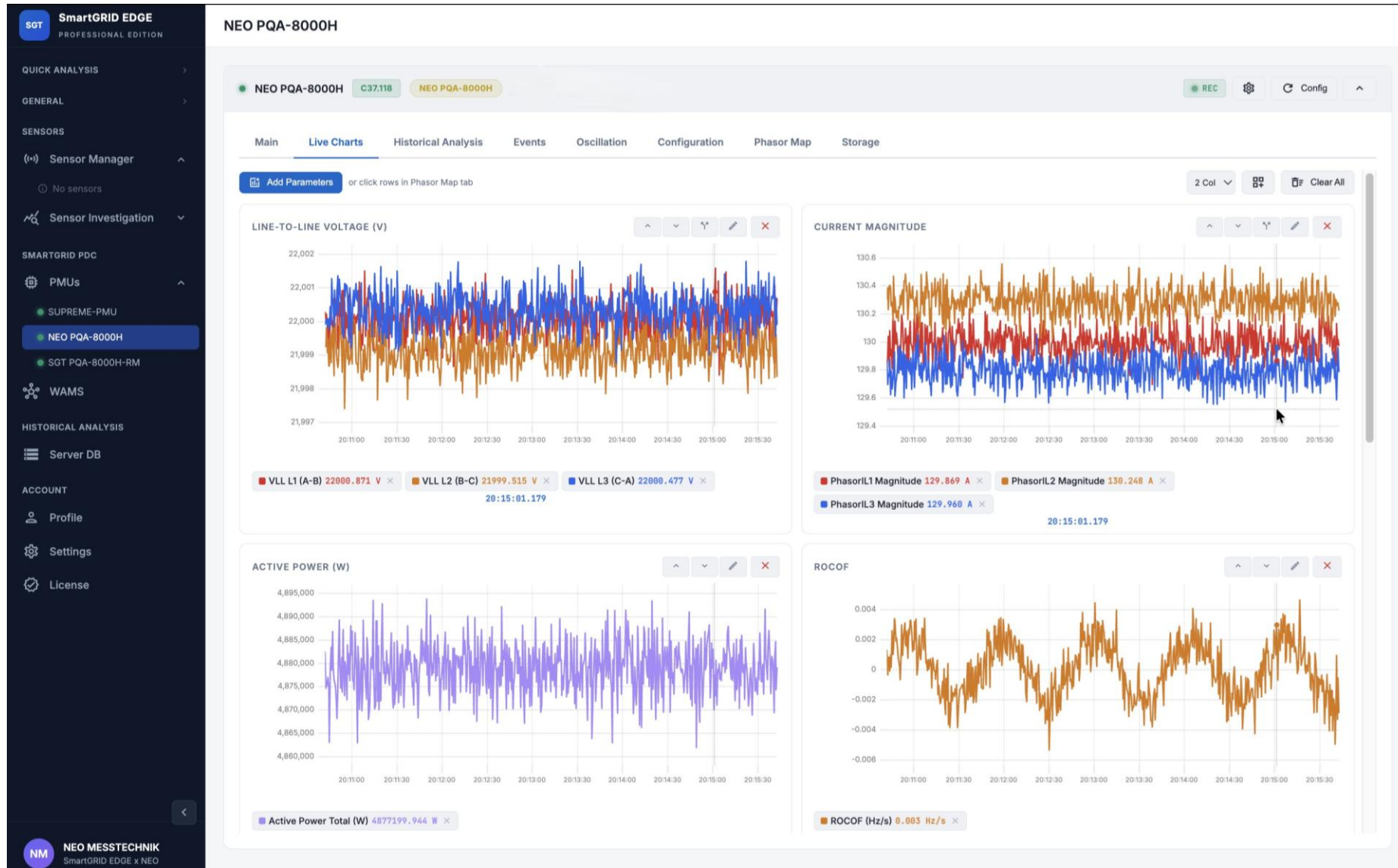
CURRENT DEMAND (15M)	MAXIMUM DEMAND

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- **Live Charts**
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- Phasor Playback
- Events (Real-Time & Historical)
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SmartGRID EDGE PROFESSIONAL EDITION

NEO PQA-8000H

REC Config

Main Live Charts Historical Analysis **Events** Oscillation Configuration Phasor Map Storage

EVENT RULES

Search rules... All Severities All

ID	NAME	CONDITIONS	LOGIC	SEVERITY	ON	ORDER	ACTIONS
1	Voltage Dip	Voltage Min Phase All < 90		WARNING	<input checked="" type="checkbox"/>	^ v	
2	Voltage Swell	Voltage Max Phase All > 110		WARNING	<input checked="" type="checkbox"/>	^ v	
3	Interruption	Voltage Min Phase All < 3		CRITICAL	<input checked="" type="checkbox"/>	^ v	
4	Frequency Event	Frequency Sys < 49.98		WARNING	<input checked="" type="checkbox"/>	^ v	

EVENT LOG (21)

Search events... All Severities All Status All Rules

ID	START	END	DURATION	EVENT	PHASE	SEVERITY	VALUE
21	20:17:51.499	20:18:13.799	22.30s	Frequency Event	System	WARNING	49.98 - 50.00
20	20:16:54.199	20:17:11.099	16.90s	Frequency Event	System	WARNING	49.98 - 50.00
19	20:15:47.599	20:16:11.099	23.50s	Frequency Event	System	WARNING	49.98 - 50.00
18	20:14:43.899	20:15:05.999	22.10s	Frequency Event	System	WARNING	49.98 - 50.00
17	20:13:47.599	20:14:01.299	13.70s	Frequency Event	System	WARNING	49.98 - 50.00
16	20:12:40.399	20:13:03.399	23.00s	Frequency Event	System	WARNING	49.98 - 50.00
15	20:11:36.299	20:11:58.199	21.90s	Frequency Event	System	WARNING	49.98 - 50.00
14	20:10:40.999	20:10:53.299	12.30s	Frequency Event	System	WARNING	49.98 - 50.00
13	20:09:33.097	20:09:55.797	22.70s	Frequency Event	System	WARNING	49.98 - 50.00
12	20:08:26.997	20:08:50.797	23.80s	Frequency Event	System	WARNING	49.98 - 50.00

NEO MESSTECHNIK  
SmartGRID EDGE x NEO

Averna  
Powered by SPHERA

# Enabled Use Cases

## Operations

Grid Monitoring & Supervision

Congestion management

Outage management

Unintentional islanding detection

Parallel switching operations

Adaptive/centralized protections

## Planning

Hosting capacity calculation

Active Dynamic Filter (ADF) Sizing

Planned outage optimization

Synchronous Condenser Optimal Placement

Short and long-term planning

Renewables Assets

## Asset management

Asset Health monitoring

Power quality monitoring and solution

Post-mortem analysis

Predictive/condition-based maintenance

## Other

Digital twin

Oscillation Stability Detection & Islanding

TSO / DSO Coordination

Bushfire Prevention

Thank you!

Questions?

## CONTACT

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