PMU Status Monitoring at BPA

1/30/2025

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BPA Synchrophasor System Architecture

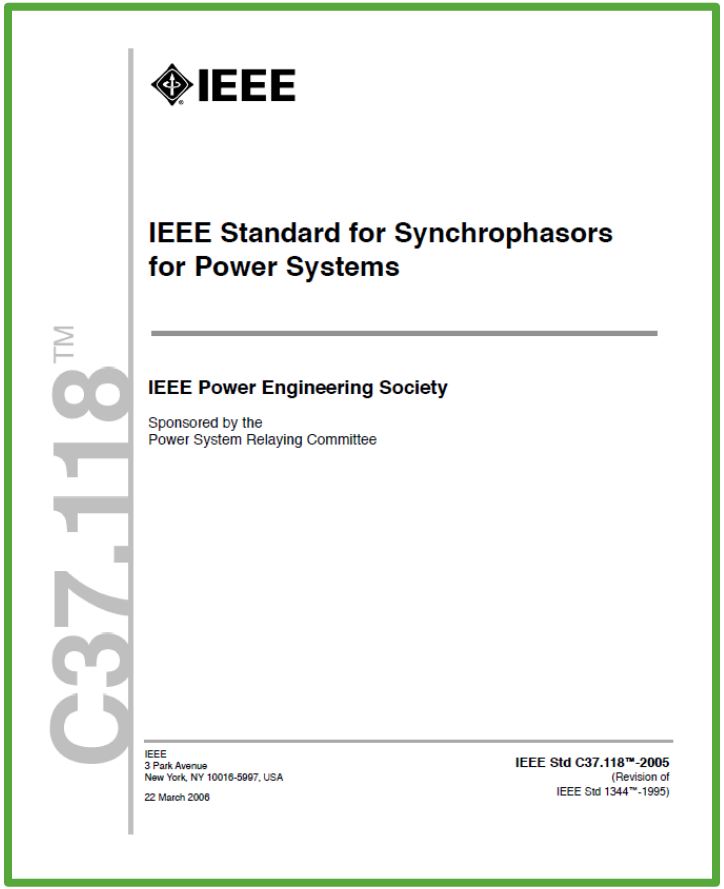
- Control vs Data PMUs at BPA
- C37.118 Protocol
- PDC functionality
- Network architecture

Control vs. Data PMU Installations

- Control PMU Installations
  - Fully Redundant (PMU, GPS, Network, etc.)
  - Encrypted stream, access control
  - Reside inside of physical and electronic security perimeters
  - 79 pairs at 55 sites (1-2 pairs per site)
  - May be used to make operational decisions
  - Referenced in dispatch operational directives (DSO)
- Data PMU Installations
  - Only used for post-event analysis
  - Not referenced in any operational directives
  - No redundancy, encryption
  - May be installed at non-BPA sites
  - Limited security and access control
  - 52 PMUs at 27 sites (1-3 per site)

IEEE C37.118

- Defines measurement performance standards ***and*** message formats
  - Configuration frame
  - Data frame
- May be bidirectional or unidirectional
- Covers both PMU and PDC streams
- Most typically used: 2005 version



IEEE C37.118 – Bidirectional

PMU

PDC

1. Request Configuration Frame
2. Send Configuration Frame
3. Request Data Frames
4. Send Data Frames
5. Stop Sending Data Frames

IEEE C37.118 – Unidirectional

PMU

1 Send Data Frames

2 Send Configuration Frame Once Every Minute

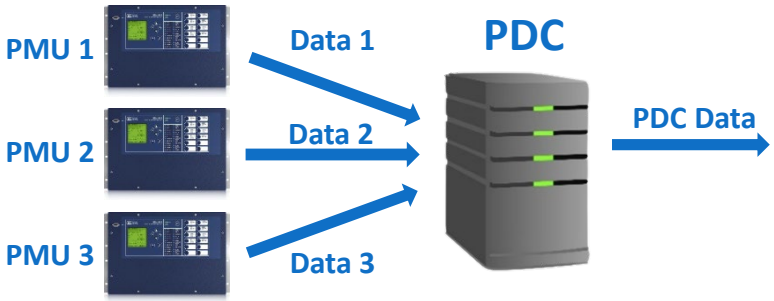
3 Continue Sending Data Frames

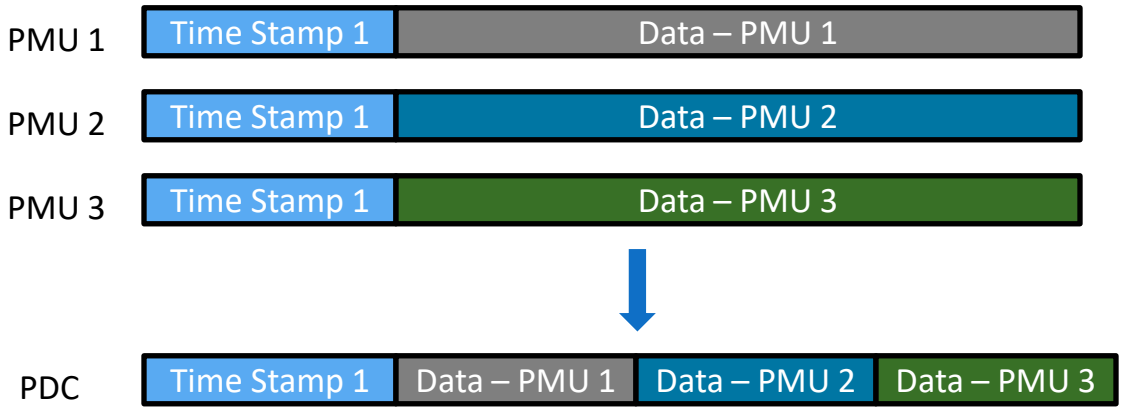
PDC

- In this mode, all C37.118 commands are ignored by the PMU
- Allows for multiple devices to receive streams from the same PMU
- ***This is the method used at BPA***

Phasor Data Concentrator (PDC)

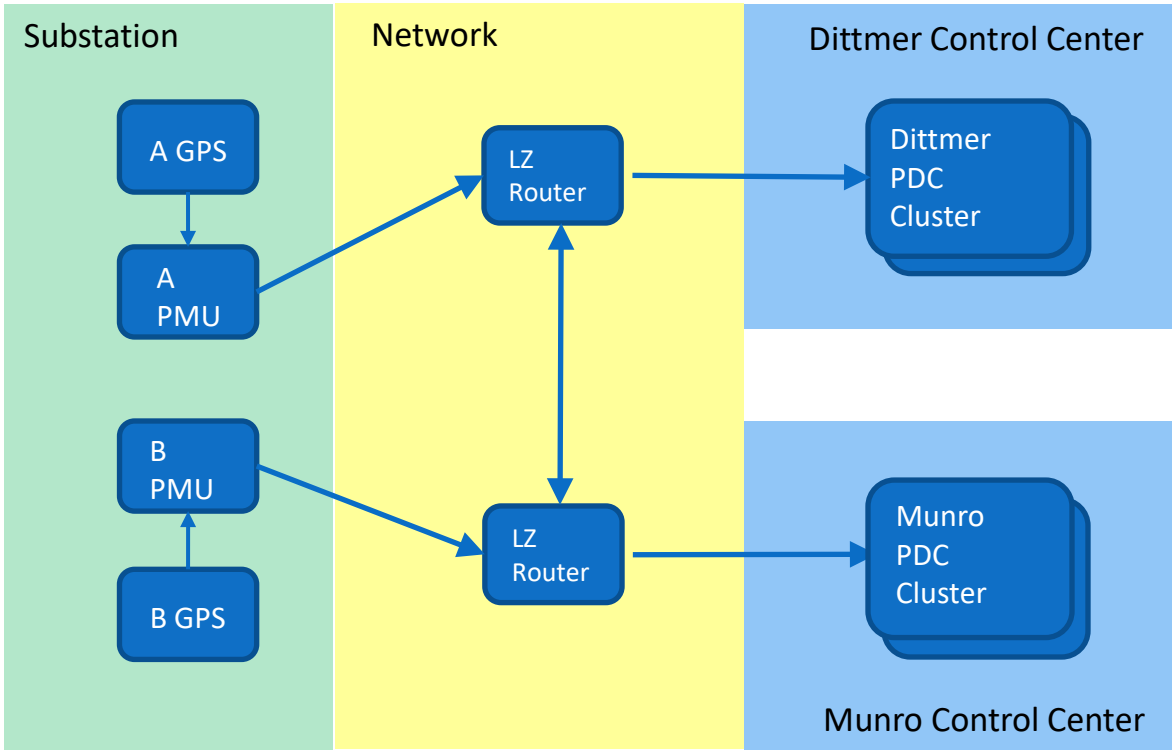
Concatenate and time align data from multiple PMUs



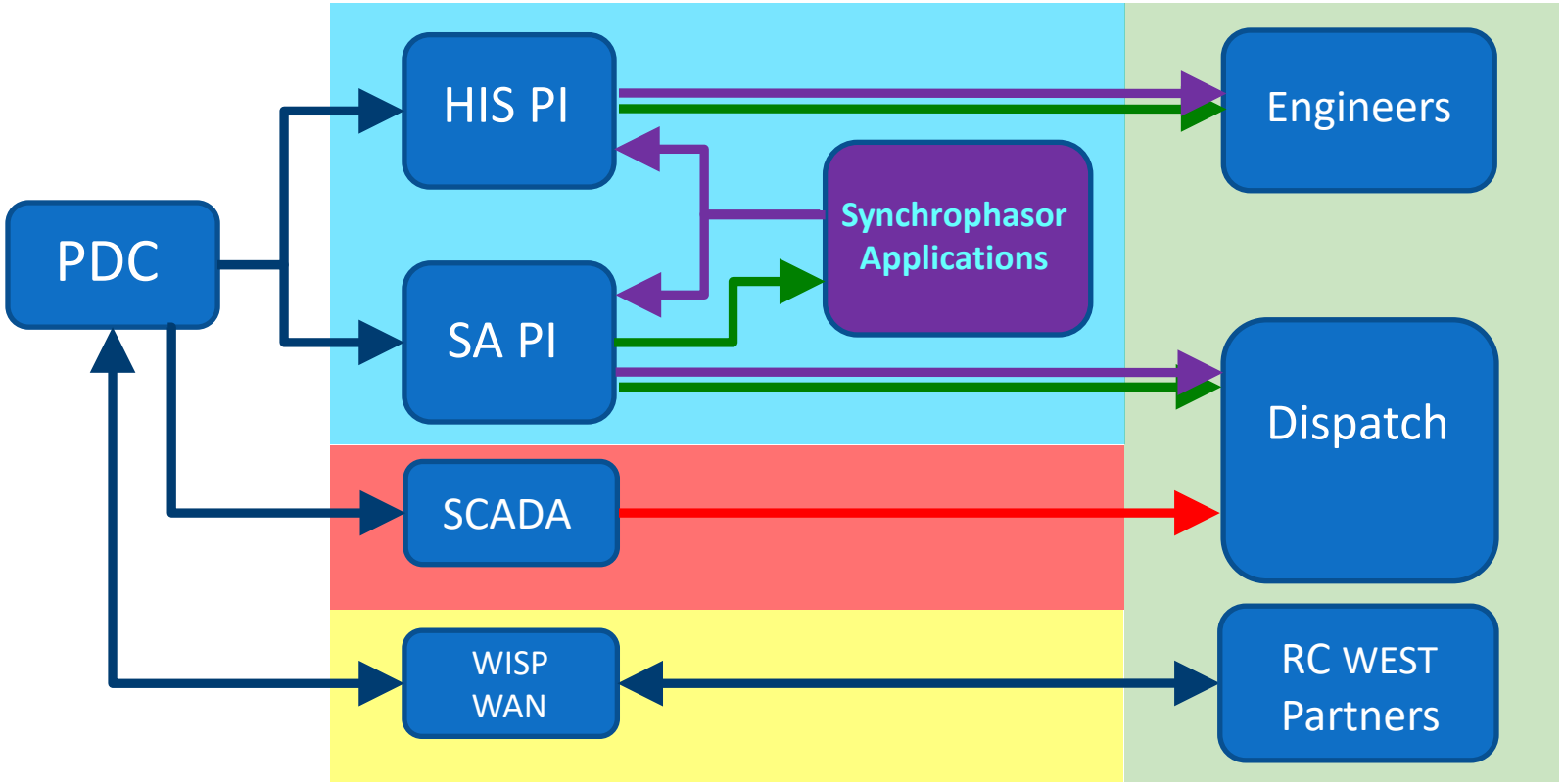


- Typically located in central environments (control centers)
- Usually software installed on PC/server
- Can receive data from PMUs and/or other PDCs
- Provides status information
- Can manage redundant data streams

Architecture: Field to Control Center



Architecture: Control Center Systems



PMU Status Problems

- Typical problems
- Atypical problems
- Other problems

Typical PMU Status Problems

- Drop Out
  - This typically occurs when a network equipment failure prevents the data packet sent by the PMU from reaching the PDC. When the PDC detects a missing data packet, it sets ALL the C37.118 status bits for that packet.
- Sync Error
  - This error is reported by the PMU in the C37.118 status word. It occurs when the PMU has a problem with its connection to the GPS clock, or if an error is detected in the accuracy of the IRIG-B clock signal.
- PMU Error
  - This error is also reported in the C37.118 status word. This error bit is set by the PMU if it detects an internal hardware or software problem.

Typical PMU Status Problems

- Data Invalid

  BPA uses the SEL-487E Relay as a PMU. These devices have been specially configured to use the following logic to set this C37.118 status bit:

  – **Undervoltage** condition for the primary bus voltage reference of the PMU.
    - If both bus voltages are low, then the Data Invalid is NOT set for either PMU.

  – **Test Mode**
    - Set with a switch on the PMU.

  – **Hardware alarm**
    - The Data Invalid bit can be set by the PMU for a device problem that is not necessarily a PMU Error condition.

  – **Access alarm**
    - Triggered when a user logs into the PMU.
    - Not yet configured for all BPA PMUs.

Atypical PMU Status Problems

- Momentary Periodic Drop-Outs
  - This is a very specific problem to BPA. It is characterized by a momentary drop-out that occurs on a 177 second period. It can affect a single PMU or multiple PMUs simultaneously.
- PI Interface status issues
  - Again, this is a problem that is probably specific to the BPA implementation of its Synchrophasor system. When this problem occurs, the PMU data is delayed in its delivery to PI. It eventually arrives. But the delay can affect the functionality of the custom BPA Synchrophasor applications.

Other PMU Status Problems

- Test-Fail Status
  - Each CONTROL PMU at BPA has a maintenance switch that sets the C37.118 Data Invalid status for all signals from that PMU. When a craftsman needs to work on a PMU, the standard procedure is to set this switch. There is also a bit in the PMU digital word mapped to a PI tag that allows distinction of a Test-Fail Data Invalid.
- Redundant Bus Undervoltage
  - Each PMU in a redundant pair is configured to monitor reference one of 2 busses for its primary voltage reference. If both busses are undervoltage, then the Data Invalid is NOT set for either PMU.
- Multiple PMUs with bad status
  - This situation is typically the result of a network or PDC server problem.

PMU Status Monitoring Systems

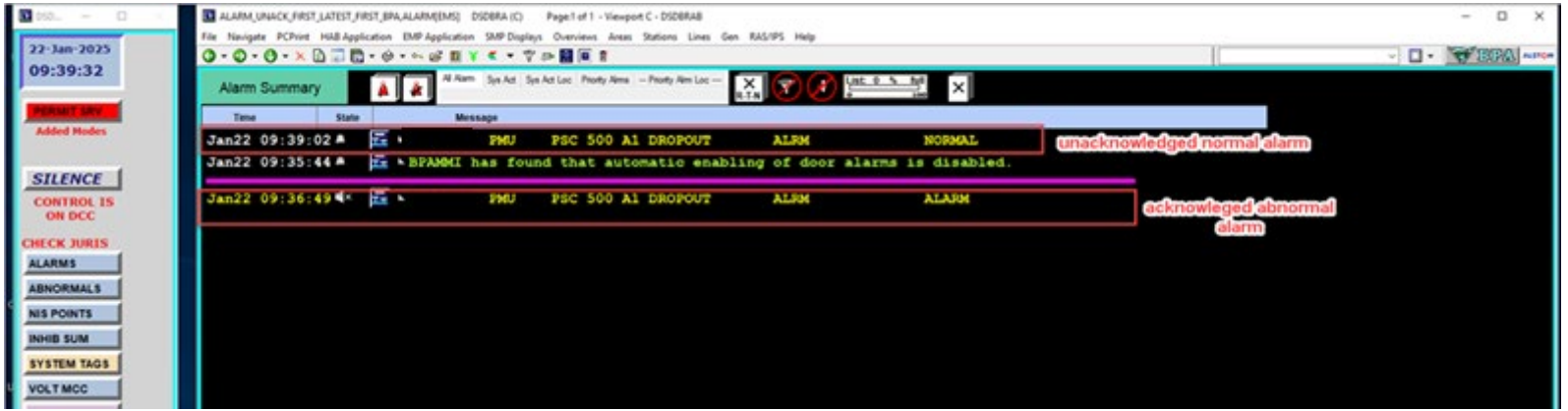
- SCADA alerts to System Operations
- PI Notifications
- PI Vision displays for Network Operations

PMU Status SCADA display and Alerts

PMU Communications

EPDC and EPDC_STS RTUs

Station		KV-Angle	PMU 3-PH KV-Mag.	PMU A-PH KV-Mag.	SCADA XDCR	Freq.	Drop Out A	Drop Out B	Out of Sync A	Out of Sync B	PMU Error A	PMU Error B	Data Invalid A	Data Invalid B
PMU Name	500 North	-14.66	542.18	540.92	544.36	60.0118	Off	Off	Off	Off	Off	Off	Off	Off
	500 South	-14.68	543.09	541.30	545.34									



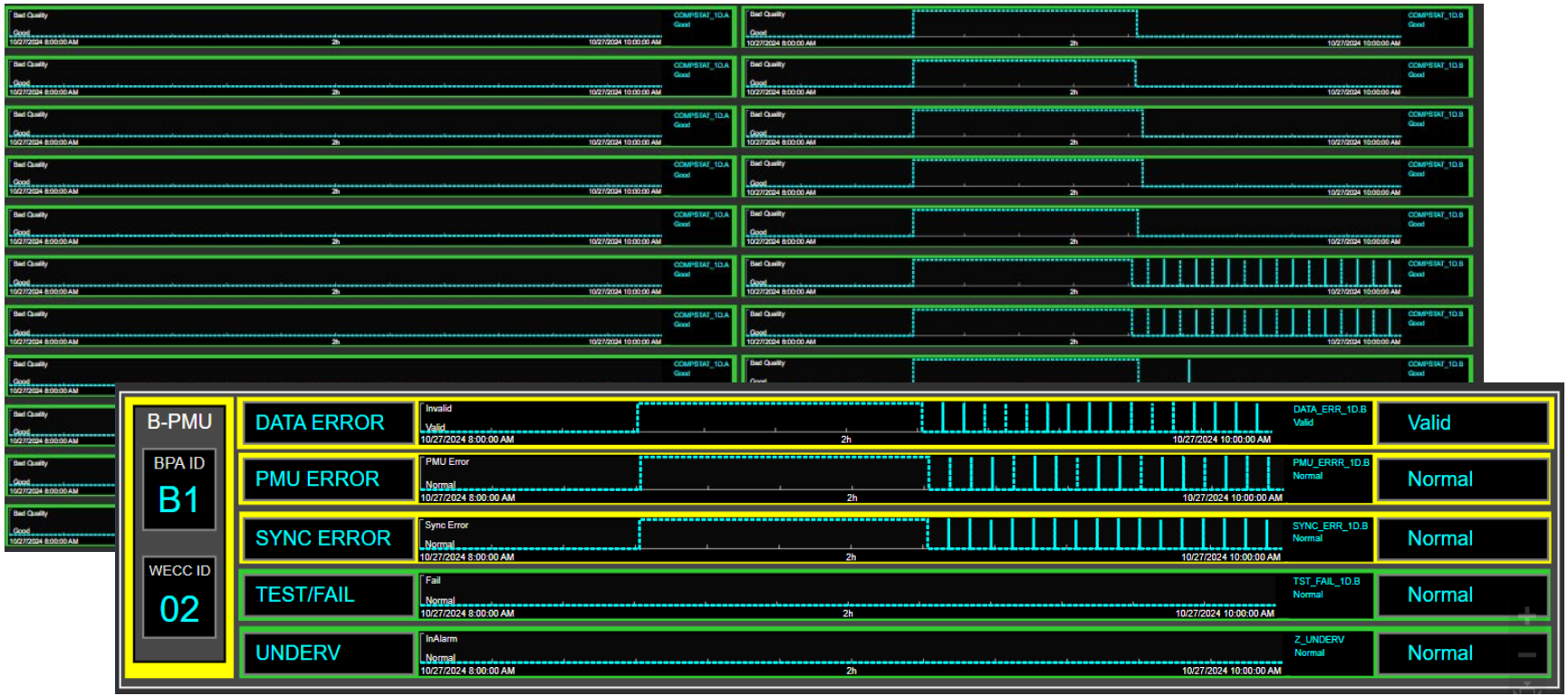
PI Notifications (email)

ERROR TYPE	SCOPE	DESCRIPTION	TYPICAL CAUSE	RECIPIENTS
Composite Status	Redundant Pair	Both PMUs in a redundant pair simultaneously report a C37.118 Composite Status problem	Communication trouble	Synchrophasor Team PMU support management
Composite Status	All PMUs at a Control Center	All redundant PMU pairs at a control center simultaneously report a Composite Status problem.	Multiple possible causes	Synchrophasor Team
Composite Status	All B-PMUs at DCC or All A-PMUs at MCC	All PMU data being transmitted (one way or both directions) across the Inter-Control Center Link stops updating.	Communication trouble	Synchrophasor Team Network support management

PI Notifications (email)

ERROR TYPE	SCOPE	DESCRIPTION	TYPICAL CAUSE	RECIPIENTS
PMU Error	Single PMU	C37.118 PMU Error status is set, but not C37.118 Data Error	PMU device problem	Synchrophasor Team Network support management Local network support team
Drop out	Single PMU	C37.118 Data Invalid is set and C37.118 PMU Error is set	GPS Clock problem or network communications	Synchrophasor Team Network support management Control center network support
Sync Error	Single PMU	C37.118 Sync Error status is set, but not C37.118 Data Error	GPS Clock problem or network communications	Synchrophasor Team Network support management Control center network support
Test-Fail	Single PMU	Test-Fail digital bit is set	PMU maintenance	Synchrophasor Team Systems Operations
177s Drop-outs	Single PMU or Multiple PMUs	Momentary drop-outs occur on a regular periodic schedule at 177sec intervals.	Communication trouble	Synchrophasor Team Control center network support

PMU Status Displays: 177-sec Drop-Outs



PMU Status Problem Report Daily email

SYNC ERR = Sync Error and NOT PMU Error and NOT Test-Fail and redundant PMU is Good

DROP OUT = Data Invalid and NOT PMU Error and NOT Test-Fail and redundant PMU is Good

A PMUs STATUS SUMMARY: 01/16/2025

PMU Status was all good today.

B PMUs STATUS SUMMARY: 01/16/2025

PMU Status was all good today.

A PMUs STATUS SUMMARY: 01/15/2025

PMU	STATUS	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	TOTAL
[redacted]	DROP OUT	-	-	-	-	-	-	-	-	-	-	-	-	-	606	-	-	-	-	-	-	-	-	-	-	606
[redacted]	SYNC ERR	-	-	-	-	-	-	-	-	-	-	-	31	126	132	-	-	-	-	-	-	-	-	-	-	288

B PMUs STATUS SUMMARY: 01/15/2025

PMU	STATUS	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	TOTAL
[redacted]	DROP OUT	-	-	-	-	-	-	-	-	-	-	761	-	-	-	-	-	-	-	-	-	-	-	-	-	761
[redacted]	SYNC ERR	-	-	-	-	-	-	-	-	-	472	2032	-	-	-	-	-	-	-	-	-	-	-	-	-	2504

PMU Status Problem Report Weekly email

Same logic as the Daily Report
SYNC ERR = Sync Error and NOT PMU Error and NOT Test-Fail and redundant PMU is Good
DROP OUT = Data Invalid and NOT PMU Error and NOT Test-Fail and redundant PMU is Good

A PMUs STATUS SUMMARY: 01/13/2025 - 01/19/2025

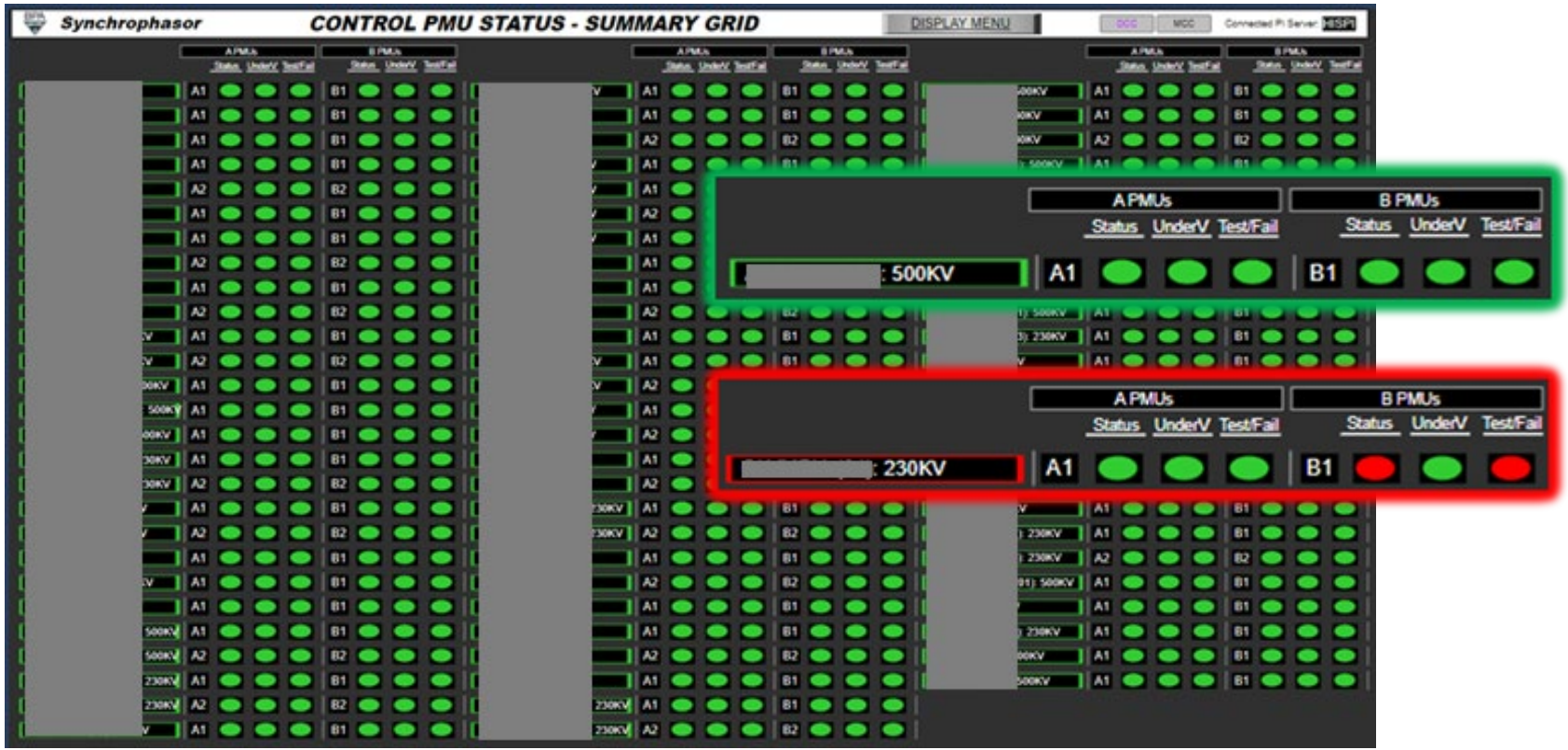
		01/13		01/14		01/15		01/16		01/17		01/18		01/19		TOTAL	
PMU	STATUS	TIME	COUNT	TIME	COUNT	TIME	COUNT	TIME	COUNT	TIME	COUNT	TIME	COUNT	TIME	COUNT	TIME	COUNT
[redacted]	DROP OUT	-	-	-	-	606	1	-	-	-	-	-	-	-	-	606	1
[redacted]	SYNC ERR	-	-	-	-	288	3	-	-	-	-	-	-	-	-	288	3
[redacted]	DROP OUT	-	-	-	-	-	-	-	-	-	-	-	-	0.07	1	0.07	1

B PMUs STATUS SUMMARY: 01/13/2025 - 01/19/2025

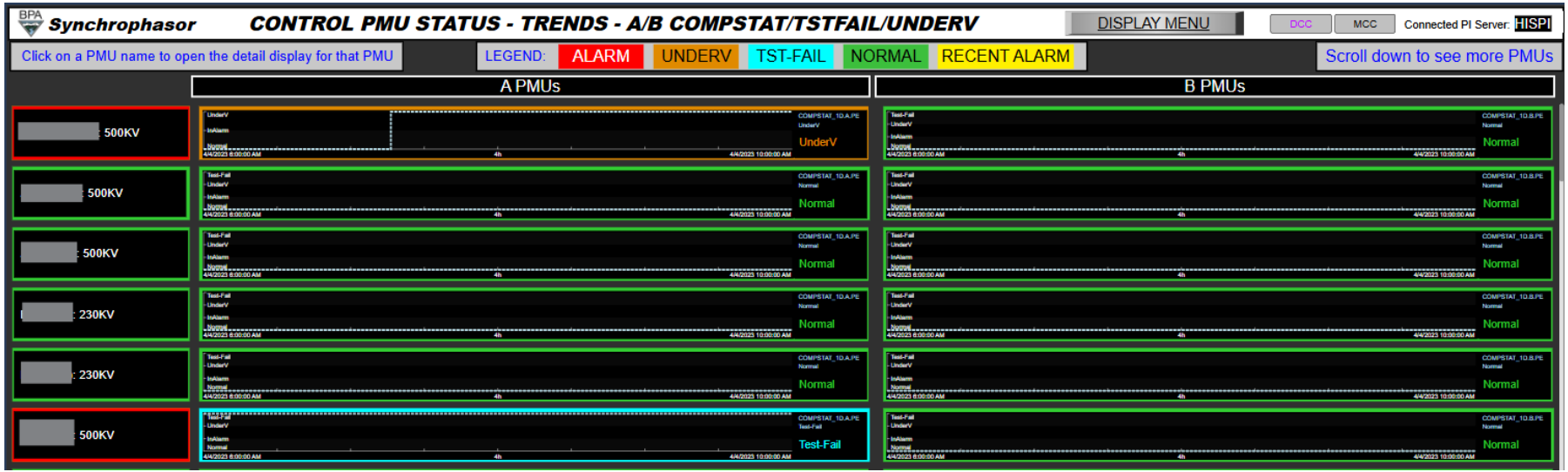
		01/13		01/14		01/15		01/16		01/17		01/18		01/19		TOTAL	
PMU	STATUS	TIME	COUNT	TIME	COUNT	TIME	COUNT	TIME	COUNT	TIME	COUNT	TIME	COUNT	TIME	COUNT	TIME	COUNT
[redacted]	DROP OUT	-	-	-	-	761	1	-	-	-	-	-	-	-	-	761	1
[redacted]	SYNC ERR	-	-	-	-	2504	5	-	-	-	-	-	-	-	-	2504	5
[redacted]	DROP OUT	-	-	-	-	-	-	-	-	18	549	-	-	-	-	18	549
[redacted]	DROP OUT	-	-	-	-	-	-	-	-	15	439	-	-	-	-	15	439

PMU Status Displays: SYNC/DROP Example

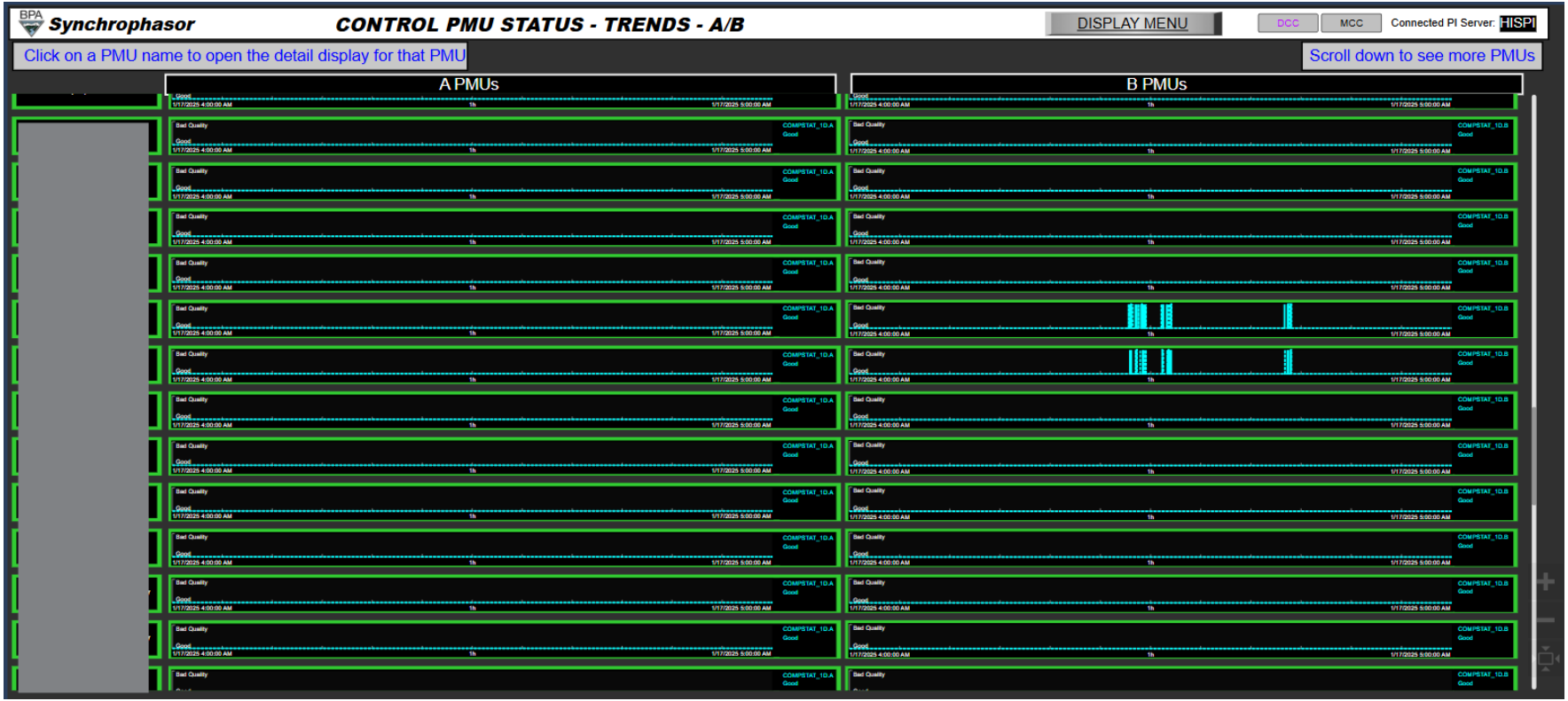
PI Vision PMU Status Summary



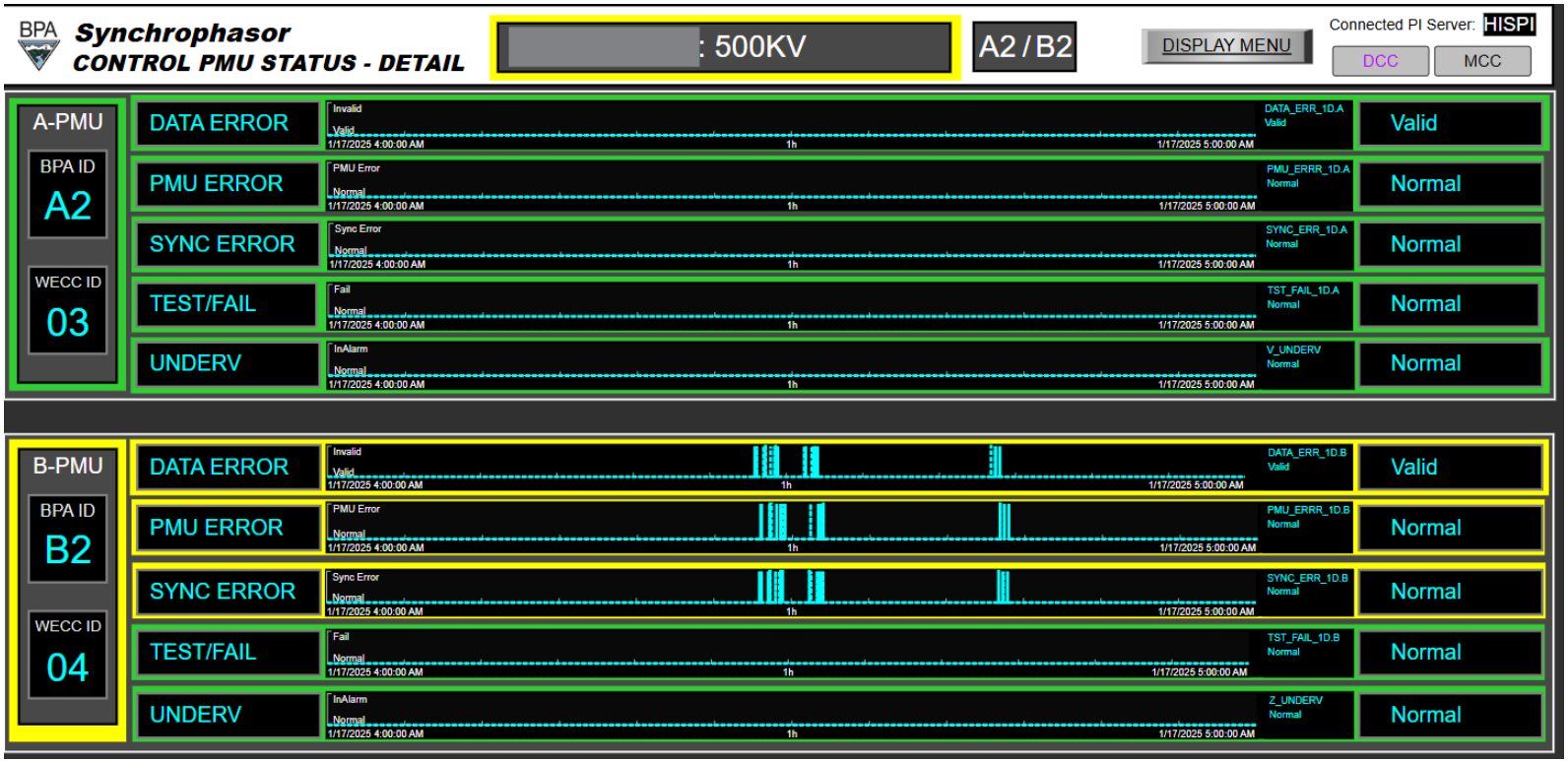
PI Vision PMU Status with COMPSTAT, TSTFAIL & UNDERV



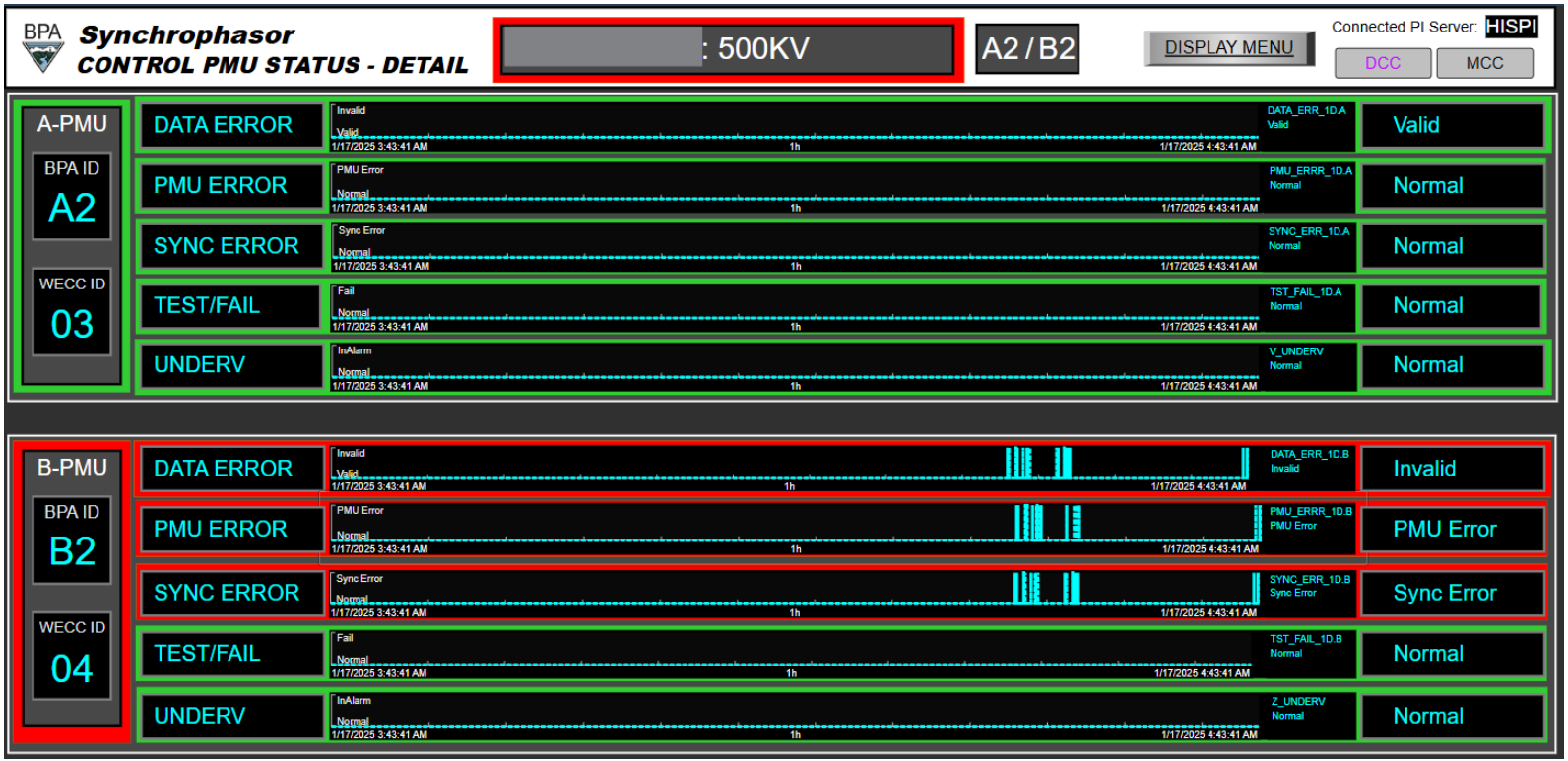
PMU Status PI Vision Display – COMPSTAT TRENDS A/B



PMU Status PI Vision Display – PMU Details



PMU Status PI Vision Display – PMU Details



PMU Status Response Systems at BPA

Synchrophasor Team

- We pay the most attention to PMU status – all the time.
- We receive PMU status notifications from both the Development and Production systems. And we receive notifications that are exclusively sent to us.
- We coordinate response activities between craftsmen in the field, system operations and control center network operations.
- We are continuously developing new monitoring tools and improving existing tools.

District & Control Center Craftsmen

- There are 2 groups of craftsmen that support PMU systems:
  - Power system device support: This group conducts work on the actual PMU devices.
  - Network communications systems support: This group supports the GPS clocks and all network systems.
- As described previously, each PMU has a Test/Fail switch that the craftsman will set before performing any maintenance. The maintenance procedures include a call to the Synchrophasor Team before any work is performed.
- There is a daily morning meeting with representation from the control centers network operations teams to discuss any existing PMU problems or planned maintenance. The Synchrophasor Team also attends these meetings.

Systems Operation Center (SOC)

- The SOC receives alerts from SCADA and contacts appropriate field staff or the Synchrophasor Team as needed.
- Operations will reach out to the SOC for support if needed.

BPA Labs
and the Synchrophasor Coordination Team

- This group isn't really a "response" entity. It is more focused on planning and development.
- If there is a recurring or persistent PMU status problem, this group will help to coordinate the response. All the other response teams have representation in this group.
- We meet monthly to keep everyone appraised of ongoing issues and development work.

Summary

And DNMTT focus points

Effective PMU Status Monitoring requires a significant investment in methods and response systems.

- Real time monitoring of multiple different types of possible status symptoms is required.
- Each PMU system may have different types of unique problems.
- Redundant alert methods are helpful.
- Constant vigilance is mandatory.
- Dedicated and qualified technical support is essential.

Contact Information

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