WASA and the Roadmap to WAMPAC at SDG&E®

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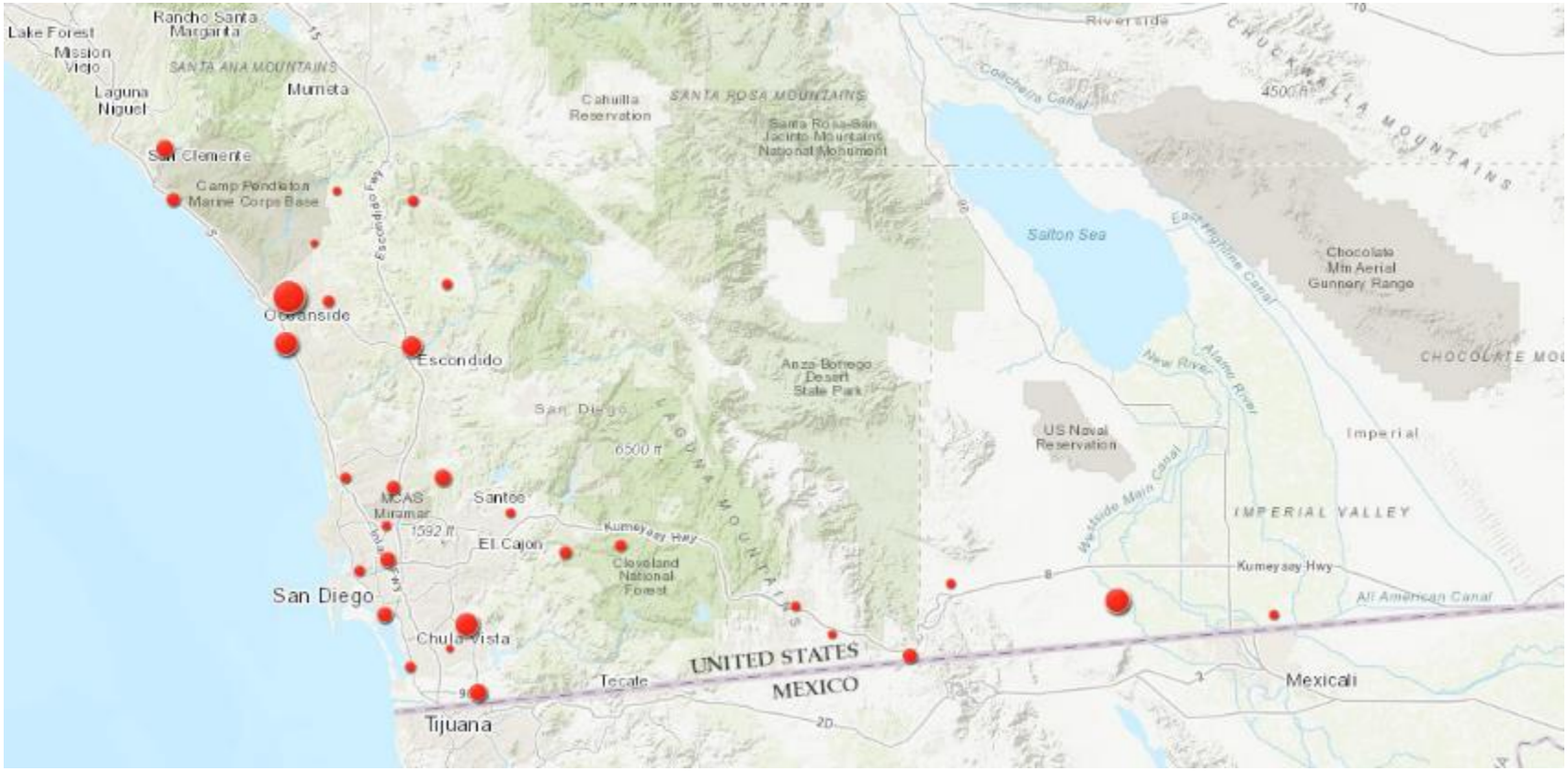
SDG&E® Synchrophasor Success

- The utility industry is accelerating its adoption of synchrophasor measurements and PMU data over the last decade.
- Since 2010 SDG&E has significantly improved reliability performance and operational response capabilities by integration of synchrophasor data for improved wide area situational awareness (WASA).
- PMU installations continue since the completion of the first phase in 2013, supported by ongoing improvements in communications and data archiving infrastructure.
- PMUs now cover all 500 kV and 230 kV tie lines, with penetration into 138 kV and 69 kV in progress.
- Presently sharing data with SCE, APS, and SRP for tie-line phase angle delta calculations.
- Plan to exchange measurements with PG&E, BPA, AESO, BCH, and CFE for improved wide area situational awareness.

PMU Locations

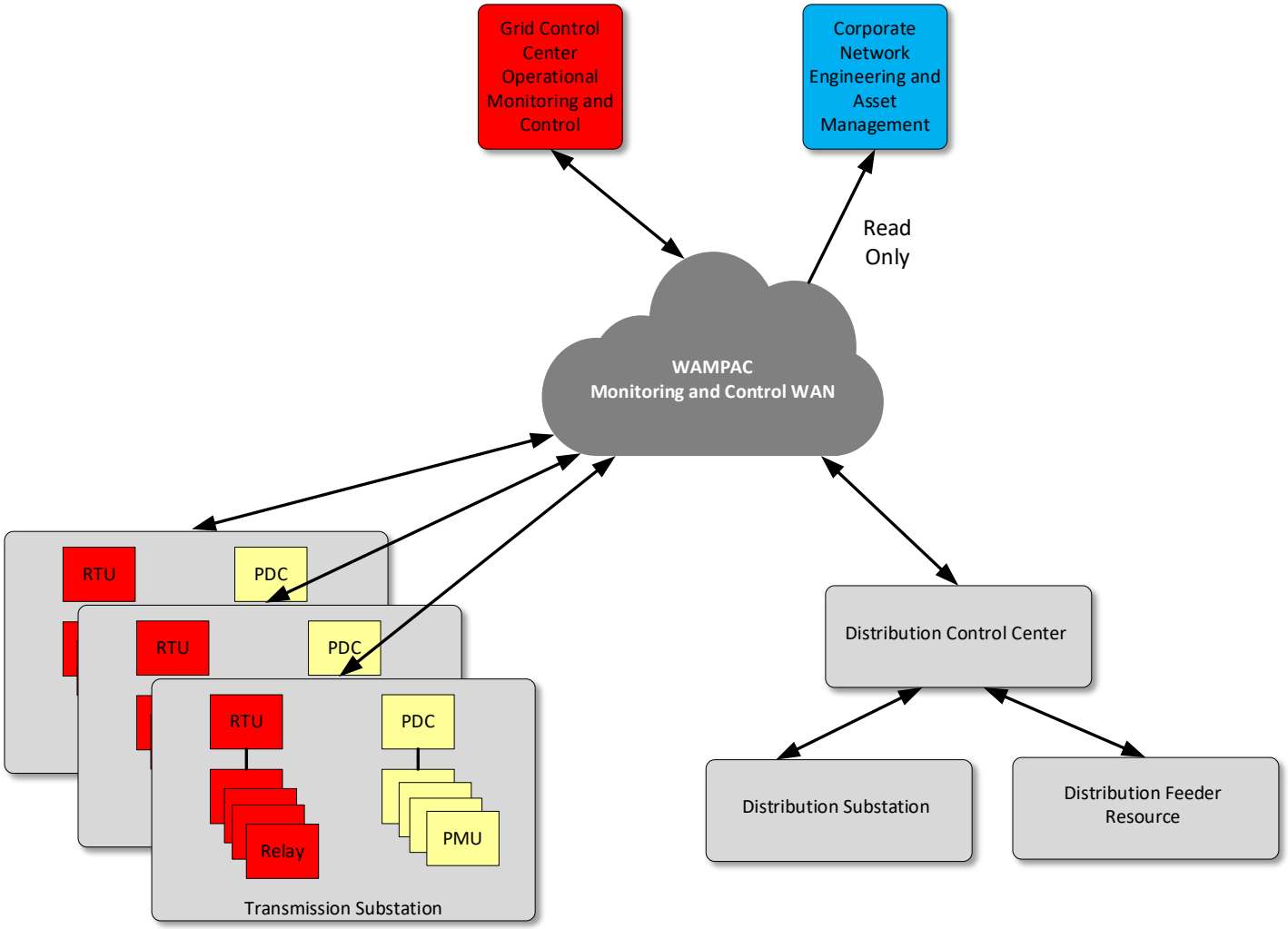
Approximately 110 PMUs installed in 23 transmission substations with ongoing additions



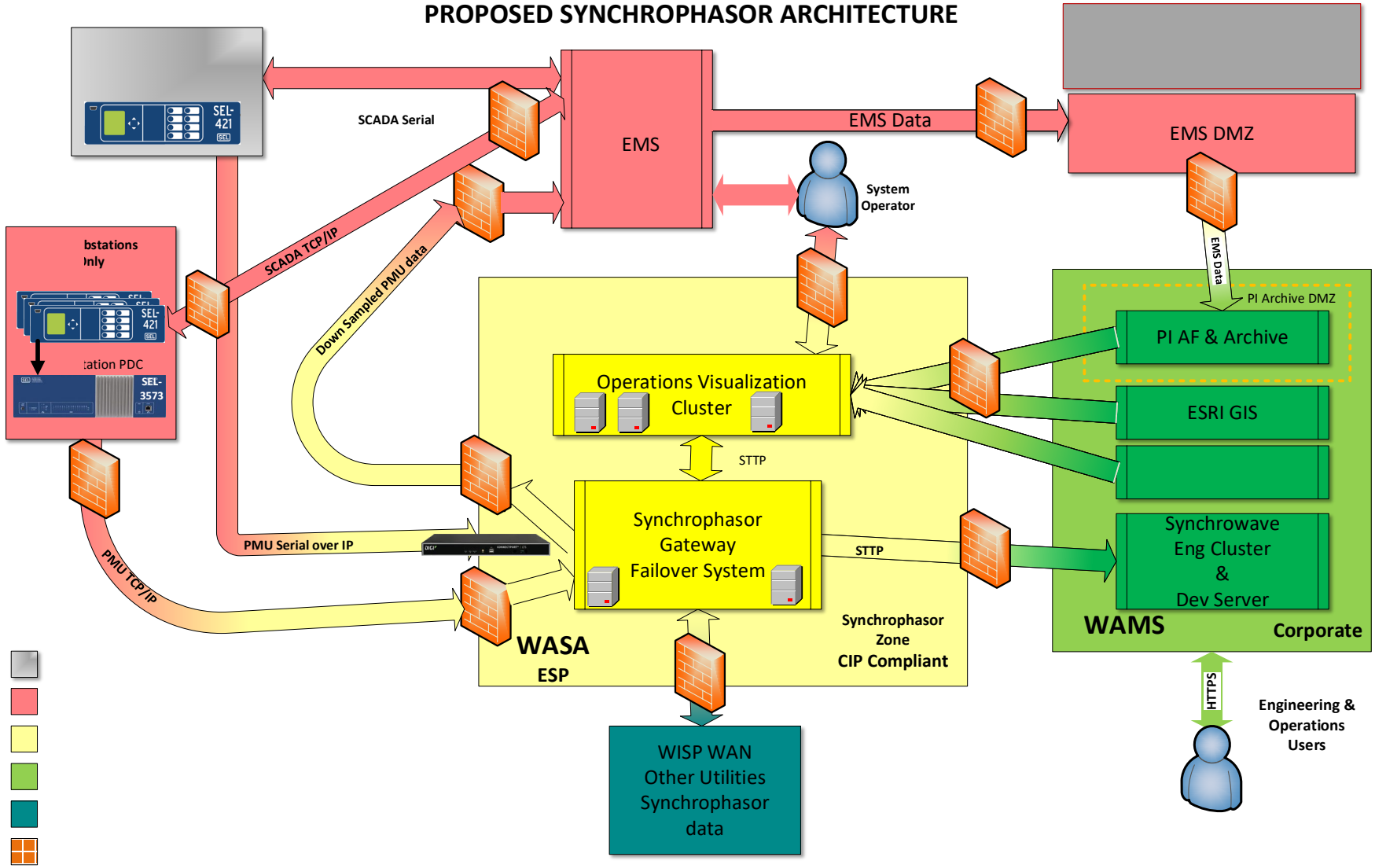
SDG&E® Synchrophasor Success

- Early adopter of the Grid Protection Alliance Gateway Exchange Protocol.
- Now participating in the DOE Advanced Synchrophasor Protocol (ASP) development and demonstration project .
- Developed and deployed falling conductor system using synchrophasor data on feeders; now adapting the falling conductor system to transmission lines.
- Committed to using synchrophasor data for decision making in the control room.
- Developed and deployed in-house WASA application using synchrophasor data.
- Now developing new state-of-the-art multifunction synchrophasor application with vendor for Operations deployment in Q1 2021.

Typical PMU System Architecture



SDG&E® WASA System Architecture



WASA and WAMPAC Functions

System operator situational awareness

- Voltage, current, phase profiles & variations.
- Voltage & angular stability warnings.
- Normal versus unusual flow patterns.

WASA and WAMPAC Functions

SCADA and EMS support

- WASA has been separate from SCADA and EMS, but...
- Dense PMU deployments are covering the entire transmission system.
- PMU data at 30-60-120 accurate measurements per second is the vastly better data gathering platform for all SCADA and EMS functions that depended on RTU or data concentrator values every 1-5 s.
- We can improve EMS functions and add new functions with phase angles across system and beyond, sequence values, F, ROCOF, redundant and derived backup measurements.
- Some EMS now integrate down-sampled PMU data.

WASA and WAMPAC Functions

Disturbance monitoring and analysis

- PMU system data storage and presentation for disturbance monitoring per DME requirements of NERC PRC-002-2.
- Stable measurements of F and ROCOF included.
- High-rate data shows oscillations, swings, event propagation not visible in SCADA data.
- Use real system responses to known events to tune models (automated tools coming).

System State and Condition Monitoring

- Improve conventional state estimation with accurate and redundant measurements.
- Holistically assess power apparatus and electrical measurements for state estimation and alarming of failures.
- Present actionable diagnostic information for field corrective maintenance of power and measurement apparatus.

STATCOM oscillation eluded SCADA – found with PMU data

Display showing most recent detected disturbances, the list is updated in real-time.

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WASA and WAMPAC Functions

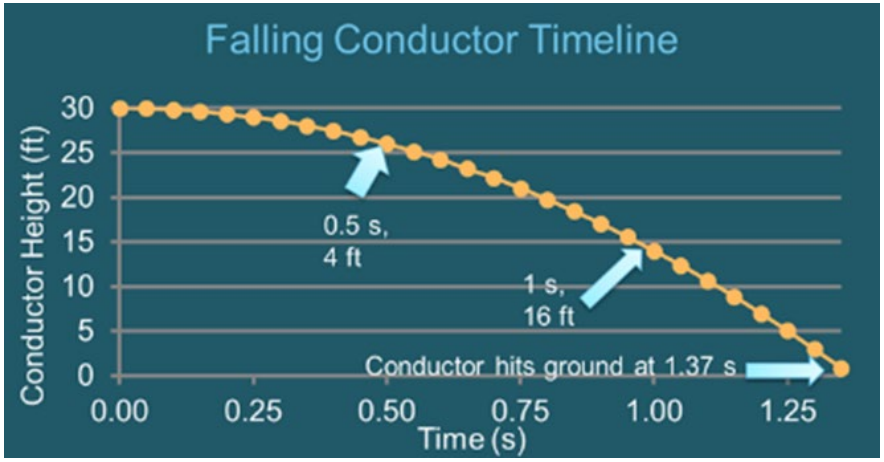
Wide-area RAS and SIPS

- Add a high-speed control messaging service – IEEE C37.94 TT, IEC 61850 GOOSE or R-GOOSE.
- Supports any conventional stability or thermal RAS.
- Angular and voltage difference measurements across grid enable adaptive RAS.
- Act to fix observed emergency or event – not tied to fixed parameters of a planning study made at one point in time on a model whose parameters may have changed.

WASA and WAMPAC Functions

Fire and hazard risk reduction

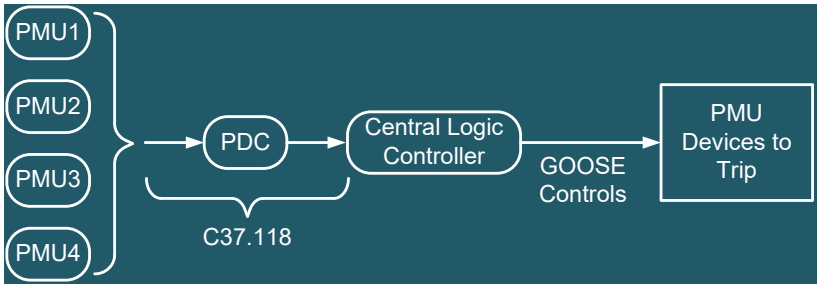
- SDG&E is actively deploying distribution falling conductor protection (DFCP), evaluated in testing mode since 2016.
- Continuing installations in FiRM (Fire Risk Mitigation) locations.
- Trips failed section after broken conductor has fallen only a few feet.
- Conductor lands dead –
  no high-impedance fault to detect,
  no arcing.

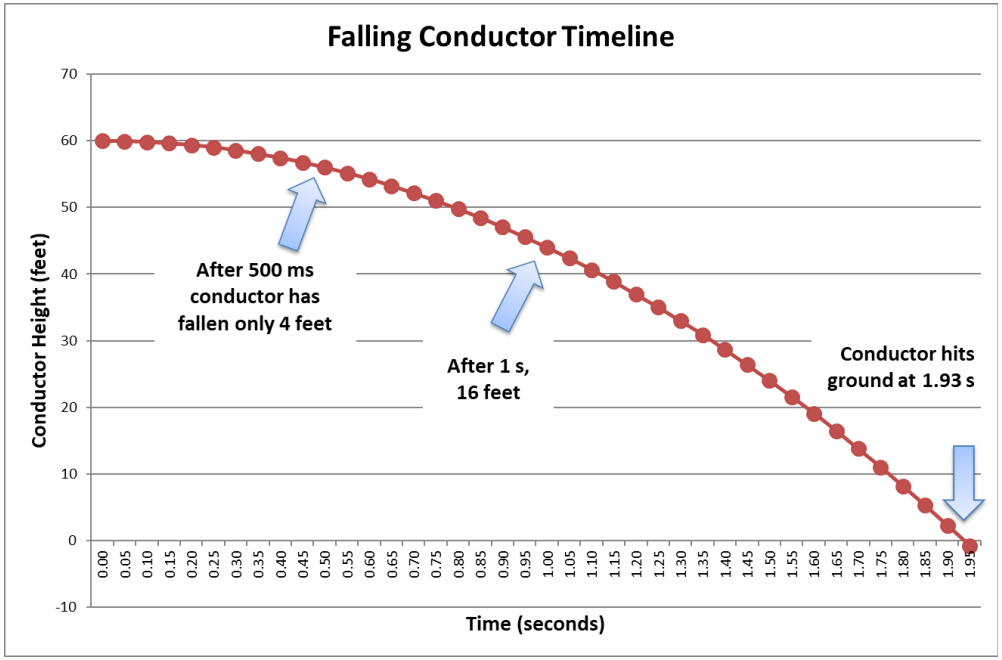


WASA and WAMPAC Functions

Fire and hazard risk reduction

- Transmission falling conductor protection (TFCP) being developed on transmission PMU infrastructure.
- Based on current and voltage synchrophasor measurement streams.
- Current comparisons detect open conductors and faults.
- TFCP uses existing PMUs and communications (DFCP needs radio system and distributed circuit PMUs).
- Initial focus on 69 kV lines.

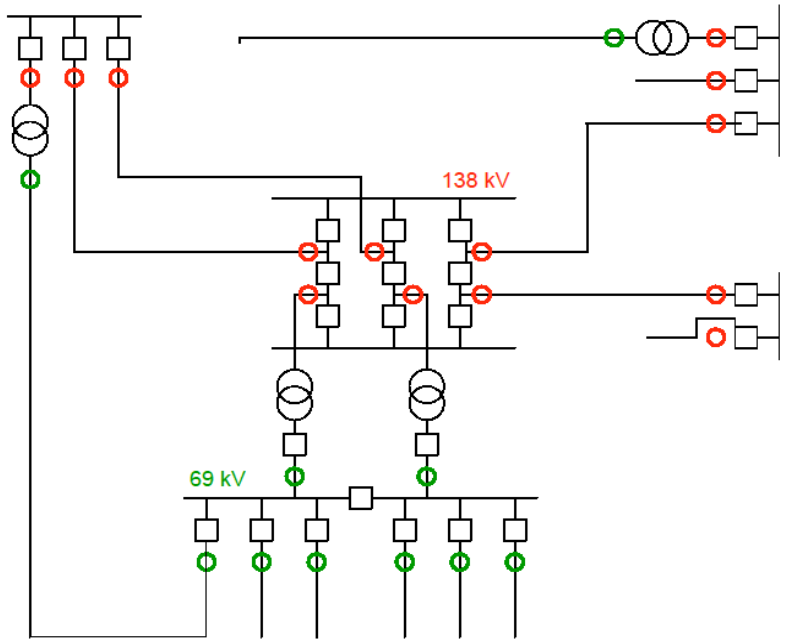




WASA and WAMPAC Functions

Wide-area fault and swing protection

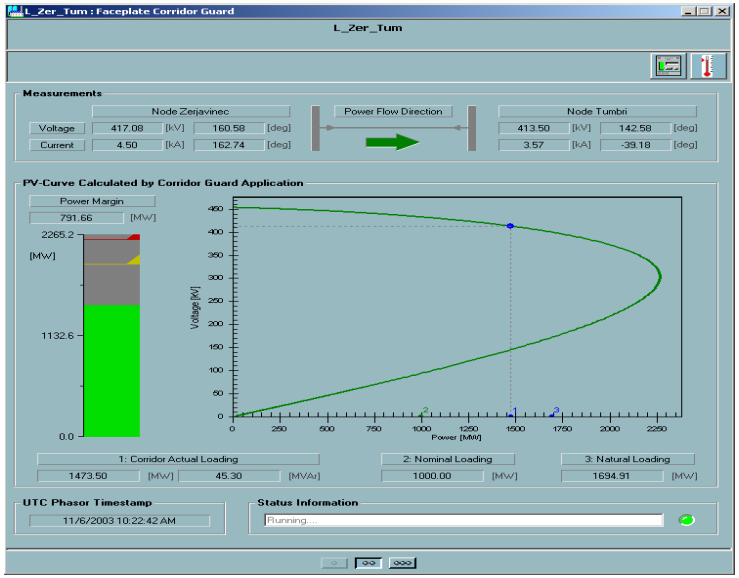
- Holistic current differential protection on high-density PMU deployment.
- A couple of cycles behind local high-speed protection.
- Surgically removes faulted zones and failed breakers before Zone 2 and Zone 3 remote backup can react.
- Z2/Z3 never get to trip – safety net needs minimal coordination maintenance.
- Immune to swings, low fault currents, and inverter-based generation.
- Separate swing protection/islanding with voltage phasors.
- See CIGRÉ Session 2014 B5-112.

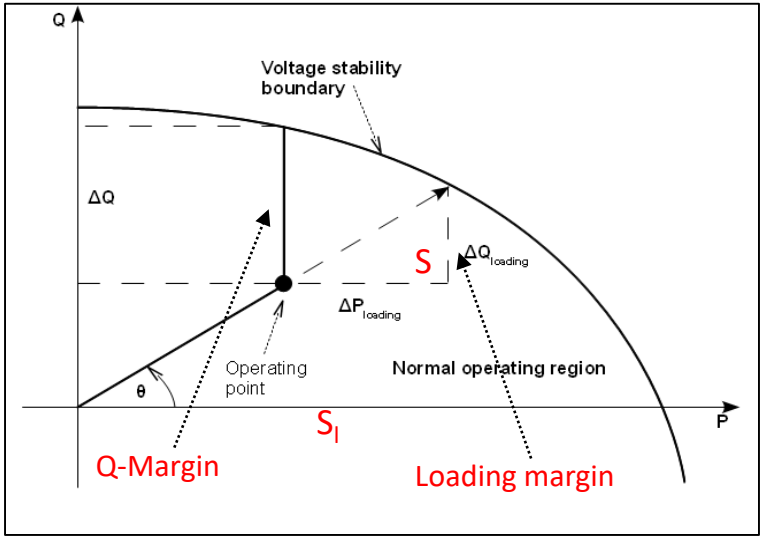


WASA and WAMPAC Functions

Wide-area voltage stability management

- PMU-based voltage stability analysis (VSA) detects fast dynamic instabilities that EMS VSA will miss.
- PMU voltage data enables real-time voltage instability indicator (RVII).
- RVII is not dependent on models and detects instability in under 1 s.
- RVII works selectively and securely when system voltage is high (UVLS would misoperate).
- RVII works reliably when voltage is low (UVLS would fail to trip to prevent collapse).





WASA and WAMPAC Functions

Wide-area control

- Based on accurate system models achieved from PMU based model tuning.
- Add high-speed control communications as for RAS.
- Holistic wide-area control inherently superior to local control of electrical values.

PMU system self-monitoring

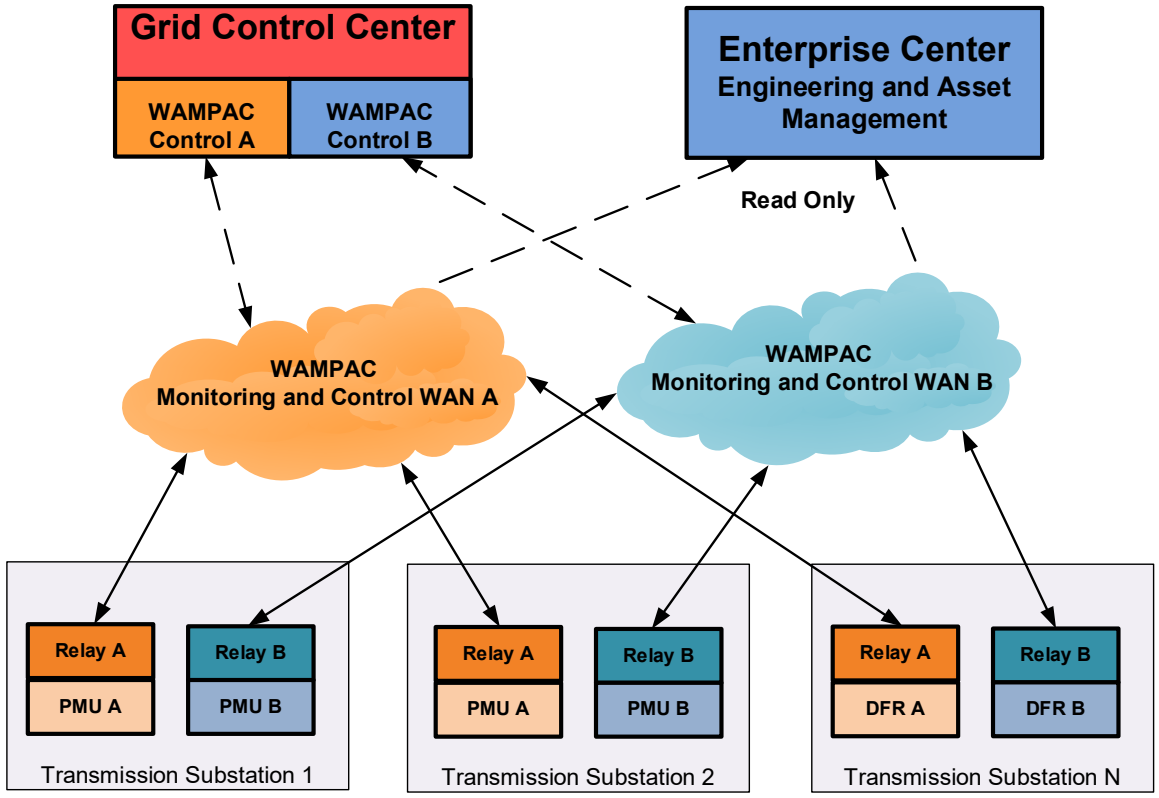
- Massive wide-area deployment of PMUs and comms requires a self-monitoring and self-diagnosing functionality.
- Built of self-monitoring IEDs with overlapping heartbeat communications exchanges – gapless monitoring for CBM.

PMU System Components

- Phasor measurement units (PMUs)
  - Stand-alone, DFRs, or relays which have control output/trip capability.
  - Synchrophasors per IEEE C37.118-2005, C37.118.1-2011 P-Class and M-Class, or IEC-IEEE 60255-118-1 Edition 1 (2019) P and M Classes.
  - Comms protocol support C37.118-2005, C37.118.2-2011; IEC 61850-8-1 Edition 2 routable sampled values (R-SV) is secure solution with automation of configuration.
  - New streaming telemetry transfer protocol (STTP).
- Phasor data concentrators (PDCs)
  - Merge and align multiple data streams of different configurations in substation or region.
  - Unify communications into one stream from substation.
  - Locally store data in substations as required for backup.
  - Field Gateway PDC or Super PDC (SPDC) at PMU communications channel hub location collects system-wide data for application servers.

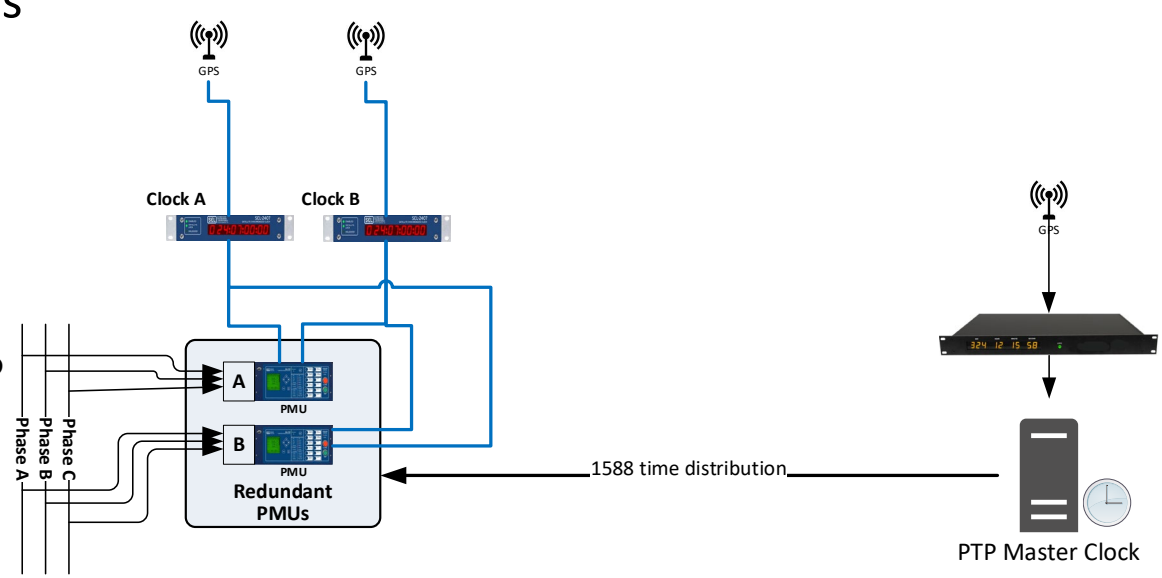
Communications network

- Legacy serial TDM – SONET DS0 on T1 or higher.
- New – Ethernet MPLS – serial DS0/T1 pseudowire or Ethernet packets.
- Transport latencies dropping far below 10 ms (phasor computations themselves may take longer).
- Redundant WAMPAC system architecture.



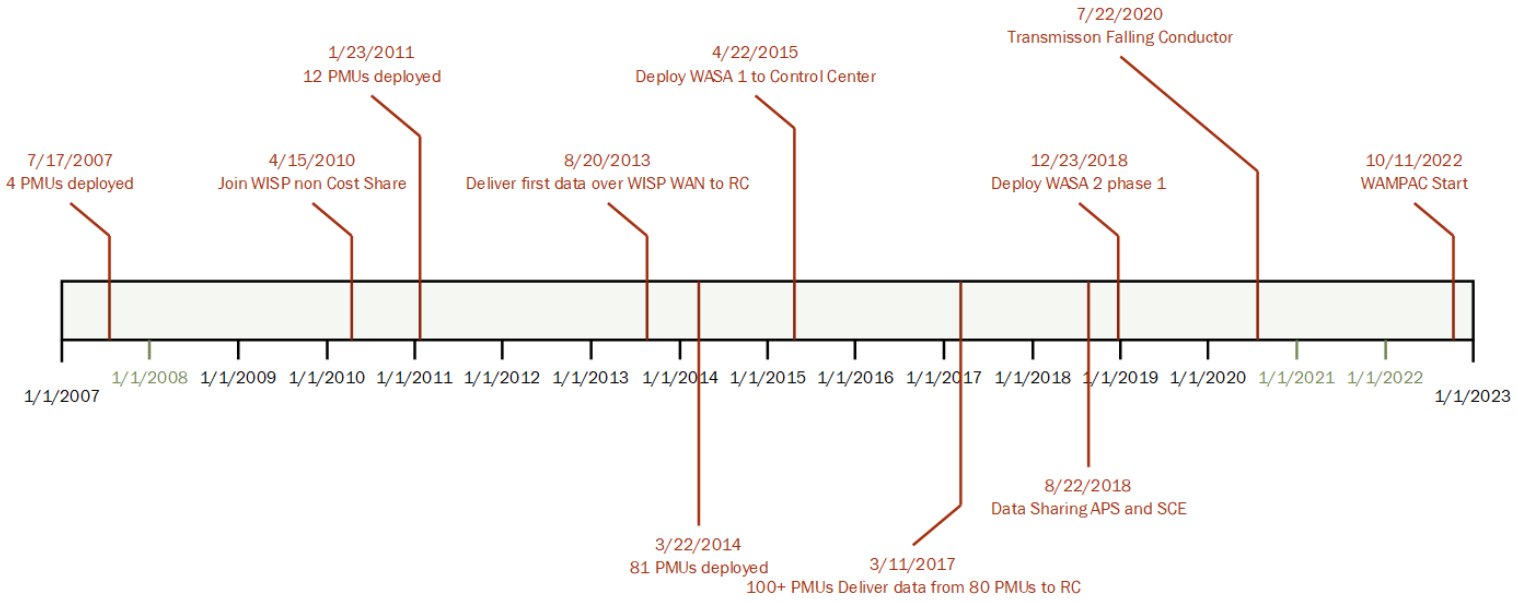
PMU System Components

- Control center/comms hub data processing and computing systems
  - Field Gateway PDC serves C37.118 or STTP custom streams to applications.
  - Single or redundant server platforms for synchrophasor applications.
  - Blade servers or application control processors.
  - Redundant field gateways and computing platforms for mission-critical P&C functions; include return control communications services on WAN.
- Time distribution services
  - GPS receivers are ubiquitous and becoming more secure – but vulnerable.
  - Use secure Ethernet WAN for IEEE 1588 PTP time distribution.
  - Redundancy of clocks and paths – keep GPS master synch.



SDG&E® Deployment Roadmap

- Continuous additions of PMUs and PDCs.
- Transition from serial to MPLS Ethernet communications.
- Development of new functions including advanced operational client, fire risk reduction, and system protection.



Conclusion - Industry WASA-WAMPAC Roadmap

- As relays are installed, add PMUs (and PDCs) communicating to engineers, to get practical functional and observational experience.
- Develop organizational roadmap of applications and infrastructure with a sustainable investment plan. Coordinate with communications and IT.
- Specify & deploy WASA with System Operations, looking towards WAMPAC. Operators will learn situational awareness, SCADA/EMS enhancement. All will get troubleshooting, DME, post-mortem analysis, and model validation experience.
- Deploy development and training platforms and environments.
- Tune system dynamic and short-circuit models as operating experience accumulates.
- Deploy non-redundant high-speed WAMPAC protection functions for trial use.
- Build out redundant PMU data collection & communications; manage performance.
- Include timing distribution in network design.
- Add P&C functions for faults, failures, instability, and RAS/SIPS.
- Develop wide-area and high-speed control algorithms and test with simulations and streamed real-time data. Close the control loops to enter WAMPAC era.
- Migrate SCADA and EMS to the reliable new data gathering and control platform.
- Use synchronized measurements for distribution applications - voltage monitoring and control, DER monitoring, intelligent load shedding, etc.

Thank you!