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SYNCHROPHASOR-BASED WIDE-AREA BACKUP PROTECTION SYSTEM

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Industry roadmap for synchrophasor apps

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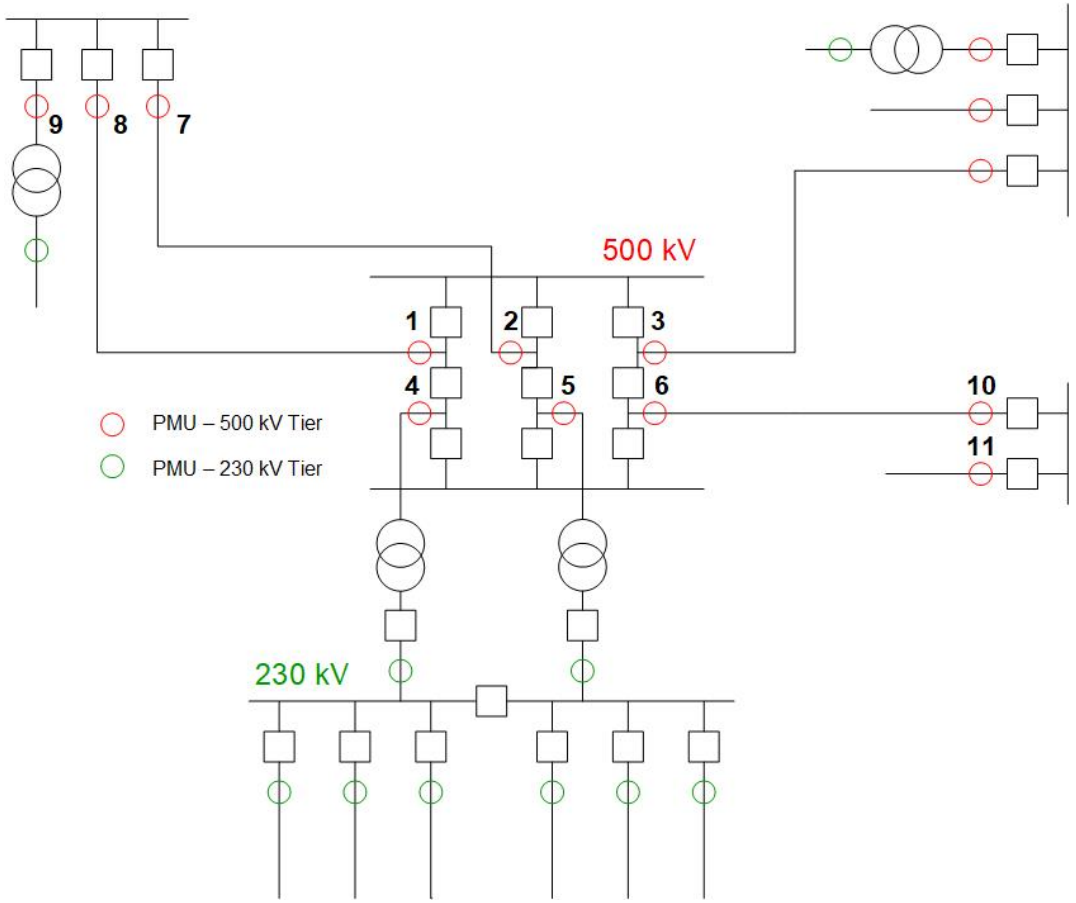
- Wide-area situational awareness (WASA) systems – control center *operating-data gathering* & visualization.
- Use real event data to get to *accurate models*.
  - Also model secondary system (P&C) behavior.
- Develop high-speed real-time control algorithms – RTDS® or similar testing validation with good models.
- Expand PMU & controller infrastructure – coverage, availability, latency, redundancy, security.
- Build practical PoC labs and trial installations.
- Close the loop – protect and control the grid.

But…one critically useful application we can do right now…

PMU deployment trends

- PMU function is sold as low-cost upgrade in popular relays and meters (dedicated comms port).
- Newest SONET and MPLS Ethernet communications networks have high bandwidth, many paths, lots of redundancy, and low latency (a few ms).
  - Both types already support teleprotection.
- Many utilities are deploying synchrophasor-based wide-area situational awareness (WASA) systems for operators at GCCs.
- Some utilities are deploying PMUs with high density – one or more at every transmission line terminal.
- For mission-critical applications, users are developing CIP-compliant secure PMU data collection schemes.
  - Includes data used for operator decision-making.

Wide-area backup fault protection - synchrophasors and current differential zones



- Remote fault location and clearing observation for local zones.
- Familiar protection zones are embedded in larger regional differential zones or tiers for redundancy or for filling gaps.
- Observe clearing failure and execute surgical backup trip.

Wide-area backup fault protection - synchrophasors and current differential zones

High-level notion in IEEE PSRC in 2009 report –

now we build the practical implementation approach:

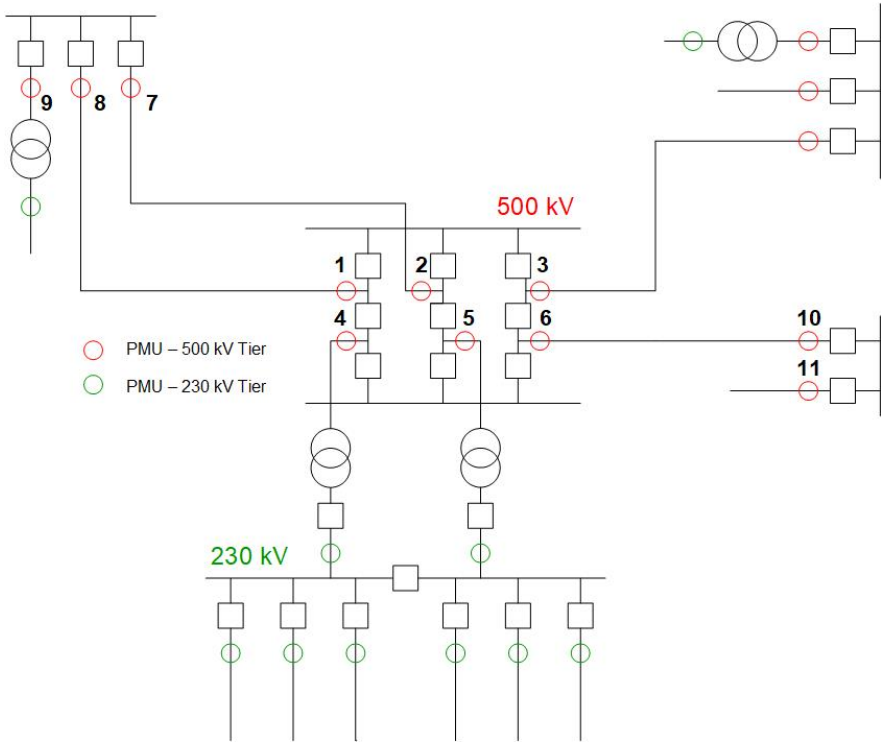
- Measurement locations.
- Timing of fault and operating events versus backup protection system response.
- Communications methods and requirements.
- Application issues.
- Non-communicating safety net.
- Important benefits for protection of today's grid.

Today‘s distance backup fault protection

- Ultimate protection of system and apparatus.
- No communications system needed.
- Zone 2 - 0.5 s ; Zone 3 - 1 s plus.
- Not so selective - can cut a big hole in the system, and even cause a cascading outage.
- Setting/coordination **maintenance costs** are large – settings must track system fault duty evolution.
- PRC-027 compliance studies.
- Setting errors.
- Risks of overreach and misoperation; loadability of circuits.

Wide-area backup protection with synchrophasors

- PMUs or relay/PMUs at each line terminal
- Centralized or distributed protection controllers target trip commands.
- Current differential zones - faulted zone identification.
- Transformer zone boundaries between voltage tiers.
- Watches primary relays and BF tripping (can also back them up).
- Surgically clears fault if it persists past BF time – minimum tripping to isolate.



- Beats Zone 2/3 backup relays.
- We can leave Z2 and Z3 *non-communicating* backup for safety net apparatus protection – *but we never give them a chance to trip*.

Timing is the key

Conventional

- Primary protection time 8-32 ms.
- Breaker time 32-80 ms.
- Breaker failure protection trip 150-250 ms from inception.
- BF clearing 180-280 ms from inception.
- Zone 2 backup 500 ms.
- Zone 3 backup 1.2 s.

PMU current diff backup

- Detect and locate fault zone < 50 ms.
  - Watches primary relays
  - Could trip for backup
- Watch local BF protection
  - Could trip for backup
- Trip only breakers needed to isolate – 330 ms from inception.
- Fault cleared – 380 ms from inception.
- 120 ms margin before Z2.

Application details

Phasor ***measurements*** – P-Class (short window, fast responding) per IEEE C37.118.1-2011 or IEC/IEEE 60255-118-1 Edition 1 (2018) – phase V and I phasors plus status points.

Phasor packet ***communications*** requirements:

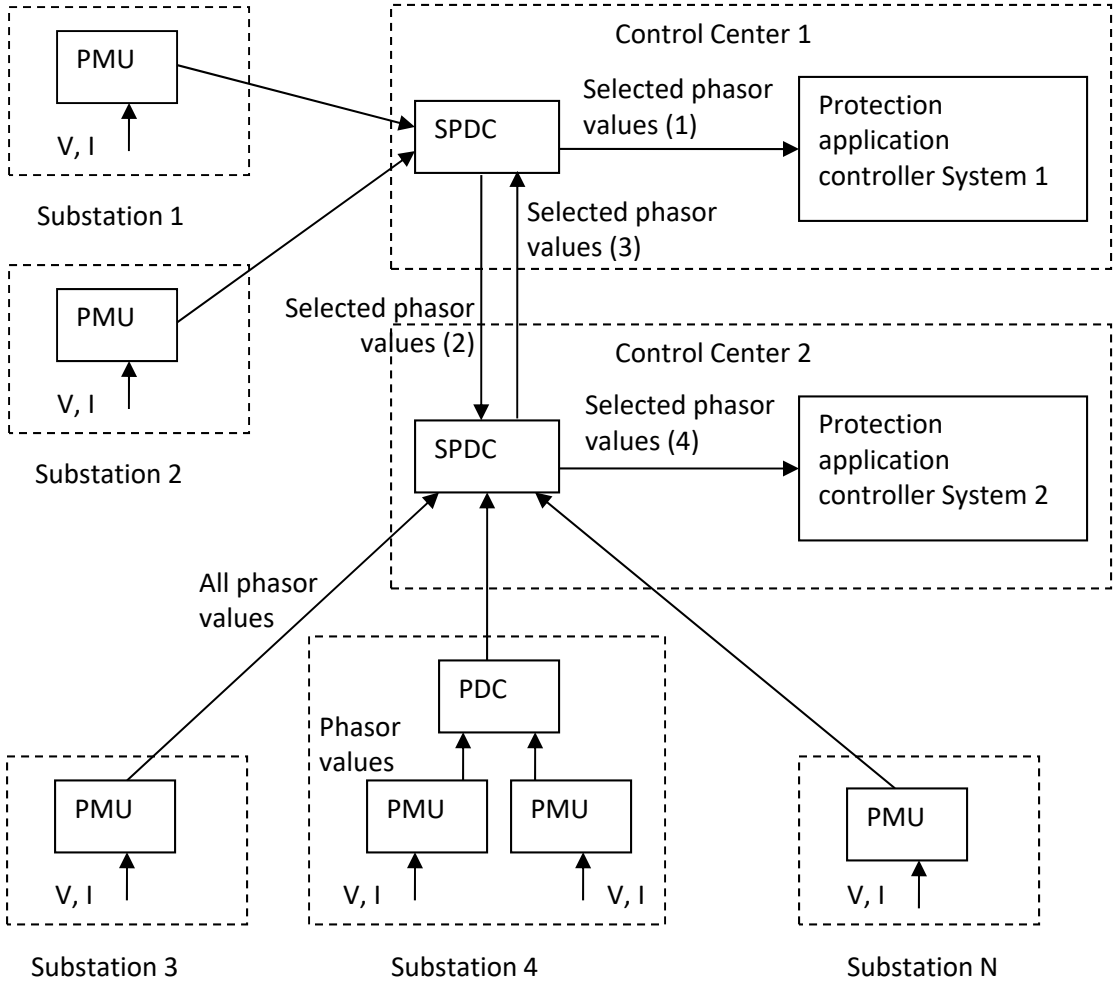
- IEEE C37.118.2-2011 or IEC TR 61850-90-5 (2011) .
- Latencies up to 50 ms acceptable; 10 ms now easily achieved.

Remote trip and control requirement - IEC 61850-8-1 GOOSE or IEC 61850-90-5 network-routable GOOSE (R-GOOSE).

Application issues to watch – line shunt admittance charging, shunt capacitors & reactors, FACTS & PAR devices need isolation or state feedback, complex substation bus configurations.

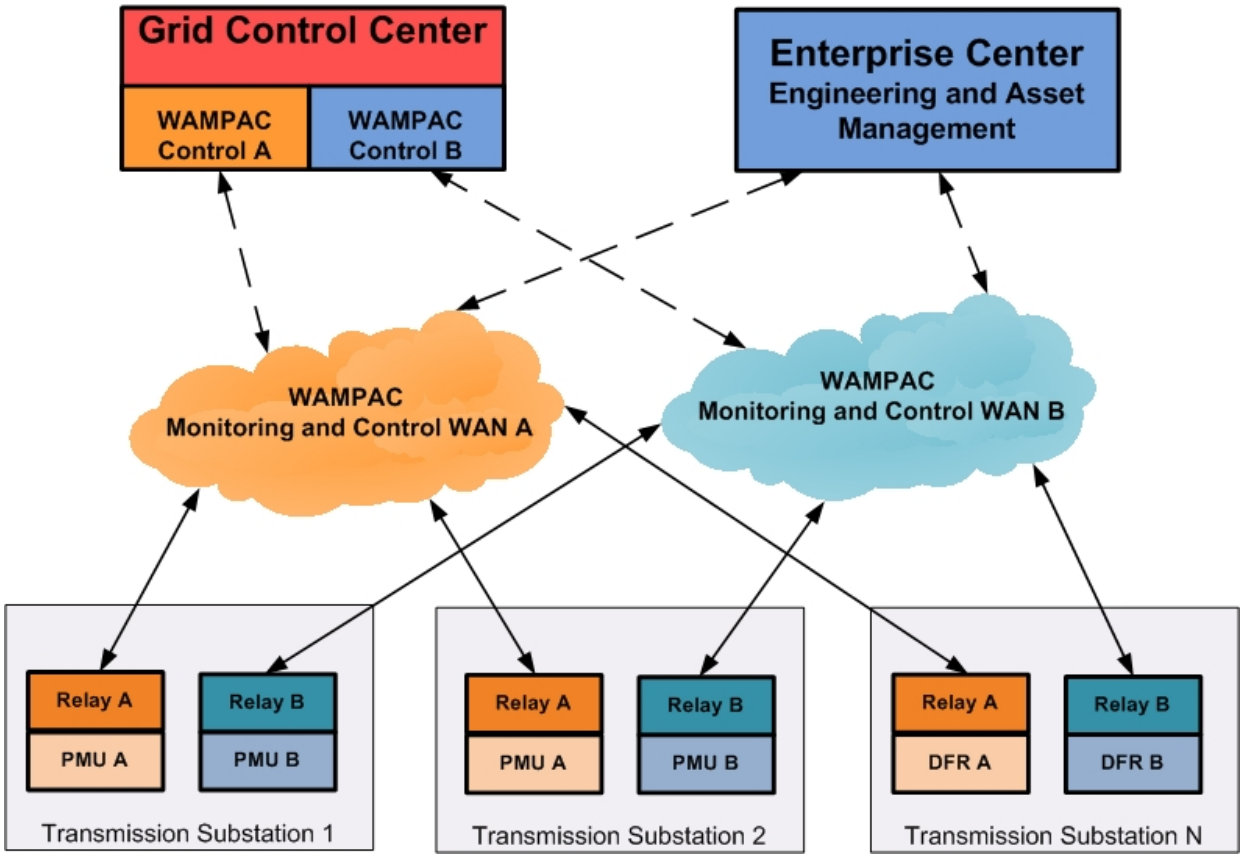
Control Center application platforms

- Application controllers with backup prot. programming can be in control centers or in substations.
- Dual redundancy not required - it is already a backup.
- But redundant controllers support maintenance and test.



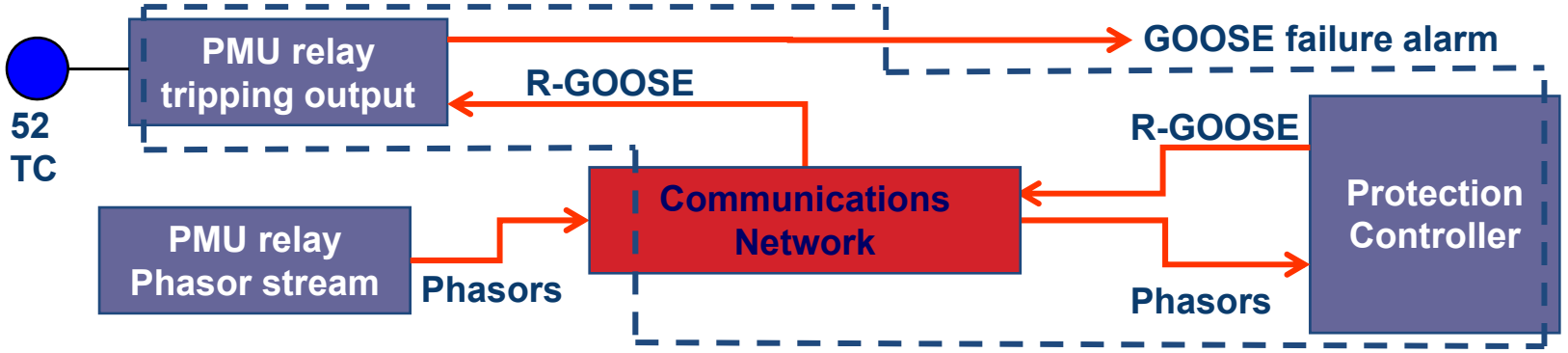
Redundant WAMPAC architecture

- Future configuration for wide-area control functions and increased reliance on remote backup of local zone relays.
- Already being built for WASA, teleprotection, RAS, and SCADA applications.



Continuous monitoring in service

- Heartbeat communications services are monitored from the source PMUs to the controller processors – no gaps.
  - Inbound phasor streams at the application controllers.
  - Outbound IEC 61850 GOOSE to tripping relay/PMU processors.
  - Missing streams and prot. zone coverage are always known.
  - PRC-005-6 CBM compliant.



- Application monitoring – at disturbance-free times, currents around local or expanded zone boundaries add up to zero.
  - State observation – alarm bad CTs or data; block misoperation.

Conclusion – Benefits of PMU-based backup protection

- Faster, precise backup - disconnects exactly what is needed – not more.
- Immune to high penetration of inverter & low-current generation sources.
- Ignores loads and swings.
  - Use V phasors for selective unstable-swing trip or block).
- No coordination studies or core application settings.
- Relaxed coordination work for slower Zone 2/3 distance backup relays – now just a safety net we always expect to beat out – can cover *better* than today.
- Reduces compliance issues for PRC-023, PRC-026, PRC-027
- Complete self-monitoring - no hidden failures; no maintenance tests – 24/7 operational state awareness.

Thank you!

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