SYNCHROPHASOR STANDARDS

North American Synchrophasor Initiative
Atlanta, GA

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Overview of Synchrophasor Standards

- History of synchrophasor standard development
- Review of communication standards
- Review of measurement standards
- Test and certification

Standards for Synchrophasors

- IEEE 1344-1995
  - First standard
  - Included measurement and communication
- IEEE C37.118-2005
  - Replaced IEEE 1344
  - Included performance requirements for measurement
  - Communication adaptable to networks
  - Basis for current methods and standards

C37.118-2005 Communication

- Message transfer protocol
  - Command frame
    - Start/stop data, send other information
  - Data frame
    - Phasor, frequency, other measurements
  - Configuration frame
    - Describes data frame, with scaling & naming
  - Header frame
- Can be used with serial, network, or other system
  - Widely used with standard IP protocol (TCP-UDP/IP)

C37.118-2005 measurement

- Measurement requirements
  - Phasor measurement accuracy over range of V, I, ϕ, & F
  - Rejection of harmonics and out of band signals (anti-aliasing)
  - Basic compliance test is TVE
- Steady-state conditions
- No frequency or ROCOF requirements

Theoretical (reference) phasor value

$$\mathbf{X} = \frac{X_m}{\sqrt{2}} e^{j\phi} = X_r + jX_i$$

Measured (estimated) phasor value

$$\mathbf{X}(t_0) = X_r(t_0) + jX_i(t_0)$$

Total Vector Error (the RMS difference)

$$TVE = \sqrt{\frac{\left(\mathrm{X_r}(t_0) - X_r\right)^2 + \left(\mathrm{X_i}(t_0) - \mathrm{X_i}\right)^2}{\mathrm{X_r}^2 + X_i^2}}$$

C37.118 split into two Standards

- Simplify further development & coordinate with IEC standards
- Synchrophasor Measurement
  - C37.118.1-2011
    - Add frequency & rate of change of frequency (ROCOF) requirements
    - Add performance under dynamic conditions
  - C37.118.1a amendment
    - Modify requirements for practical considerations
  - IEC 60255-118-1
    - Currently under development, based on C37.118.1a
- Phasor data communication
  - IEEE C37.118.2-2011
    - Compatible extension of 2005 standard
  - IEC 61850-90-5
    - Extension based on established practices

Standard IEEE C37.118.1-2011

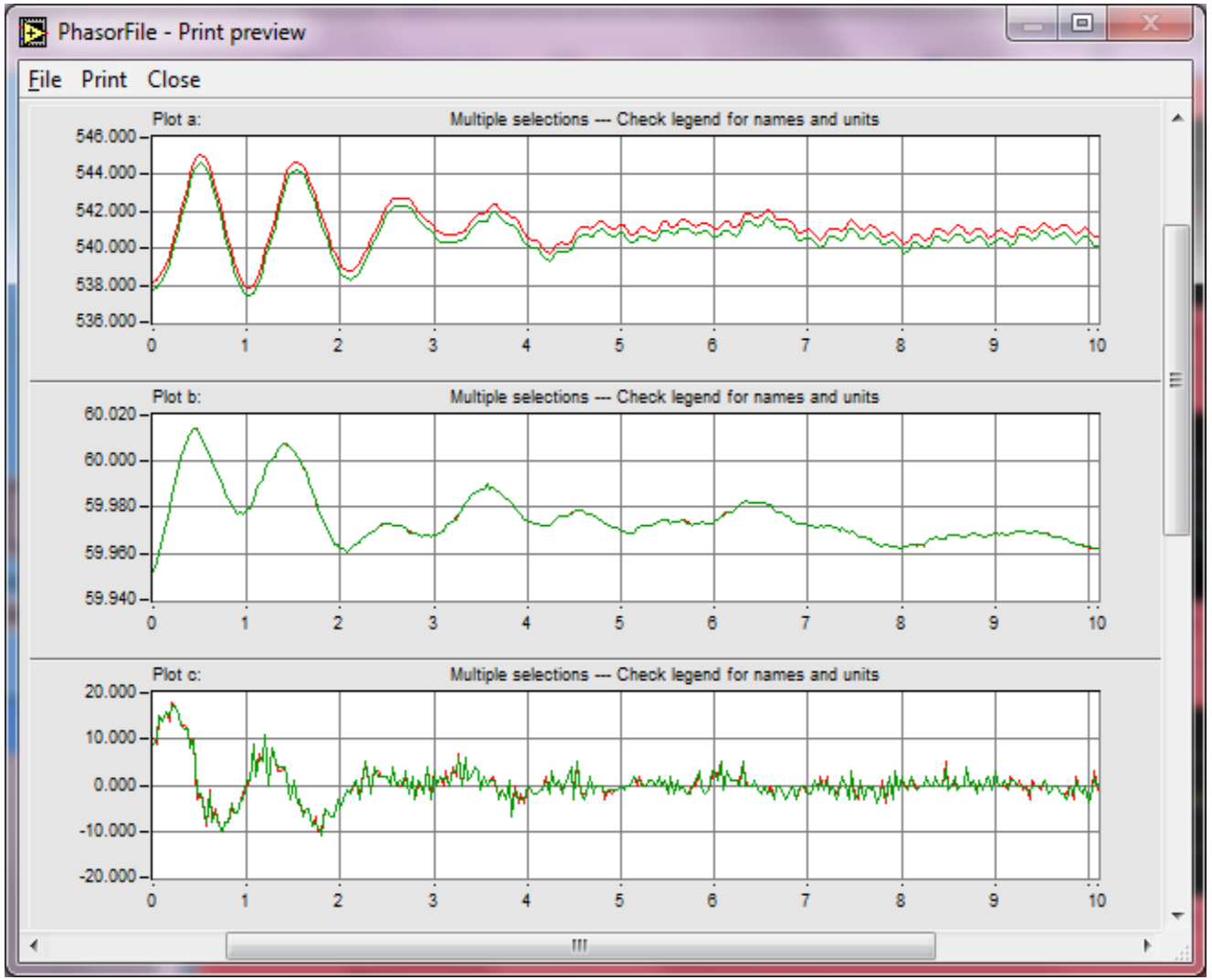
- Principal changes – added requirements for:
  - Frequency and & ROCOF measurements
  - Measurement under dynamic operating conditions
- Two classes of performance – M & P class
- Operation under multiple reporting rates required
- Steady-state measurement
  - Accuracy over frequency, amplitude, angle, & temperature ranges
  - Rejection of interference – aliasing & harmonics
- Measurement requirements under dynamic conditions
  - Measurement bandwidth of both phase and amplitude
  - Tracking under frequency ramp
  - Response time for amplitude and phase step changes
- Tests apply to phasors, frequency, & ROCOF measurements

Issues with C37.118.1-2011

- Main difficulty is frequency & ROCOF measurement
  - New requirements – most previous implementations inadequate
  - Interference & harmonics rejection insufficient
- For F & ROCOF error is amplified by differentiation
  - Given phasor $Ve^{\phi t}$
  - $F = d\phi(t) / dt$
  - $ROCOF = dF/dt = d^2\phi(t) / dt^2$
- Also some difficulty with exclusion for ramp, latency definition & other details

Noise in Frequency & ROCOF

- Voltage measurement shows normal variations in signal
- Frequency shows similar activity but with a little apparent noise
- ROCOF follows swing but signal dominated by noise



Changes made by Amendment

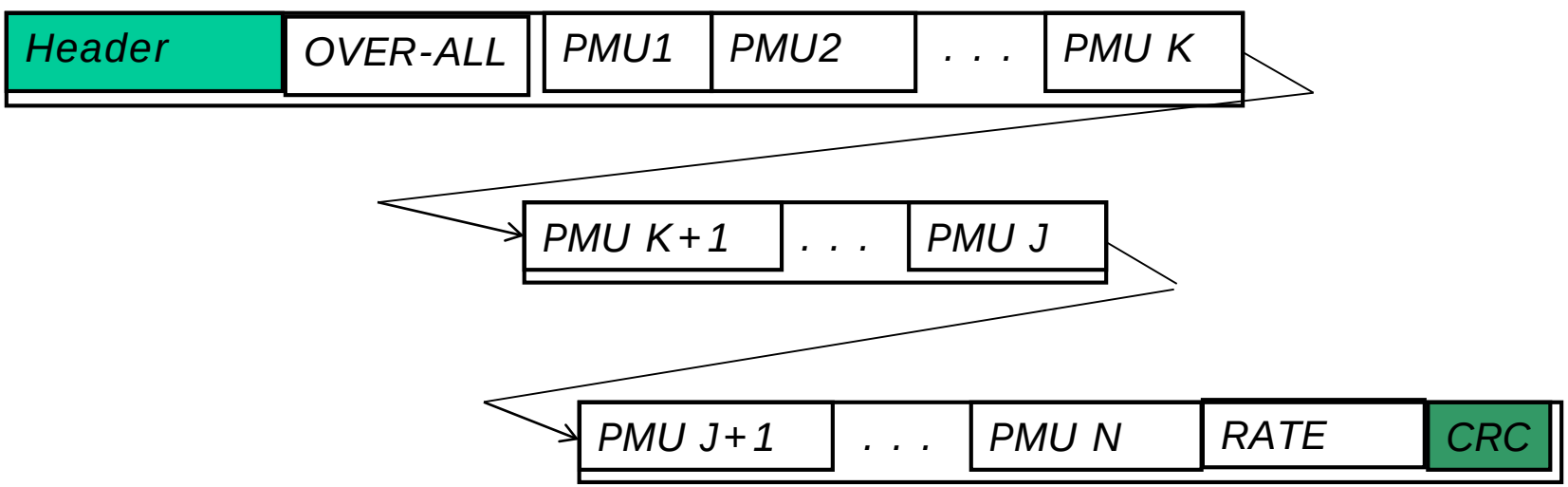
- Corrects some wording errors
- Relax some Frequency & ROCOF requirements
  - Harmonic & out-of-band, suspend ROCOF
  - Key modulation to bandwidth
  - Ramp tests
- Longer ramp test exclusion
- Longer step test compliance for all measurements
- Latency definition clarified, longer allowance
- Annex C - longer M-class filter, align F & ROCOF

IEEE standard C37.118.2 - 2011

- Compatibility maintained
  - All 2005 implementations compatible
  - 2011 implementation transparent to 2005 version
- Corrections and clarifications made
  - PMUID identifies stream not source PMU
- New features
  - New expanded config message
  - Reserved bits in STAT word used for time quality

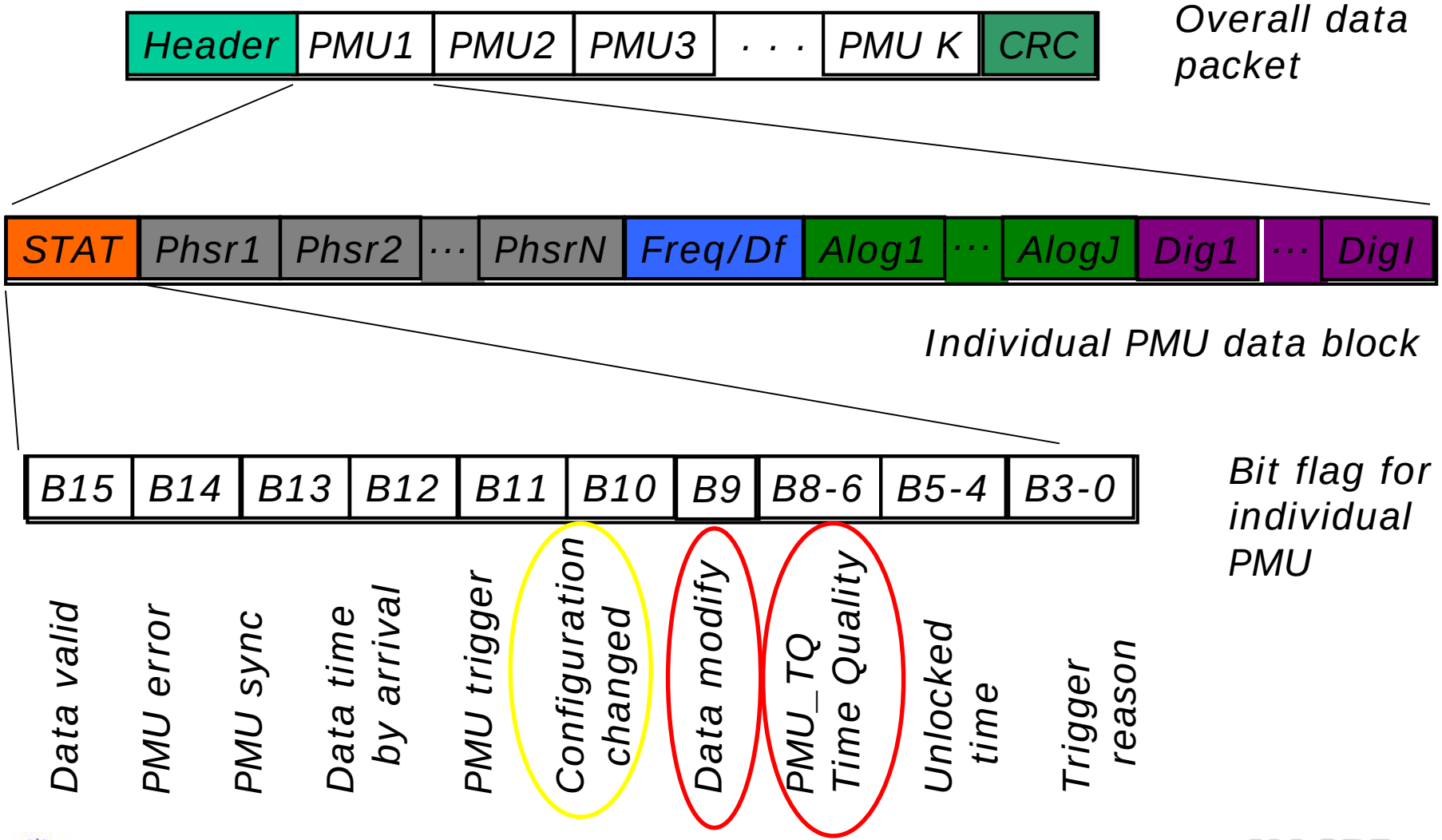
New configuration message – config3

- Message extensible to multiple frames (previous limit one 64K frame)
  - Necessary for large data sets
- Variable length names - up to 254 bytes (previous limit 16 bytes)
  - UTF-8 encoding (includes all languages)
- Scaling extended for phasors & analogs
  - Full mX + b scaling
- More measurement description
  - PMU location
  - PMU measurement parameters



STAT word changes – data packet

- Bits 6-8 now PMU_TQ, bit 9 data modify flag



IEC 61850 communication

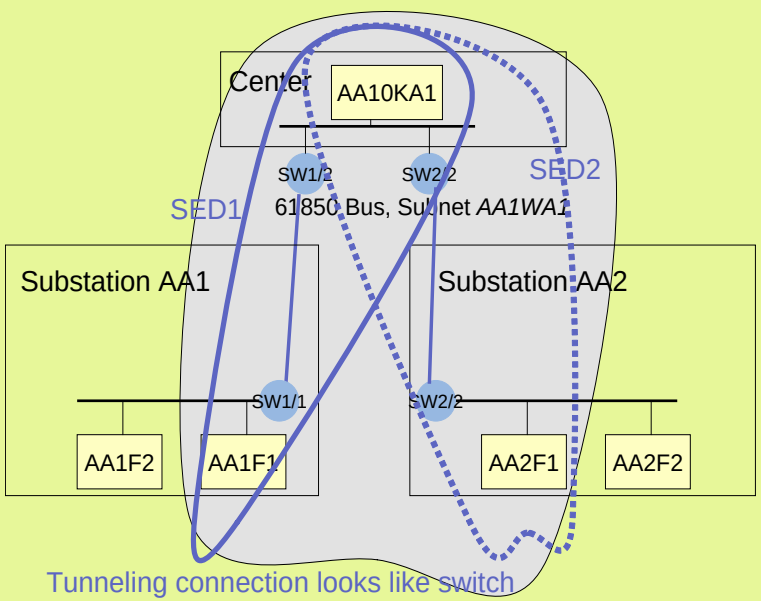
- Substation configuration & control
  - IEC TC57, WG10
  - Takes advantage of
    - Proliferation of Intelligent Electronic Devices (IED)
    - Wide bandwidth network communications
- Primary focus is substation automation
- Now increasing scope to include wide area
  - TR 61850-90-5 for synchrophasors

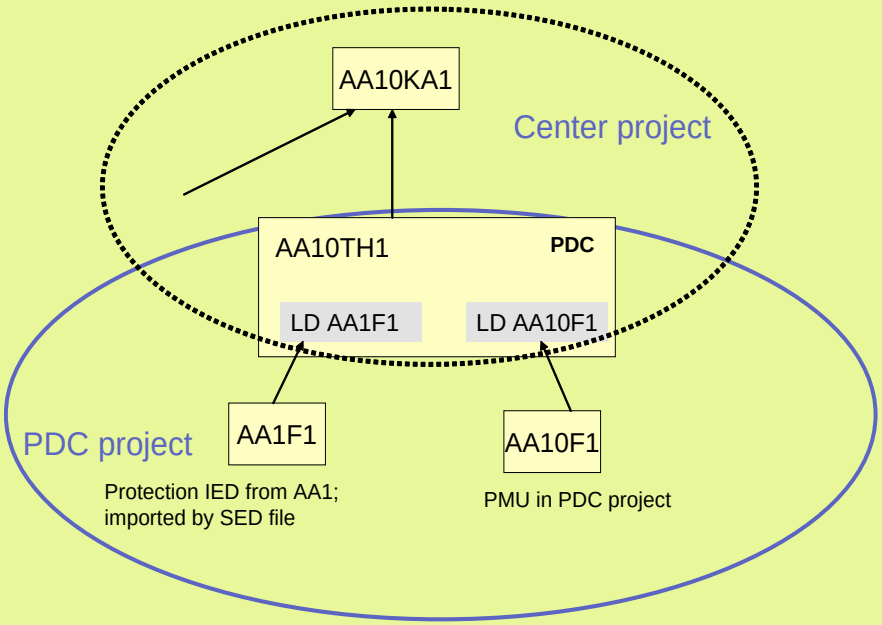
90-5 key features

- Profile mappings
  - A-profile & T-profile
  - Control block modifications
  - Conversions between 37.118 & std 61850
- Extensions for new classes & LNs
  - ROCOF data object added
  - LTIM logical node class (leap second time)
  - Performance classes assigned
- Security concerns and methods discussed
  - Includes E-to-E integrity, key distribution, other issues
  - Uses methods developed under 62351
- Application of security optional – use where required

90-5 key features - modeling

- Communication requirements set
  - Tunneling & gateway approach for PDC
  - Modeling considerations for both approaches
- Sample Values (SV) extended for routability





15

Tunneling

Gateway

IEC/IEEE 60255-118-1

- Work started January 2014
- First CD issued March 2016
- Started with C37.118.1 including amendment
- Make needed changes, but no more
  - Simplify testing where possible
    - Reduce required reporting rates
    - Eliminate all environmental requirements
    - Only test one class & one system frequency
  - Restated basic definitions
  - Clarified requirements as needed
- Hope to complete both IEC and IEEE approvals by end of 2017

Additional Standards & Guides

- IEEE C37.244-2011 : PDC guide
  - Guide to terminology & operation of Phasor Data Concentrators
- IEEE PC37.247 : PDC standard
  - Standardizes requirements from concepts in C37.244
  - Expect completion in 2016
- IEEE C37.242-2011 : Guide for synchronization, measurement, installation, and testing of PMUs
  - Covers the environment in which the PMU will be operating
  - Provides details for certification testing of the PMU
  - Is currently being updated to cover the new standard requirements
- IEC 60255-24/IEEE C37.111 : COMTRADE standard
  - File format for recorded measurement data
  - Complete profile for use with phasor data

PMU test & certification

- Certifying organization to assure all testing is comparable
  - Qualify testing laboratories
  - Create testing procedures
  - Examine testing results
  - Certify products
- IEEE Conformance Assessment Program (ICAP)
  - Sponsored by IEEE
  - Participation by many standards labs
- Other certifying bodies may be formed as well

Summary

- First standard, IEEE 1344 – 1995
- C37.118 in 2005
  - Set the basic concepts we use today
  - Performance verification- TVE
  - Communication methods
- C37.118.1 for measurements
  - Adds dynamic measurement requirements
  - Includes Frequency & ROCOF
- C37.118.2 Communication similar to that set in 2005
- 61850-90-5 integrated communication
- Joint standard IEC/IEEE 60255-118-1 developing

Thank you

Questions?