C37.118.2 – 2024

Synchrophasor Data Transfer for Power Systems

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History

- IEEE 1344-1995
  - First Synchrophasor standard
  - Header, Config, Data frames

- C37.118-2005
  - Major revision
  - Sync, Frame Size, Station name, Fraction of second based time stamp, Time quality, Analog values, Concatenation . . . .

- C37.118.2-2011 (Version 2)
  - Minor revision.
  - Message format essentially unchanged.
  - CFG3 added

- C37.118.2-2024 (Version 3)
  - Major revision.

Purpose

- Revise the standard: IEEE C37.118.2-2011 Synchrophasor Data Transfer for Power Systems.

  - Add needed features

  - Remove Ambiguities

  - Simplify. Eliminate unused / under used features
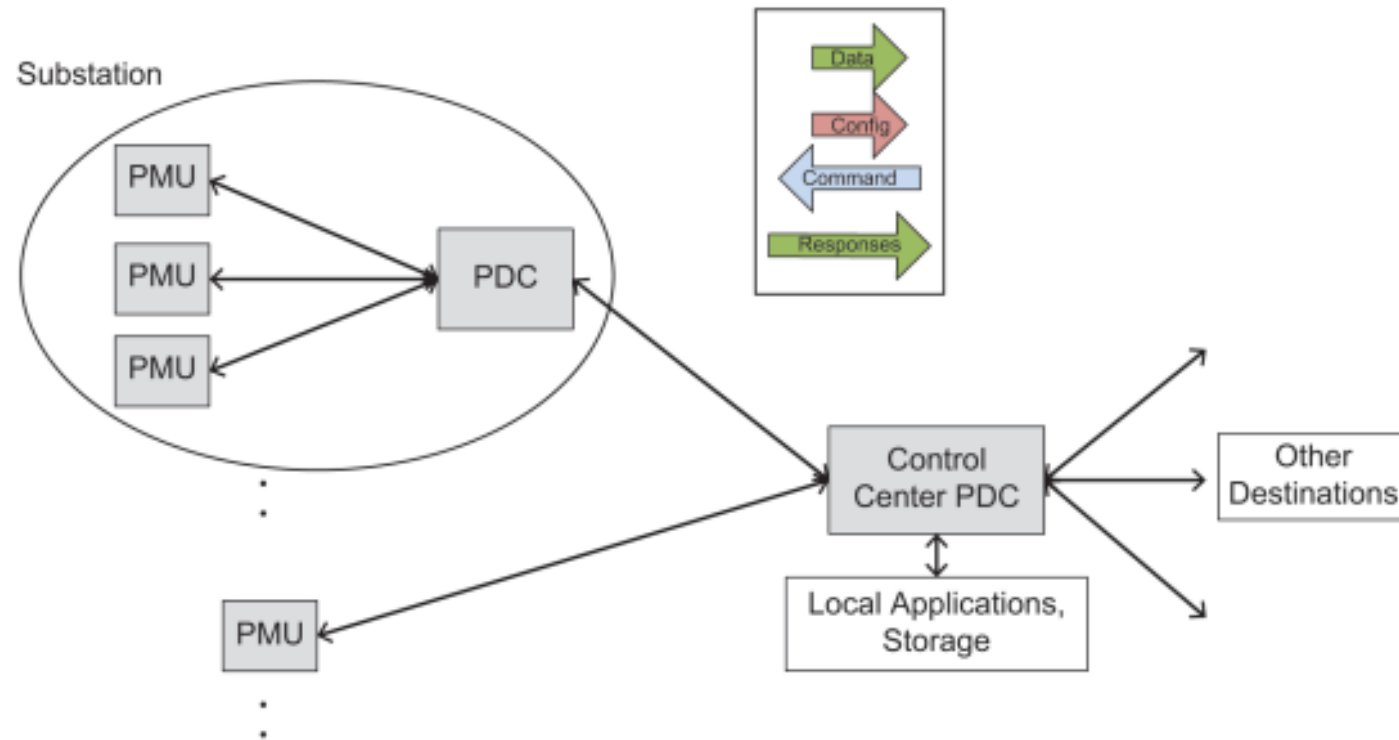
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Scope


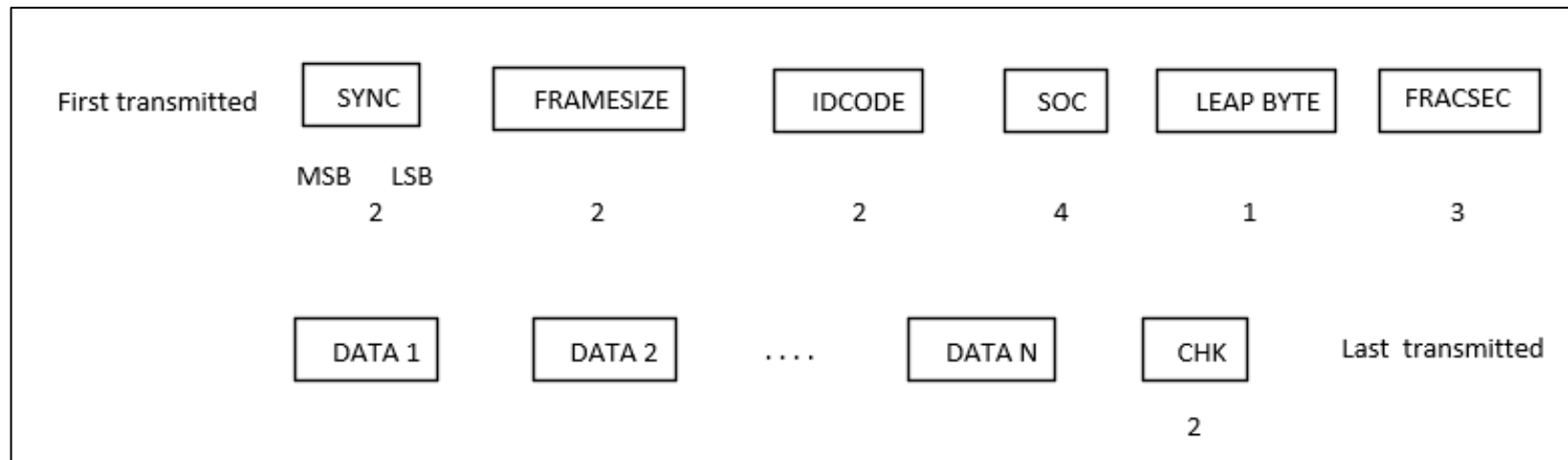Figure 1—An example of a synchrophasor system

What is 118.2

- Data

    - Periodic measurements, raw binary data, optimizes bandwidth use

- Configuration

    - Description of data being sent – list of signals, scaling factors, format etc.

- Header

    - User defined static information. Not used generally

- Commands

    - Data on/off, send configuration

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Synchrophasor Message Frame Structure
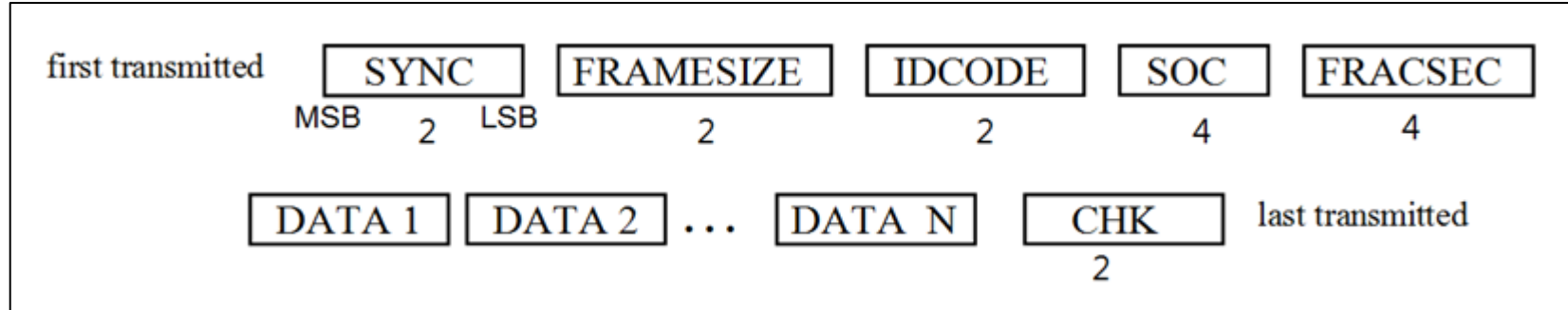

2011

2024

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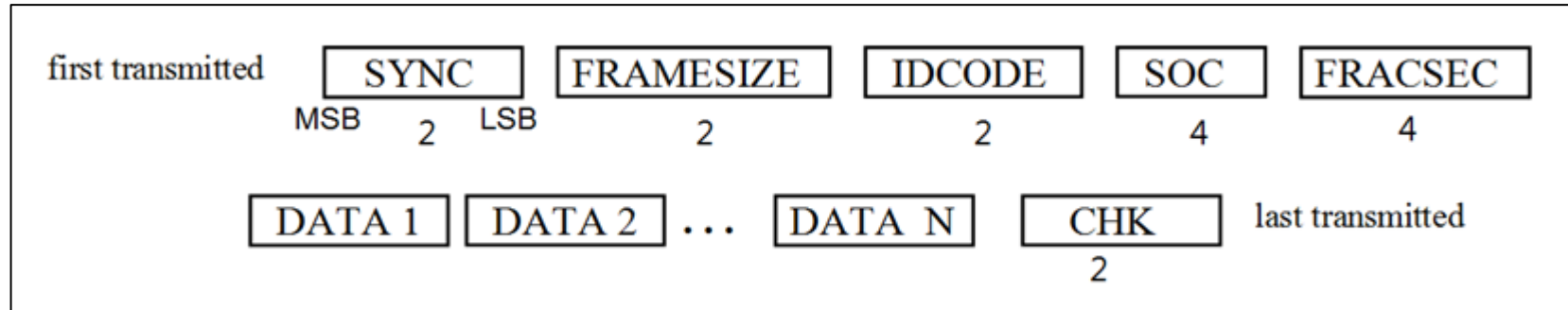
Version 2 Limitations Identified

- STAT flag bits open to different interpretations

- Time quality information anomalies

- No signal-based data quality information

- Frequency/ROCOF were mandatory

- Digital events time stamps not accurate

- No remote configuration

- No response from PMUs to indicate any problems

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STAT word in Data Frame

first transmitted | SYNC | FRAMESIZE | IDCODE | SOC | FRACSEC

MSB 2 LSB   2   2   4   4

DATA 1 | DATA 2 | . . . | DATA N | CHK | last transmitted

2

STAT | PHASORS | FREQ | DFREQ | ANALOGS | DIGITALS

DATA 1 . . . . DATA N

STAT word - 2011 Version

Field	Size (bytes)	Comments
STAT	2	Bit mapped flags.
		Bit 15–14: Data error: 00 = good measurement data, no errors
		01 = PMU error. No information about data
		10 = PMU in test mode (do not use values) or absent data tags have been inserted (do not use values)
		11 = PMU error (do not use values)
		Bit 13: PMU sync, 0 when in sync with a UTC traceable time source
		Bit 12: Data sorting, 0 by time stamp, 1 by arrival
		Bit 11: PMU trigger detected, 0 when no trigger
		Bit 10: Configuration change, set to 1 for 1 min to advise configuration will change, and clear to 0 when change effected.
		Bit 09: Data modified, 1 if data modified by post processing, 0 otherwise
		Bits 08–06: PMU Time Quality. Refer to codes in Table 7.
		Bits 05–04: Unlocked time: 00 = sync locked or unlocked < 10 s (best quality)
		01 = 10 s ≤ unlocked time < 100 s
		10 = 100 s < unlock time ≤ 1000 s
		11 = unlocked time > 1000 s
		Bits 03–00: Trigger reason:
		1111–1000: Available for user definition
		0111: Digital 0110: Reserved
		0101: df/dt High 0100: Frequency high or low
		0011: Phase angle diff 0010: Magnitude high
		0001: Magnitude low 0000: Manual

- This flag is a mix of several bits of information.

- Usage has been open to interpretation, and at times it is difficult to reconcile data from different manufacturers.

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STAT word (2011 Version)

Bit #		
15-14	Data Error	Multiple interpretations
13	PMU sync	OK to use
12	Data sorting	OK to use
11	Trigger detected	Rarely used.
10	Config Change bit	Rarely used
9	Data modified	OK to use
8 - 6	Time Quality	Partial Time Quality
5-4	Unlocked time	Partial Time Quality
3 - 0	Trigger	Rarely used. Settings undefined.
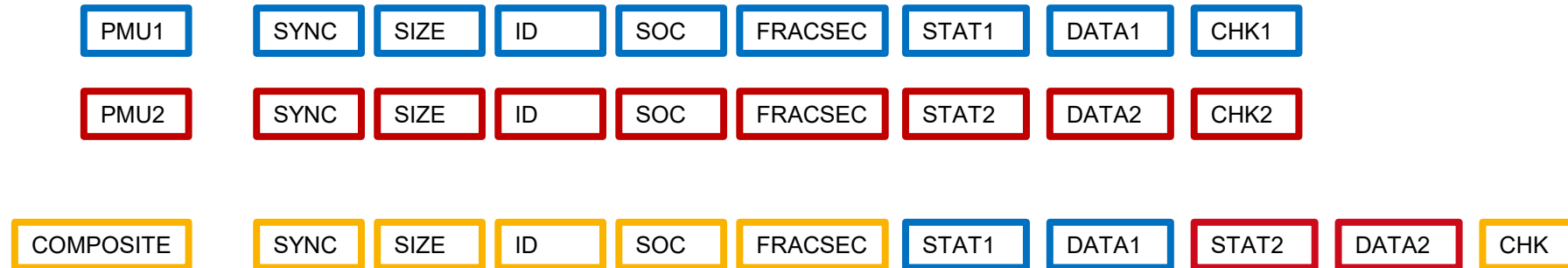
STAT-FLAG word (2024 Revision)

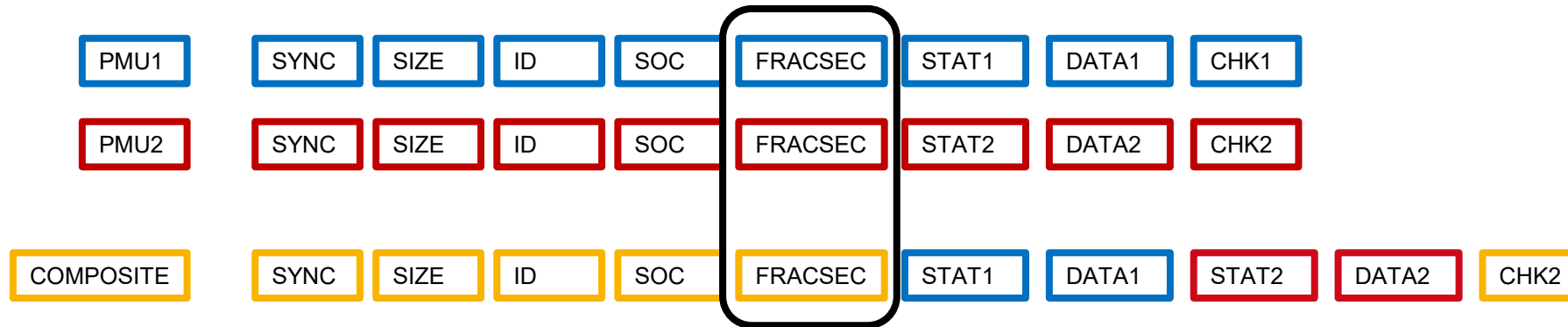| Bit no.	Set by	Field	Definition
15 to 14	PMU only	Data error	0 0 = Good measurement data, no errors. 1 0 = PMU in test mode. 0 1 = Internal error detected by PMU. Data should be used with caution. 1 1 = Reserved.
13	PMU only	PMU sync	Time sync uncertainty indicator (see 4.5.1.2). 0 = Time sync uncertainty is 250 ns or less. 1 = Time sync uncertainty exceeds 250 ns.
12	PDC	Local time stamp	0 = Normal data. 1 = The data had a different time stamp. The PDC has assigned the current time stamp to this data frame.
11	PDC	Data bad	0 = Normal data. 1 = Do not use. PMU data is included in the data frame, but PDC's ask users to not use it.
10	PMU/PDC	Inserted data	Always set to 0 by PMU. Set to 1 by PDC only when there is no PMU data, and PDC substitutes it with any data.
9 to 0	PMU	Reserved	Always set to 0 by PMU.

Composite data stream, 2011 Version (. . . TimeQuality)

| PMU1 | | SYNC | SIZE | ID | SOC | FRACSEC | STAT1 | DATA1 | CHK1 |

| PMU2 | | SYNC | SIZE | ID | SOC | FRACSEC | STAT2 | DATA2 | CHK2 |

| COMPOSITE | | SYNC | SIZE | ID | SOC | FRACSEC | STAT1 | DATA1 | STAT2 | DATA2 | CHK |

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Time Quality: Composite data stream, 2011 Version

PMU1		SYNC	SIZE	ID	SOC	FRACSEC	STAT1	DATA1	CHK1

PMU2		SYNC	SIZE	ID	SOC	FRACSEC	STAT2	DATA2	CHK2

COMPOSITE		SYNC	SIZE	ID	SOC	FRACSEC	STAT1	DATA1	STAT2	DATA2	CHK2

- ## FRACSEC
  - Bits 3 – 0: 4 bits, various accuracy values in a table
  - Composite stream conflict, if different

- ## STAT word
  - Bits 8 – 4: 5 bits, time quality code, and unsynched duration time

- ## Ambiguity
  - How to create new composite FRACSEC

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Composite data stream, 2024 Version

PMU1		SYNC	SIZE	ID	SOC	LEAPBYTE	FRACSEC	STAT_FLAG1	TQ1	DATA1	CHK1

PMU2		SYNC	SIZE	ID	SOC	LEAPBYTE	FRACSEC	STAT_FLAG2	TQ2	DATA2	CHK2

COMPOSITE		SYNC	SIZE	ID	SOC	LEAPBYTE	FRACSEC	STAT_FLAG1	TQ1	DATA1	STAT_FLAG2	TQ2	DATA2	CHK

- STAT_FLAG
  - Bits 13: PMU in synch (or not). Details in TQ field
- FRACSEC (LEAPBYTE)
  - Time Quality information removed
- PMU specific Time Quality
  - Retained in composite stream

Time Quality(2024 Revision)

Bit no.	Field	Version 3 (Native)
		Definition
15	Version Indicator	0 = Version 3 (2024 Revision)
14 – 12	Multiplier	10^n
11 - 0	Time sync uncertainty	Time sync uncertainty in nanoseconds

Bit no.	Field	Version 3 (Converted from Version 2)
		Definition
15	Version Indicator	1 = Converted from Version 2 (2011 Revision)
14 – 9	Reserved	Set to 0
8 - 6	From STAT word	Bits 8 to 6 from STAT word PMU time quality field.
5 - 4	Reserved	Set to 0
3 - 0	From FRACSEC	Bits 3 to 0 from FRACSEC time quality field.

Data Quality : STAT word - 2011 Version

Field	Size (bytes)	Comments

STAT	2	Bit mapped flags.
		Bit 15–14: Data error: 00 = good measurement data, no errors
		          01 = PMU error. No information about data
		          10 = PMU in test mode (do not use values) or absent data tags have been inserted (do not use values)
		          11 = PMU error (do not use values)
		Bit 13: PMU sync, 0 when in sync with a UTC traceable time source
		Bit 12: Data sorting, 0 by time stamp, 1 by arrival
		Bit 11: PMU trigger detected, 0 when no trigger
		Bit 10: Configuration change, set to 1 for 1 min to advise configuration will change, and clear to 0 when change effected.
		Bit 09: Data modified, 1 if data modified by post processing, 0 otherwise
		Bits 08–06: PMU Time Quality. Refer to codes in Table 7.
		Bits 05–04: Unlocked time: 00 = sync locked or unlocked < 10 s (best quality)
		          01 = 10 s ≤ unlocked time < 100 s
		          10 = 100 s < unlock time ≤ 1000 s
		          11 = unlocked time > 1000 s
		Bits 03–00: Trigger reason:
		1111–1000: Available for user definition
		0111: Digital 0110: Reserved
		0101: df/dt High 0100: Frequency high or low
		0011: Phase angle diff 0010: Magnitude high
		0001: Magnitude low 0000: Manual

- Bits 15-14 are the only indication of quality

- Applied to the entire PMU

- No signal level information

Data Attributes (Quality?) – 2024 version

- The word "Quality" is very widely used and defined in different contexts.

- This standard has used the word "Attributes" to avoid any conflict.

			Part of Periodic Data Frame
9	PHASOR + (DAPHASOR)	4 or 8 (+2) × PHNMR	Phasor estimates. . . . . Each phasor may be followed by an optional 2-B data attributes field (DAPHASOR). The option to include data attributes in the periodic data frame shall be included in the configuration metadata (see Table 3, Table 8).

			Part of Configuration Frame
30	PMUFLAG	2	Bit 12: 1 = data attributes included in this data stream, 0 = not included

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Data Attributes

Bit #	Field	Set By	Description
15	Data modified	PDC	1 = Modified by PDC/application function.
14	Data error	PMU	1 = Erroneous data. Do not use.
13	Test data	PMU	1 = Test data. Data from PMU, but not actual system measurement. Not to be used for application functions, like test mode in STAT_FLAG word (Table 5). The data shall not be rejected by the PDC but shall be passed through as is.
12	Step detected	PMU	1 = Step/fault detected. Measurement window encompasses a transient.
11	Repeated value	PMU/PDC	1 = Last known value – repeated data.
10	Inconsistent data	PDC	1 = Inconsistent data, based on nearby observations. Use with caution, value is suspect.
9	Estimated value	PDC	1 = Estimated value.
8	Phase adjusted	PDC	1 = Phase adjusted for reference phase rotation in system.
7	Format change type	PDC	1 = Format change (int/float).
6	Format change type	PDC	1 = Format change (polar/rectangular).
5	Reserved	PMU	Always set to 0 by PMU.
4	Reserved	PMU	Always set to 0 by PMU.
3	Value unreasonable	PDC/application	1 = Engineering values not within reasonable range.
2	Reserved	PMU	Always set to 0 by PMU.
1	Reserved	PMU	Always set to 0 by PMU.
0	Reserved	PMU	Always set to 0 by PMU.

Mandatory frequency / rate of change of frequency – 2011 Version

7	PHASORS	4 × PHNMR or 8 × PHNMR	Phasor estimates. . . . . The number of values is determined by the PHNMR field in configuration 1, 2, and 3 frames.
8	FREQ	2 / 4	Frequency (fixed or floating point).
9	DFREQ	2 / 4	ROCOF (fixed or floating point).
10	ANALOG	2 × ANNMR or 4 × ANNMR	Analog data . . . . The number of values is determined by the ANNMR field in configuration 1, 2, and 3 frames.

- 2011 version data frame must include exactly one frequency and one rate of change of frequency

- Difficult to maintain accuracy for ROCOF

- It must be included, even if the user does not want it, and vendor does not want to provide it

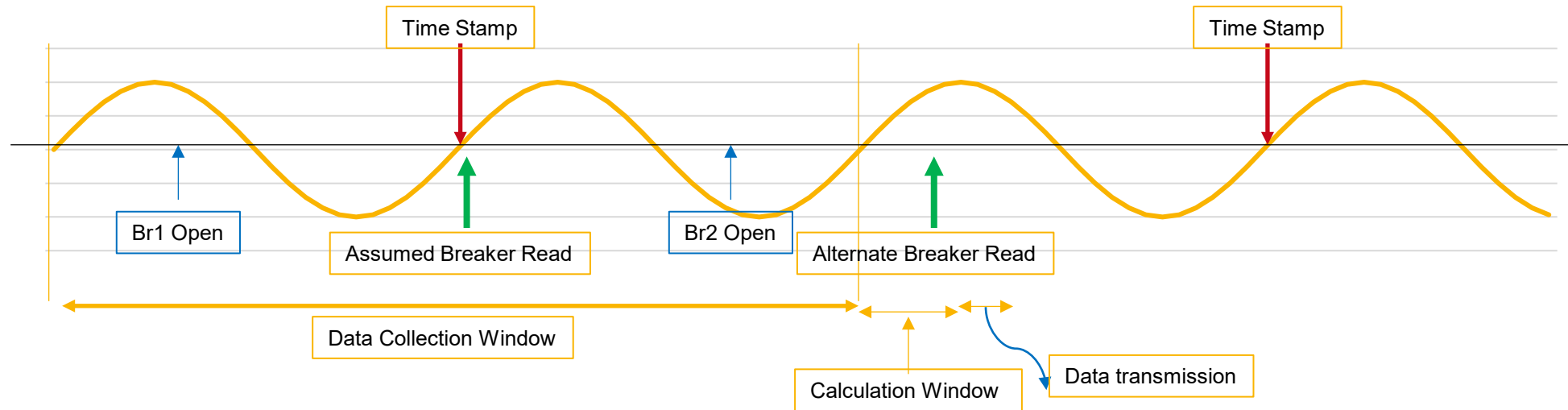# Mandatory frequency / rate of change of frequency – 2024 Version

9	PHASOR + (DAPHASOR)	4 or 8 (+2) × PHNMR	Phasor estimates. . . . . Each phasor may be followed by an optional 2-B data attributes field (DAPHASOR). The option to include data attributes in the periodic data frame shall be included in the configuration metadata (see Table 3, Table 8).
10	FREQ + (DAFREQ)	2 or 4 (+2) x FRNMR	Frequency. . . . . Each FREQ measurement may be followed by an optional 2-B data attributes field (DAFREQ). The option to include data attributes in the periodic data frame shall be included in the configuration metadata (see Table 3, Table 8).
11	DFREQ + (DADFREQ)	2 or 4 (+2) x DFDTNMR	ROCOF (fixed or floating point), in Hertz per second times 100. . . . . . Each DFREQ measurement may be followed by an optional 2-B data attributes field (DADFREQ). The option to include data attributes in the periodic data frame shall be included in the configuration metadata (see Table 3, Table 8).
12	ANALOG	2 × ANNMR or 4 × ANNMR	Analog data. . . . . The number of values is determined by the ANNMR field in configuration frames.

Digital events – 2011 Data Frame

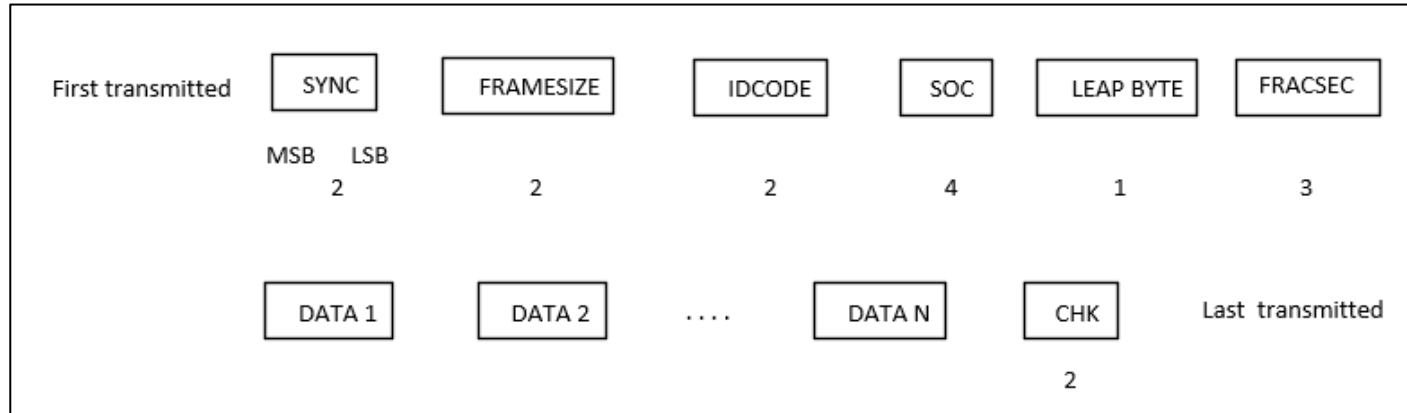|		
PHASORS	4 × PHNMR or 8 × PHNMR	Phasor estimates. . . . The number of values is determined by the PHNMR field in configuration 1, 2, and 3 frames.
FREQ	2 / 4	Frequency (fixed or floating point).
DFREQ	2 / 4	ROCOF (fixed or floating point).
ANALOG	2 × ANNMR or 4 × ANNMR	Analog data . . . . The number of values is determined by the ANNMR field in configuration 1, 2, and 3 frames.
DIGITAL	2 × DGNMR	Digital data, usually representing 16 digital status points (channels). The number of values is determined by the DGNMR field in configuration frames . . . .

Digital events – 2011 Version

Time Stamp

Time Stamp

Br1 Open

Assumed Breaker Read

Br2 Open

Alternate Breaker Read

Data Collection Window

Calculation Window

Data transmission

- Data transmission at 30 frames / second

- 118.2 Data frame transmission includes calculated phasors, digital status, with indicated time stamp

- (Assumption) : Transmitted data includes breaker status "at" the time stamp
  - Br1: Open, Br2: Closed

- (Alternate) : Read both breaker statuses just before data transmission – send the "latest"
  - Br1: Open, Br2: Open

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Discrete Event Data Frame

First transmitted	SYNC	FRAMESIZE	IDCODE	SOC	LEAP BYTE	FRACSEC
	MSB LSB					
	2	2	2	4	1	3

	DATA 1	DATA 2	. . . .	DATA N	CHK	Last transmitted
					2	

DIGITALS

DATA 1 . . . . DATA N

- Discrete event data frame is similar to the periodic data frame

- It includes all digital signals, and only the digital signals, from the periodic data frame.

- Time stamps can be aperiodic

Time Stamp Calculation / Discrete event data frame

- FRACSEC = ROUND ((fractional second of time stamp) * TIME_BASE)

- Time = SOC + (FRACSEC / TIME_BASE)

- For synchronized, periodic data, FRACSEC values will be evenly spaced

	Periodic		
TIME_BASE >>	60	720	9000
Time	FRACSEC values		
. . .			
0.400	24	288	3600
0.433	26	312	3900
0.467	28	336	4200
0.500	30	360	4500
. . .			
0.600	36	432	5400
. . .			
0.967	58	696	8700

|	Discrete Events		
TIME_BASE >>	60	720	9000
Time	FRACSEC values		
0.619	37	446	5571
0.620	37	446	5580
0.624	37	449	5616
0.7372	44	531	6635
0.7373	44	531	6636
0.7374	44	531	6637
Resolution (ms)	16.667	1.389	0.111

Remote Network Configuration
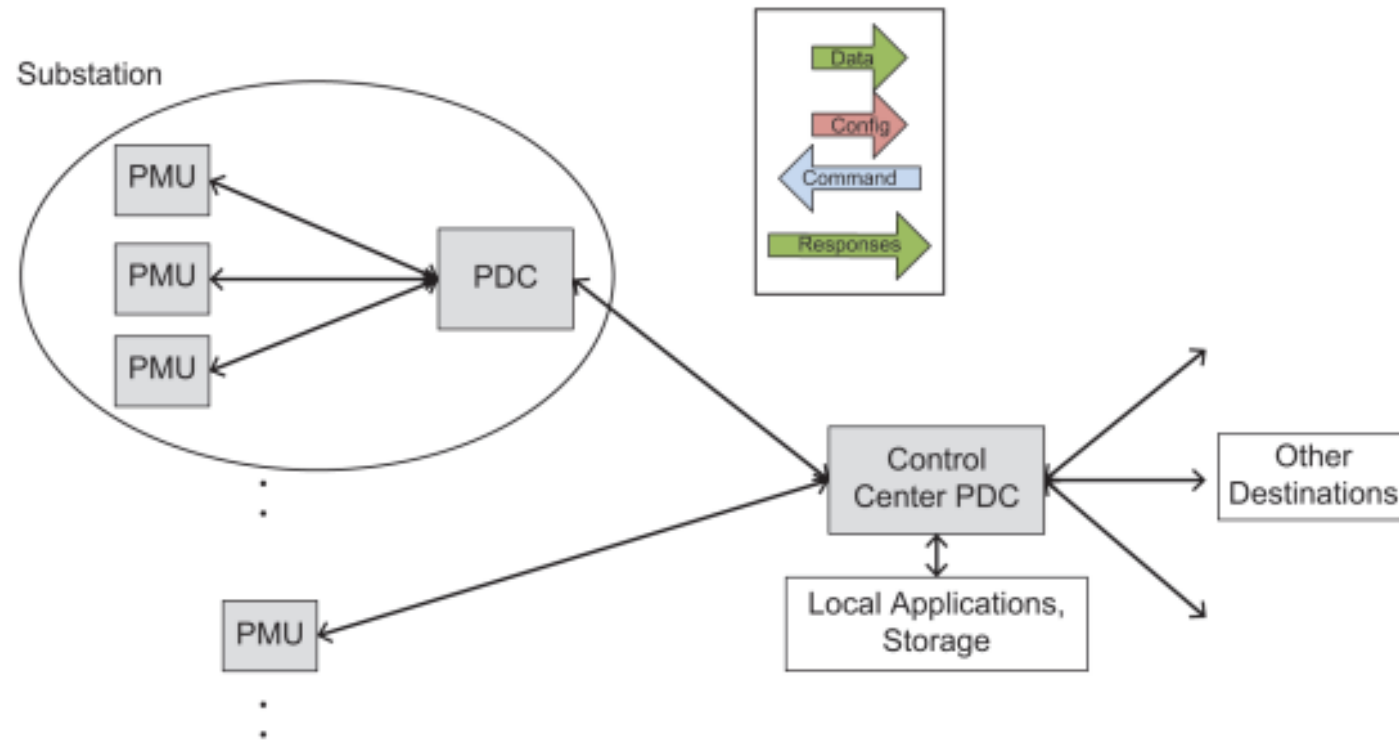
Figure 1—An example of a synchrophasor system

Configuration Frames in 2024 Version

- ## Capacity (Old CFG1)

  - PMU >> PDC >> CC: A list of available signals (default factory names on installation)

- ## Rename (New command)

  - PMU << PDC << CC: Change signal names, based on configuration strategy

- ## Configure Stream (specific) (New Command)

  - PMU << PDC << CC: Which signals to include in this stream

- ## Stream Configuration (Old CFG2/CFG3)

  - PMU >> PDC >> CC: A list of signals included in this stream
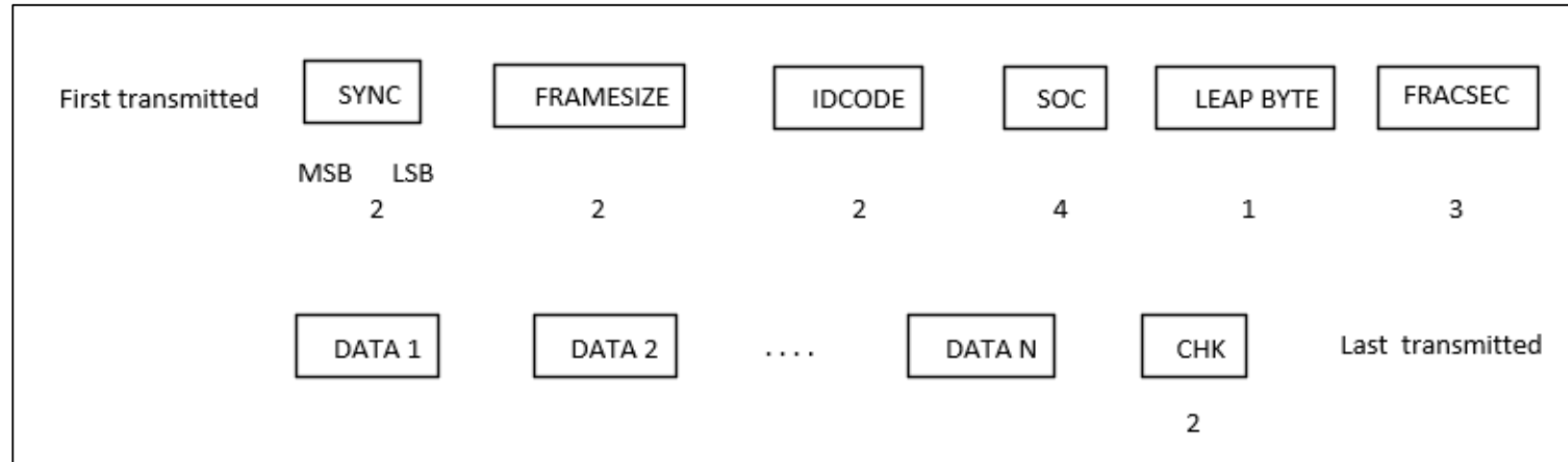
Remote Configuration
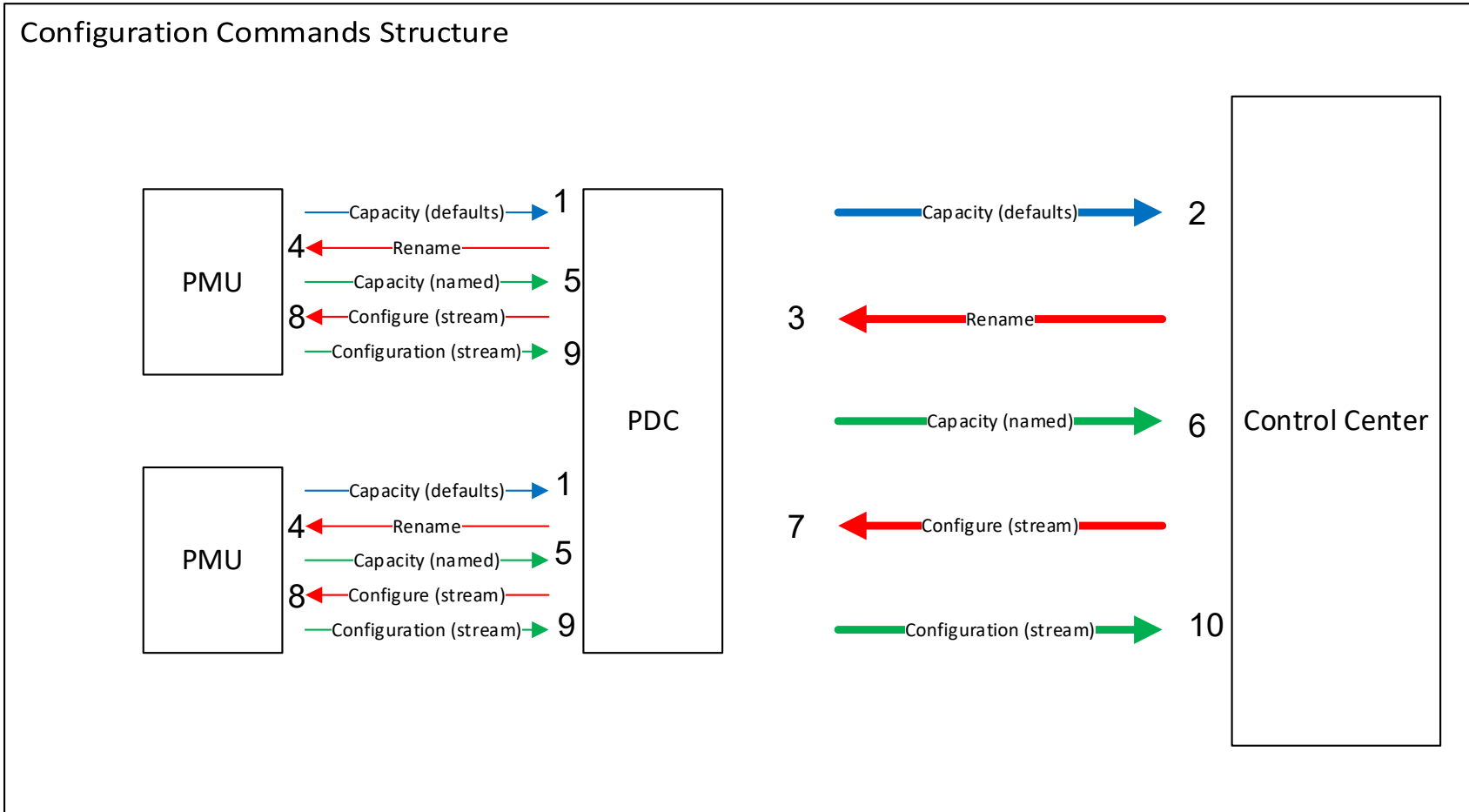
PMU Response to Commands

Figure 1—An example of a synchrophasor system

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Error Response Frame

PMU response to commands

No.	Field	Size (bytes)	Comment
1	SYNC	2	See Table 1.
2	FRAMESIZE	2	See Table 1.
3	STREAM_ID	2	See Table 1.
4	SOC	4	See Table 1.
5	LEAP_BYTE	1	See Table 1.
6	FRACSEC	3	See Table 1.
7	ERROR-RESPONSE-1	2	Error-response word 1 defined in Table 17.
8	ERROR-RESPONSE-2	2	Error-response word 2. It shall be 0, unless defined otherwise in Table 17.
9	CHK	2	See Table 1.

PMU response to commands

ERROR-RESPONSE-1 decimal value	Description
0	Reserved.
1	Could not interpret command or rejected command.
2	Wrong STREAM_ID or PMU_ID. Users may enable this during testing/calibration/installation etc. and disable it during normal operation.
3 to 31	Reserved.
Rename command errors	
32	Number mismatch. One of the (NUM_PMU, PHNMR, ANNMR, FREQNMR, DFDTNMR) does not match. ERROR-RESPONSE-2 indicates the first of the expected matching fields with the mismatch.
33	Too many names included. ERROR-RESPONSE-2 indicates which PMU number has this error.
34	Too few names included. ERROR-RESPONSE-2 indicates which PMU number has this error.
35	Unacceptable characters in a name (see Table 2). ERROR-RESPONSE-2 indicates first of the expected names with this error.
36	Data stream is ON. Command not accepted.
37 to 63	Reserved.
Configure stream command errors. In most cases, ERROR-RESPONSE-2 indicates the sequence number of the field where the error occurred.	
64	Invalid TIME_BASE. The assigned value does not support any of the data rates in Table 18.
65	Mismatched field. ERROR-RESPONSE-2 indicates which expected matching field does not match.
66	NUM_PMU error. Too many PMUs, or zero PMUs. ERROR-RESPONSE-2 indicates the number.
67	FORMAT field invalid.
68	Number mismatch. One of the (PHNMR, ANNMR, FREQNMR, DFDTNMR) is larger than the number of signals available. ERROR-RESPONSE-2 indicates the first of the expected matching fields with the mismatch.
69	PHSCALE invalid. ERROR-RESPONSE-2 indicates the first of the fields with this error.
70	Floating point number error in FRSCALE, DFDTSCALE, ANSCALE. ERROR-RESPONSE-2 indicates the first of the fields with this error.
71	Invalid LATITUDE. ERROR-RESPONSE-2 indicates which PMU number has this error.
.	
.	

Version 2 Limitations

- STAT flag bits open to different interpretations

- Time quality information anomalies

- No signal-based data quality information

- Frequency/ROCOF were mandatory

- Digital events time stamps not accurate

- No remote configuration

- No response from PMUs to indicate any problems

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Version 2 Compliance

- Previous version of a standard is obsolete the instant a new version is published.

- All devices in the field would be obsolete (technically)

- Version 2 requirements included as normative annex

1 ◢ **Annex A (normative)**

2 **Version 2 compliance requirements (optional)**

3 **A.1 Introduction**

4 The 2011 edition of this standard [B7] describes the version 2 of this standard. This annex summarizes those
5 requirements. These requirements shall be met by devices and applications to remain compliant with version
6 2 of this standard.

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Mixed Version Usage
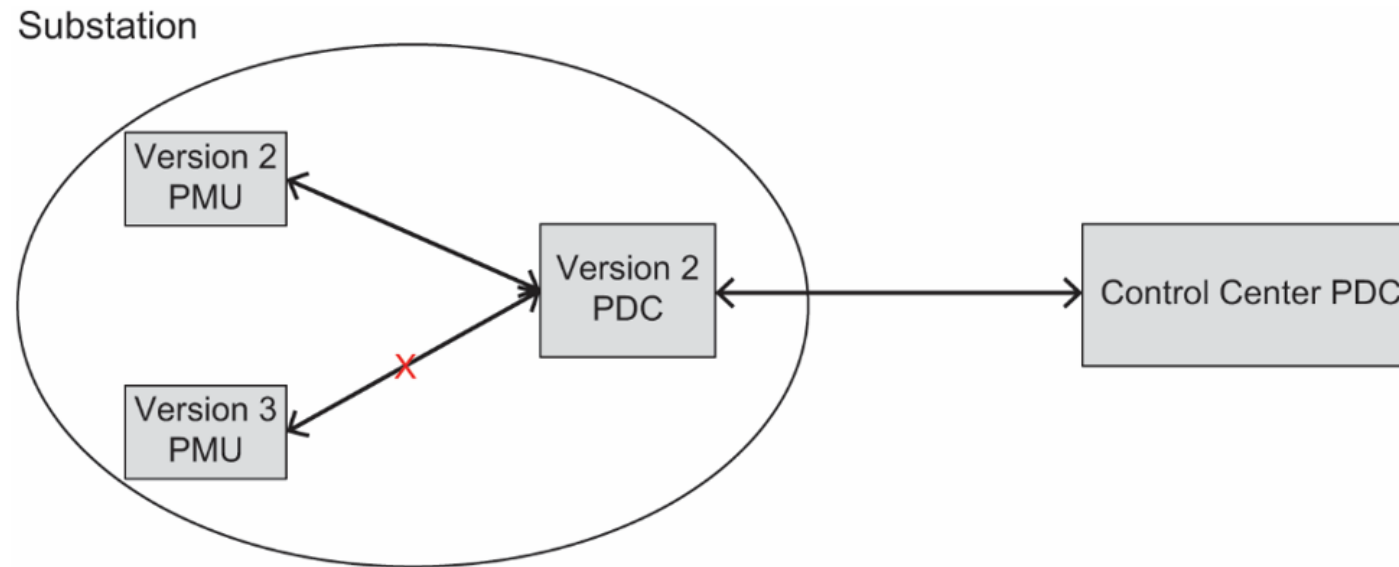
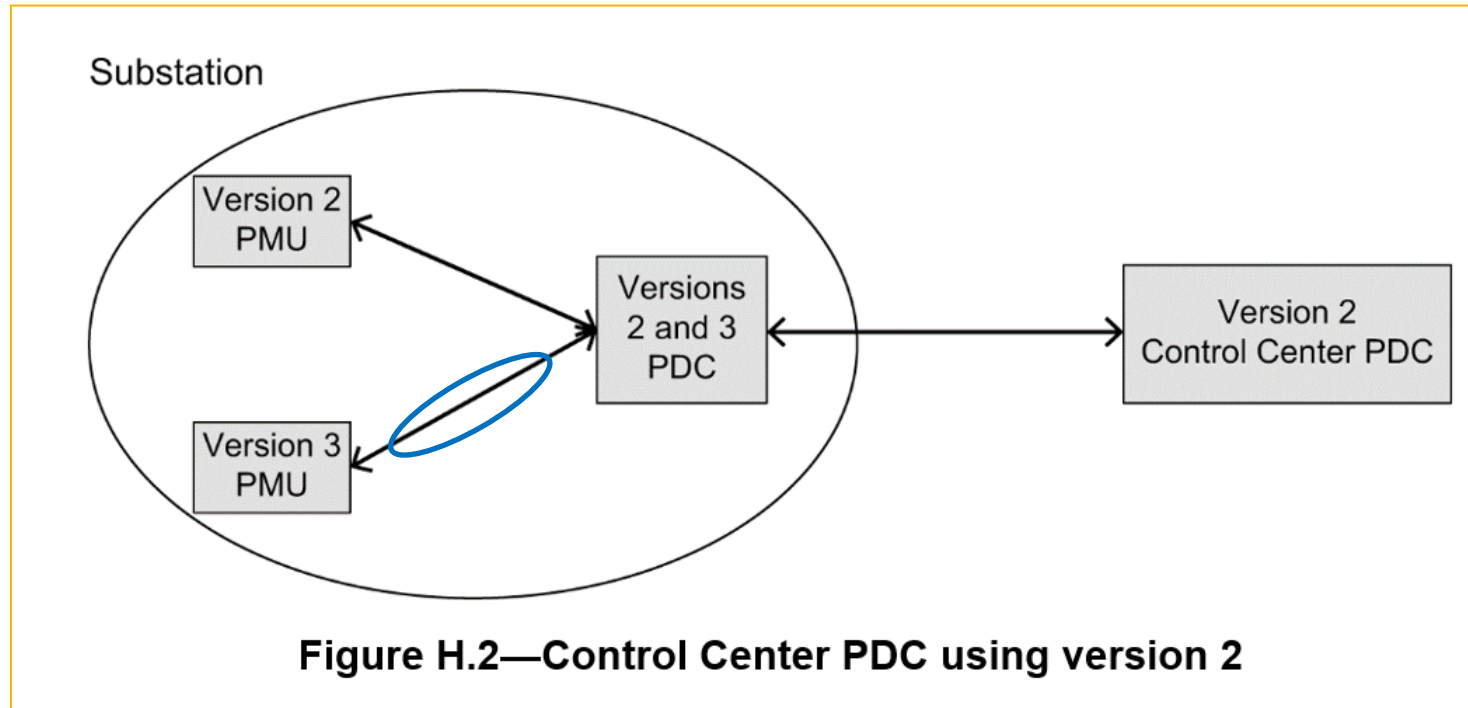Figure H.1—Substation PDC using version 2, control center PDC version irrelevant

- Version 2 PDC cannot handle Version 3 PMU

Mixed Version Usage
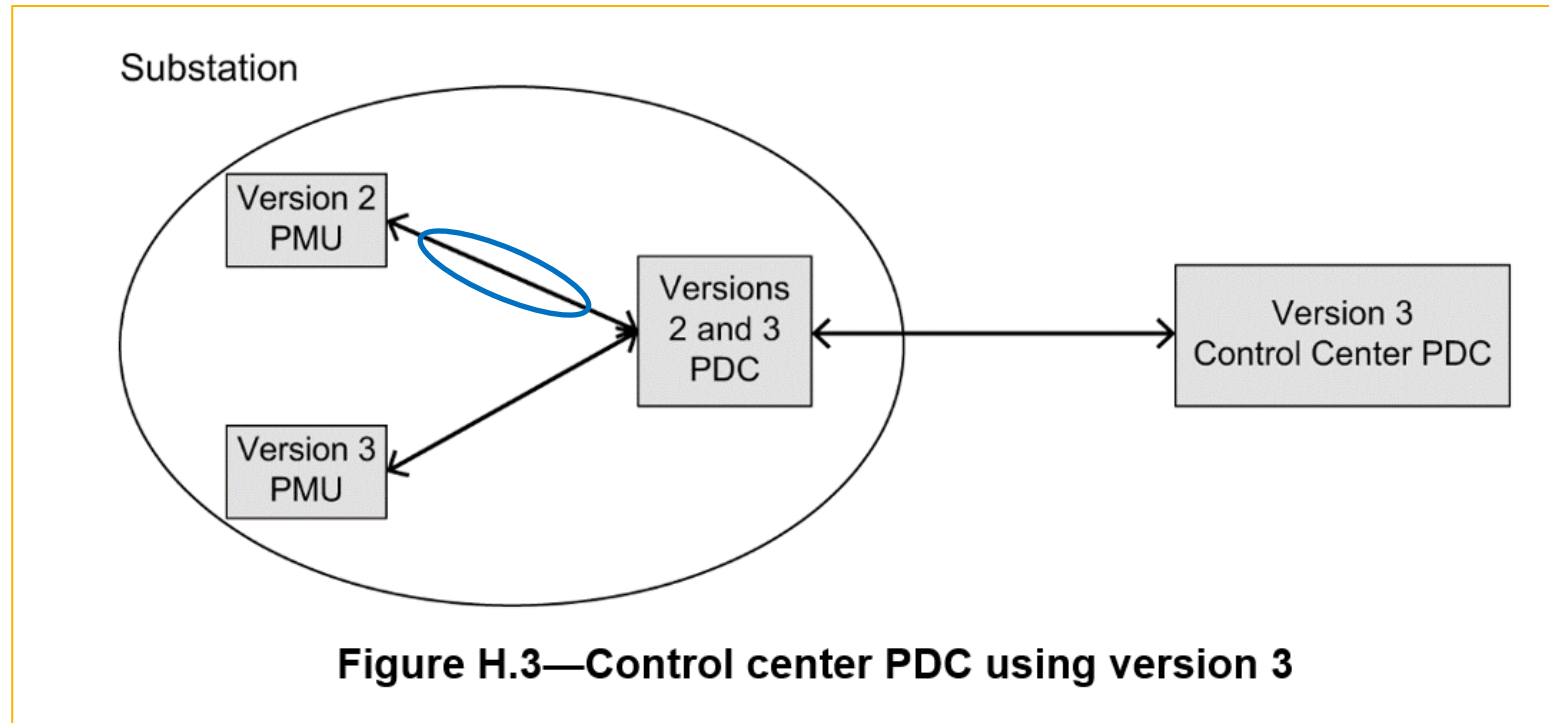

Figure H.2—Control Center PDC using version 2

<< Commands <<

>> Configuration >>

>> Periodic Data >>

- PDC to convert Version 3 PMU stream to Version 2, for version 2 control center.

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Mixed Version Usage

Figure H.3—Control center PDC using version 3

<< Commands <<

>> Configuration >>

>> Periodic Data >>

- PDC to convert Version 2 PMU stream to Version 3, to send to version 3 control center.

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Other changes

- Configuration frames in XML format

    - Purpose

        - Archival

        - Information exchange

- Old data request

    - In case PDC stores archival data

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Questions or Comments?

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