SPP PMU Communications Handbook

Southwest Power Pool

Revision History

Date or Version Number	Author	Change Description	Comments
11/09/16	Lance Reaves	Initial Creation of Approach for Review.	First Draft
12/1/16	Lance Reaves	First revision.	Adding to draft.
5/23/17	Lance Reaves	Second revision.	Adding to draft.
6/22/17	Lance Reaves	Third revision.	Data quality section changes.
6/28/17	Mike Nugent	Fourth revision.	Updated naming conventions.
9/27/17	Lance Reaves	Fifth revision	Added recommended SIEGate/PDC listening port numbers.
10/25/17	Lance Reaves/Mike Nugent	Sixth revision	Changes discussed on 10/2 SST conference call.
12/1/17	Lance Reaves/Mike Nugent	Seventh revision	Ready to be reviewed for approval by SST
12/12/17	Mike Nugent	Seventh revision discussed in 12/11/17 SST meeting	Edits reviewed with SST and accepted. Minor edits to bandwidth table
1/5/2018	Lance Reaves	Version 1.0	SST approved Version 1.0.
1/11/21	Lance Reaves/Ryan Lott	Version 1.1	Addition of EInet, SPPNet and WISP connection options,

			Western Interconnect nomenclature.
5/11/2022	Lance Reaves	Version 1.2	Highly available multi-site architecture changes, Area Identifier changes for Evergy.

1 Table of Contents

2 Introduction

The *SPP PMU Communications Handbook* sets practices, conventions, and fundamental parameters required for PMU data to be exchanged with SPP. Also included in the Handbook is a description of the physical network infrastructure required. Specifics regarding the use of this data are beyond the scope of this document.

The Handbook specifies important configuration and functional requirements for PMU implementations so that the user's system will interoperate with SPP's system. Users and vendors, if applicable, will need this information to include the required features and to build the properly delivered PMU configuration.

SPP has the following planned uses of PMU data:

- Diagnosing Mis-Operations
- Model Validation
- Oscillation Detection and Monitoring
- Phase Angle Monitoring
- Post Event Analysis
- Voltage Stability Monitoring
- Wide Area Situational Awareness

2.1 Intended Audience

This handbook is for the reader seeking to quickly acquaint themselves with PMU naming conventions, PMU data connections, how the network operates, and how to request information.

Diagrams will be available throughout this handbook to aid in visualization and understanding. Criteria will be quoted and referenced throughout the document.
Anyone using this document should have:

- General knowledge of data communications concepts
- Working knowledge of PMU functions and concepts
- Familiarity with modern data communications technology
- Knowledge of TCP/IP protocol concepts

2.2 References

Grid Protection Alliance: Open source software corporation specializing in Synchrophasor related software. Makers of SIEGate and openPDC software as shown in the deployment diagram in this document. https://www.gridprotectionalliance.org/

Electric Power Group: Commercial software corporation specializing in Synchrophasor related software. Makers of ePDC, RTDMS, ISG, and PDGA software as shown in the deployment diagram in this document. http://www.electricpowergroup.com/

North American Synchrophasor Initiative: https://www.naspi.org/

NASPI PMU Data Quality White Paper, March 2017 v1.0
https://www.naspi.org/sites/default/files/reference_documents/PARTF_WhitePaper_20170314_Final_PNNL_26313.pdf?fileID=1689

NERC Reliability Guideline – PMU Placement and Installation
https://www.nerc.com/comm/PC_Reliability_Guidelines_DL/Reliability%20Guideline%20-%20PMU%20Placement.pdf#search=pmu%20placement

PEAK PRSP Phasor Gateway Evaluation Report
https://www.naspi.org/sites/default/files/2017-03/PRSP_Phasor_Gateway_Whitepaper_Final_with_disclaimer_Final.pdf

2.3 Glossary

Synchrophasor: Are time-synchronized numbers that represent both the magnitude and phase angle of the sinusoidal waves found in electricity, and are time-synchronized for accuracy. They are measured by high-speed monitors called Phasor Measurement Units (PMUs) that are 100 times faster than SCADA. PMU measurements record grid conditions with great accuracy and offer insight into grid stability or stress.

PMU (Phasor Measurement Unit): Are substation devices that directly measure amplitude and phase angle of current and voltage quantities at a high sampling rate (typically 30-60 samples per second.) PMU devices have high-precision time synchronization (via GPS) which supports direct comparison of measured values (synchrophasors) from different points on the grid. PMU devices also derive Frequency and Rate of Change of Frequency (ROCOF) from the measured voltage phase angle.

PDC (Phasor Data Concentrator): Are devices which aggregate and time synchronize (or time align) phasor data streamed from Phasor Measurement Units (PMUs) and output the data for applications and archival.

Grid Protection Alliance SIEGate: An application designed to securely exchange data among devices (such as other SIEGate nodes) using GPA's Gateway Exchange Protocol.

SPPNet: Southwest Power Pool's private WAN used for secure, redundant communications between SPP and Market Participants.

EInet (The Electric Information Network): EIDSN's (Eastern Interconnect Data Sharing Network) private WAN used for secure, redundant communications between its Members and Participants. More information at https://eidsn.org/.

WISP (Western Interconnect Synchrophasor Project): A private WAN used for secure communication of synchrophasor data in the Western Interconnect.

TCP (Transmission Control Protocol): A low-level protocol for use mainly on Ethernet or related networks. Most of the higher-level protocols use TCP/IP to transport the data. TCP/IP provides a highly reliable connection over unreliable networks, using checksums, congestion control, and automatic resending of bad or missing data. TCP/IP requires time to handshake new connections and will block if missing data is being resent.

UDP (User Datagram Protocol): A low-level IP protocol that provides low-latency communication across Ethernet or related networks. UDP/IP does not provide any error-control or resending of missing or bad data. The Application will need to check data for correctness. UDP/IP however, does not require time for handshaking and will not block, making it ideal for real-time data communications.

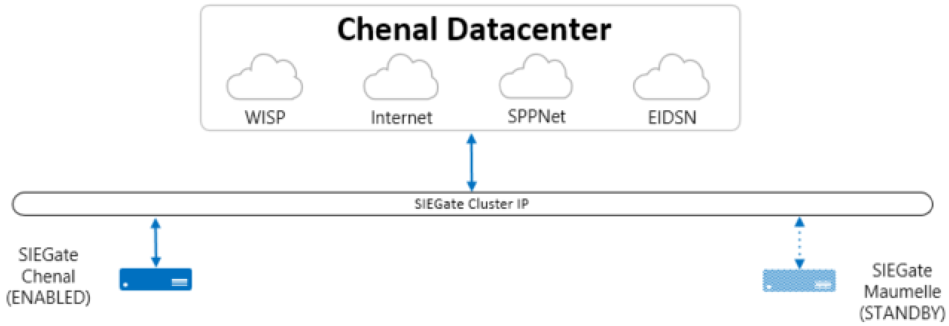
VPN (Virtual Private Network): A VPN extends a private network across a public network, such as the Internet. It enables a computer to send and receive data across shared or public networks as if it is directly connected to the private network, while benefiting from the functionality, security and management policies of the private network. A VPN is created by establishing a virtual point-to-point connection through the use of dedicated connections, virtual tunneling protocols, or traffic encryptions.

WAN (Wide Area Network): A network of computers interconnected over large distances for sharing resources or exchanging data.

3 SPP Synchrophasor System Architecture

SPP uses a multi-site architecture residing in SPP's non-ESP Production environment as shown below. SPP supports multiple communication networks with Members and other external entities' SIEGate/PDCs; see section 6 for more details. SPP supports using the Gateway Exchange Protocol via a SIEGate connection, or C37.118 via a PDC connection within a VPN tunnel if needed.

Deployment Model – Non-ESP Production



4 SPP Synchrophasor Standards, Policies, and Conventions

4.1 C37.118 Naming Conventions

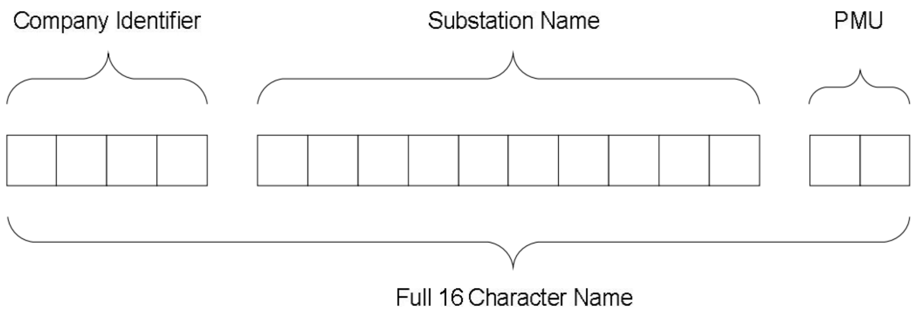
The C37.118 data protocol used to send and receive synchrophasor has specific built-in fields for identifying measurements. This naming and identification data will typically be configured in each PMU and automatically passed upstream to all PDCs and data clients. In situations where the PMU does not support changing signal or device names, those names should be configured in the PDC before sending on to SPP or other downstream consumers. There are two configuration parameters, STN or Station Name and CHNAM or Channel Name.

The Station Name is the name of substation and PMU identifier. There will generally be several signals, or CHNAM channels, under each STN. All STN and CHNAM are 16 characters or bytes long.

SPP has chosen to adopt common naming conventions based on those in use by PJM, MISO, WECC and others in the industry. This convention aims to identify the company, substation, measurement location, voltage level, device type, and equipment name using the 16-character STN/PMU and CHNAM/Signal names, and provides a relationship to the EMS model.

Note: The same nomenclature also applies to PMU connection links using GEP or STPP protocol.

4.1.1 16-Character PMU Name



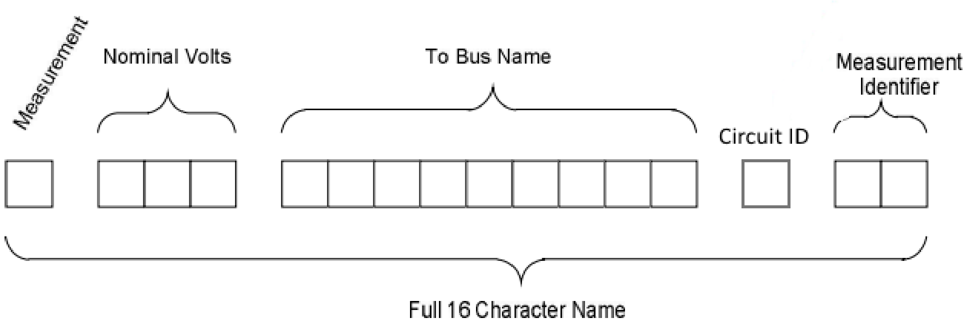
1. Company Identifier (4 characters) - Company identifier based on the entity (see Appendix 10.1.1 for eastern interconnection and Appendix 10.1.2 for western interconnection). Pad to the right with underscores if less than 4 characters.

2. Substation Name (10 characters) – SPP EMS Model Substation name. SPP staff can assist with determining the correct name, if necessary. Pad to the right with underscores if less than 10 characters.

3. PMU # (2 digit integer from 01-99) – Order of PMU in the substation (e.g. '01', '02', '03' if multiple PMUs are installed). Should correspond with measured equipment identifier, if possible. For example, if a substation has generators 1-3 each with its own PMU device, the PMU device ID's should be named '01'-'03'. If only one PMU is installed, use '01'.

East Example: SPS_STATION01_01
West Example: W077STATION01_01
For readability and compatibility, it is best practice to avoid using embedded spaces in signal or device names.

4.1.2 16-Character Signal Name



1. Measurement (1 character) - to identify measurement location or equipment type.
   i. **B** - Bus Side Phasor
   ii. **L** – Line Side Phasor
   iii. **T** – Transformer Phasor

iv. **G** – Generator Phasor
v. **C** – Capacitor Phasor
vi. **R** – Reactor Phasor
vii. **S** – Static Var Compensator Phasor
viii. **A** – Analog (non-phasor use for frequency, df/dt, Watts, VARs, or any single value scalar)
ix. **D** – Digital or status i.e. 1 or 0

2. Nominal Volts (3 digit integer from 001-999) - nominal voltage in kV (e.g. '345'). For voltages such as 13.8 round to the nearest whole number. For 2 digit voltages, prefix with a 0, e.g. '069'. For transformers, this value should be set to the nominal voltage of the winding (primary, secondary, tertiary) the PMU measurement is made on.

3. "To Bus" Name (9 characters)
   i. If the signal is measuring a transmission line's current, this field should be set to the SPP EMS Name of the substation on the opposite end of the line. SPP staff can assist with determining the correct name, if necessary.
   ii. For a bus section, the identifier of the bus being measured (e.g. 'NORTH', 'SOUTH', '1', etc.). If substation has multiple bus sections, use this field to describe each unique measurement point.
   iii. For generators and reactive devices, a descriptive name of the equipment (e.g. 'UN2_GSU', 'UNIT1', 'BANK1', etc.)
   iv. For transformers, a descriptive name of the voltage ratio and location of PMU measurement point on either high or low side (e.g. '345x138_H' or '345x138_L').
   v. For all frequency and df/dt (ROCOF) measurements (regardless of grid element type), these value for the "To Bus" field shall be "FREQ_____".

4. Circuit ID (1 character) – If parallel elements exist (e.g. multiple lines or transformers), enter the applicable circuit ID of the equipment (e.g. 'A','B','1','2','N','S'). Otherwise, enter '1'.

5. Measurement Identifier (2 characters) – applicable signal identifier as noted in the table below:

Signal Identifier	Measurement Quantity	Measurement Type
VP	Voltage	Positive Sequence
IP	Current	Positive Sequence
VZ	Voltage	Zero Sequence
IZ	Current	Zero Sequence
VN	Voltage	Negative Sequence
IN	Current	Negative Sequence
F	Frequency	Frequency
R	df/dt or ROCOF	Rate of change of Frequency
VA	Voltage	Phase A

VB	Voltage	Phase B
VC	Voltage	Phase C
IA	Current	Phase A
IB	Current	Phase B
IC	Current	Phase C

4.1.3 Naming Examples

The following examples use made-up Area, Substation, and Equipment names to demonstrate the PMU and Signal naming convention for C37.118 protocol data streams.

1. Eastern Interconnection Entity with an Area name "EX" has 2 PMUs located at station "STATN1", each measuring a parallel 230kV line going to "STATN2".
   a. Line PMU1: EX__STATN1____01
      i. Freq: A230FREQ_____1F_
      ii. Pos. Sequence Voltage: L230STATN2___1VP
      iii. Pos Sequence Current: L230STATN2___1IP
      iv. df/dt: A230FREQ_____1R_

   b. Line PMU2: EX__STATN1____02
      i. Freq: A230FREQ_____1F_
      ii. Pos. Sequence Voltage: L230STATN2___2VP
      iii. Pos Sequence Current: L230STATN2___2IP
      iv. df/dt: A230FREQ_____1R_

2. Eastern Interconnection Entity with an Area name "POWR" has 2 PMUs located at station "PW_PLANT". One PMU directly measures a 13.8kV Generator named "Unit 1". The other PMU measures a Generator Step Up transformer on the high side at 345kV, as well as a 345kV line to SWTCHST.
   a. Generator PMU: POWRPW_PLANT__01
      i. Freq: A014FREQ_____1F_
      ii. Pos. Sequence Voltage: G014UNIT1____1VP
      iii. Pos Sequence Current: G014UNIT1____1IP
      iv. df/dt: A014FREQ_____1R_

   b. Line/XFMR PMU: POWRPW_PLANT__02
      i. Freq: A345FREQ_____1F_
      ii. Pos. Seq. V for 345 bus: L345SWTCHST__1VP
      iii. Pos. Seq. I for 345 line: L345SWTCHST__1IP
      iv. Pos. Seq. I for XFMR: T345345x14__H1IP
      v. df/dt: A345FREQ_____1R_

3. Western Interconnection Entity with an Area name "W999" has 2 PMUs located at station "STATN1", each measuring a parallel 230kV line going to "STATN2".
   a. Line PMU1: W999STATN1____01

        i. Freq: A230FREQ_____1F_
        ii. Pos. Sequence Voltage: L230STATN2___1VP
        iii. Pos Sequence Current: L230STATN2___1IP
        iv. df/dt: A230FREQ_____1R_

    b. Line PMU2: W999STATN1____02
        i. Freq: A230FREQ_____1F_
        ii. Pos. Sequence Voltage: L230STATN2___2VP
        iii. Pos Sequence Current: L230STATN2___2IP
        iv. df/dt: A230FREQ_____1R_

4. Western Interconnection Entity with an Area name “W999” has 2 PMUs located at station “PW_PLANT”. One PMU directly measures a 13.8kV Generator named “Unit 1”. The other PMU measures a Generator Step Up transformer on the high side at 345kV, as well as a 345kV line to SWTCHST.
    a. Generator PMU: W999PW_PLANT__01
        i. Freq: A014FREQ_____1F_
        ii. Pos. Sequence Voltage: G014UNIT1____1VP
        iii. Pos Sequence Current: G014UNIT1____1IP
        iv. df/dt: A014FREQ_____1R_

    b. Line/XFMR PMU: W999PW_PLANT__02
        i. Freq: A345FREQ_____1F_
        ii. Pos. Seq. V for 345 bus: L345SWTCHST__1VP
        iii. Pos. Seq. I for 345 line: L345SWTCHST__1IP
        iv. Pos. Seq. I for XFMR: T345345x14__H1IP
        v. df/dt: A345FREQ_____1R_

4.2 Gateway Exchange Protocol (GEP) Additional Fields

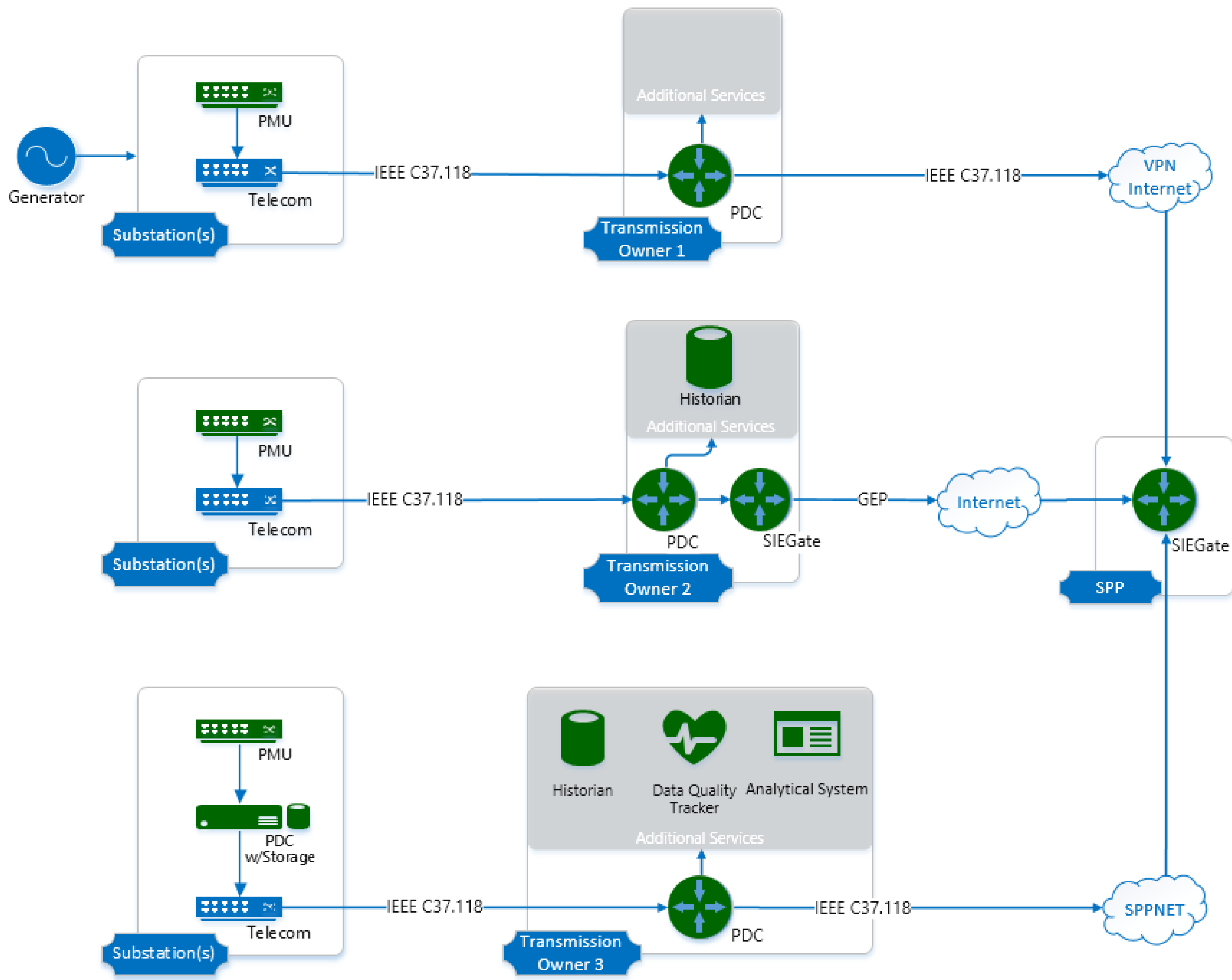
The Gateway Exchange Protocol offers additional metadata fields that can be configured if data is being sent using GEP. Typically, these fields would be configured in the user’s openPDC, and would be automatically propagated downstream to SIEGate and SPP.

- Device Level Metadata Fields
    - Acronym – Same as 16-Character PMU Name in section 4.1.1
    - Name – Option for Friendly Name/Common Name, or same as Acronym
    - Company – The Company that owns the device
    - Interconnection (Eastern or Western)
    - Device Vendor (optional) – Model of PMU device
    - Longitude/Latitude – GIS coordinates of the device
    - Frames per Second
- Phasor Metadata Fields
    - Label – Same as 16-Character Signal Name in section 4.1.2
    - Type – Voltage or Current

- Phase – A,B,C, + Sequence

5 Synchrophasor Communication System

The SPP Synchrophasor Communication System allows SPP to collect and manage data from both standalone phasor measurement units (PMUs) as well as Relays and Digital Fault Recorders (DFRs). Below are examples of minimum PMU architectures that support streaming PMU data to SPP's control center, starting from the substation and ending at SPP.



5.1 Phasor Measurement Unit Device Requirements

A phasor measurement device (PMU) is a device which measures electrical quantities from the grid in real-time, using a common time-source for synchronization. Please refer to the section titled *PMU Installations* in the *SPP Members PMU Planning Approach* document for more information.

- The performance of the PMU must comply at minimum with the 2005 revision of the IEEE C37.118 standard. The protection (P) performance class PMU is preferred. Synchrophasor data acquisitions are defined in the following main IEEE standards and guides:
    - C37.118.1-2011 – Measurement requirements.
      Synchrophasor measurements including frequency and rate of change of frequency
    - C37.118.2-2011 – Communication requirements.
      Extension of the original synchrophasor standard (2005)
    - IEEE 1588 – Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems
- The PMU shall have the capability to calculate positive-sequence values for voltage and current Phasor data; as well as to provide the positive-sequence synchrophasor values to a PDC at the minimum rate of 30 samples per second.
    - **Note:** For all positive sequence calculations, Phase A shall be used as the reference phase.
- The PMU shall have GPS (UTC) synchronization function either through an internal or external GPS receiver. All data recorded shall be in the Coordinated Universal Time (UTC).
- Accuracy and resolution of time synchronization shall be less than or equal to 5 micro seconds to UTC (recommended in NERC Reliability Guideline on PMU Placement).

5.2 Phasor Data Concentrator (PDC) Requirements

The PDC at the Transmission Owner (TO) control center is the central point of collection, management, and distribution of PMU data for authorized real-time and non-real time uses.

- The performance of the TO PDC should comply with the current revisions of standards such as IEEE C37.118.

- The TO PDC shall be able to consolidate and synchronize data from all connected PMUs before sending it to SPP.

- The TO PDC shall have capability of assigning positive sequence reference to any phase (rotate it by 120 or 240 degrees on per signal basis).

- All data streaming from the TO PDC to SPP PDC shall be in compliance with IEEE C37.118 communication standards or SIEGate gateway exchange protocol or equivalent.

- The TO PDC should have the capability to down-sample PMU signals to a rate of 30 samples per second before transmitting to the SPP PDC. This is only needed if the source sampling rate is greater than 30 samples per second.

- The TO PDC should have a clock that is synchronized to UTC. It is recommended that this clock be an external GPS clock. Resolution and accuracy of time synchronization at the PDC should be equal or under 1 micro second to UTC.

5.3 Network Requirements

The following table summarizes the data transmission bandwidth requirements using the C37.118 and Gateway Exchange (GEP) protocols, assuming a TCP/IP network. Three typical situations are presented:

- PMU transmitting 2 phasors (positive-sequence V and I), Frequency and dF/dT analogs and status digital.
- PMU transmitting 8 phasors (three-phase and positive-sequence V and I), Frequency and dF/dT analogs and status digital.
- DDR transmitting 32 phasors (three-phase and positive sequence V and I for four separate measured terminals), Frequency and dF/dT analogs and a status digital for each terminal.

Bandwidth Needed (in kbps) for Data Transmission of Floating-Point Synchrophasor Data Using the C37.118 (un-encrypted) and Gateway Exchange Protocols over TCP/IP

Protocol	c37.118	GEP	c37.118	GEP	c37.118	GEP
# Of PMU @ Data Rate (Frames/Sec)	2 Phasors, 2 Analog, 1 Digital (PMU Pos. Seq. Data)	2 Phasors, 2 Analog, 1 Digital (PMU Pos. Seq. Data)	8 Phasors, 2 Analog, 1 Digital (PMU 3-Phase + Pos. Seq. Data)	8 Phasors, 2 Analog, 1 Digital (PMU 3-Phase + Pos. Seq. Data)	32 Phasors, 2 Analog, 4 Digital (DDR 3-Phase + Pos. Seq. x 4 Devices)	32 Phasors, 2 Analog, 6 Digital (DDR 3-Phase + Pos. Seq. x 4 Devices)
1 PMU @ 30	32.8	21.3	44.1	28.7	90.5	58.8
5 PMU @ 30	66.6	43.3	122.8	79.8	396.1	257.5
10 PMU @ 30	108.8	70.7	241.9	157.2	788.4	512.5
50 PMU @ 30	508.1	330.3	1153.1	749.5	3865.3	2512.4
1 PMU @ 60	65.6	42.6	88.1	57.3	180.9	117.6
5 PMU @ 60	133.1	86.5	245.6	159.6	792.2	514.9
10 PMU @ 60	217.5	141.4	483.8	314.5	1576.9	1025
50 PMU @ 60	1016.3	660.6	2306.3	1499.1	7730.6	5024.9

Table values for C37.118 calculated using: http://www.gridprotectionalliance.org/docs/products/gsf/GEP-bandwidth-estimator.zip. GEP values are calculated as 65% of the C37.118 bandwidth requirement, based on extensive testing of both protocols detailed in the "PRSP Phasor Gateway Evaluation Report." The C37.118 calculator also includes estimates for transmitting data over serial.

Data encryption will increase bandwidth requirements, potentially by a factor of 50-150% (assuming a PDC to PDC data transfer over a VPN connection).

5.4 Technical Specifications

****Standards below taken from the PJM Technical Guidelines for Installation of Synchrophasor Measurements at Generation Facilities.*

The technical requirements and guidelines below are for reference to aid new generation facilities in early planning to design and install synchrophasor measurement system that is compliant and interoperable with SPP. These requirements and guidelines can be used for initial plans, which should then be shared and reviewed with SPP during the Interconnection process.

Measured Phases	Voltage and current signals are required to be streamed to SPP as the Positive Sequence component. Actual measurement of all 3 phases is required for the calculation of Positive Sequence. Note: The Transmission Owner may

	desire all 3 phases, SPP only requires Positive Sequence.
Signals	Required for each measurement point: Voltage, Current, Voltage Angle, Current Angle, Frequency, df/dt (rate of change of frequency)
Scan Rate	30 samples per second streamed to SPP is required.
Data Protocol	C37.118 communicating via TCP/IP, or SIEGate GEP or equivalent.
PMU to SPP PDC Latency (maximum)	Maximum 3 seconds

6 Connecting to SPP – SIEGATE/PDC

Connections to the SPP SIEGate or PDC may be made using four options:

- Internet
  - GEP protocol
  - C37 protocol over VPN
- SPPNet
- EInet
- WISP

6.1 Internet

There are two options for connecting via the internet:

- Grid Protection Alliance SIEGate – SIEGate is open source software that allows for encrypted communication. A direct connection can be made if SIEGate is used. More information on SIEGate is linked in the References section of this document. SPP IT staff will work directly with Member IT staff to form this connection.
- VPN – in the case of PDC to PDC connections, encryption can be at the network level using a VPN. SPP IT staff will work directly with Member IT staff to create the VPN tunnel and form the PDC to PDC connection.

Connections made via the internet cannot be guaranteed to be highly available. Highly available connections must be made via SPPNet or EInet as detailed in the sections below.

Required information to form an internet connection are:

- Externally facing IP address for the Member SIEGate server or PDC.
- Listening port number on the Member SIEGate server or PDC. In an effort to standardize connection ports numbers, it is recommended that port 6172 be configured as the listening port on the Member SIEGate or PDC. If port 6172 is already in use, increment the port number by 1, continuing until an available port is found, preferably not to exceed port 6181.

- Firewalls configured to allow connections from SPP IP address (supplied by SPP).
- Firewalls/network configured to allow server to server (IP to IP) authentication.

SPP IT Cyber Security recommendations for using TLS and certificates for secure communications across the internet:

- Minimum TLS version 1.2.
- Certificates should be issued by a CA, rather than being self-signed.
- The server certificate should be X.509 version 3.
- SHA-256 is the recommended signature hash algorithm.
- A 2048-bit RSA public key and a strong encryption cipher. (e.g. ECDHE_RSA with P-256 and AES_256_GCM).
- The use of the server DNS name in the Subject Alternative Name field.

6.2 SPPNet

SPPNet is a private network used by Southwest Power Pool for secure, redundant communications between SPP and our member organizations. Details on connecting to SPPNet can be found in Section 7 of this document.

6.3 EInet

EInet can be used if you are an existing EIDSN Member.

6.4 WISP

WISP can be used if you are in the Western Interconnect and join the WISP.

7 Connecting to SPPNet

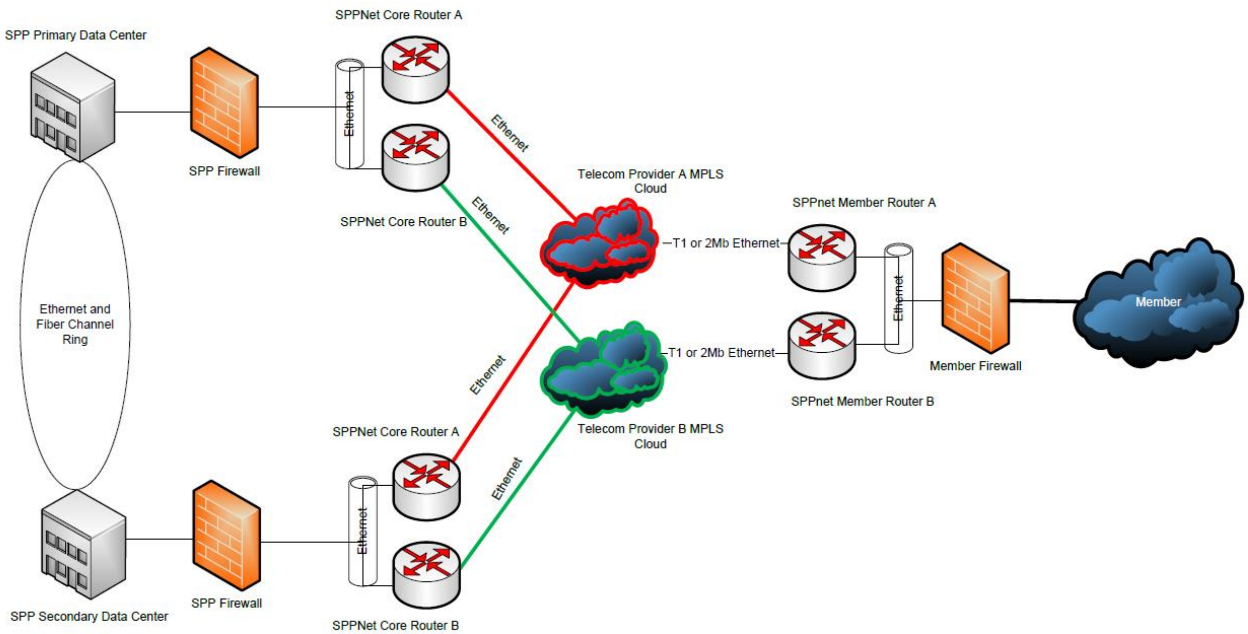
The sections below detail the SPPNet architecture and connection information.

7.1 SPPNet Network Topology Overview

SPPNet is a private network used by Southwest Power Pool for secure, redundant communications between SPP and our member organizations. Data can be exchanged between any member and SPP or between members. The data network is designed to provide redundant, secure, reliable data communications between SPP and our members with automated failover in case of loss of a circuit or router.

SPPNet uses dual circuits provided by two carriers to each location. Each location connects to SPPNet via a Telecom Vendor A circuit and a Telecom Vendor B circuit. Two routers, owned and managed by SPP, are at each location. These routers are connected to the member’s network via a

member supplied firewall. Members do not have access to the SPPNet routers at their location, and SPP does not have access to member firewall to provide for multi-tier security.
Data passes through the member system to their endpoint firewall and then is routed by the SPPNet routers to the destination. The backbone routing structure of SPPNet is over a dual homed design as previously mentioned. Members may transmit different types of data to SPP and are not necessarily limited to ICCP or PMU data. The SPP staff maintains the architecture and communications from member to vendor.
SPPNet circuits and routers are provided to our members as part of the basic membership agreement. Non-members such as Market Participants may also join SPPNet on a contract basis.



SPPNet Overview

7.2 Remote Entity Site Connections

SPP provides two circuits through different vendors; Telecom Vendor A and Telecom Vendor B. SPP also provisions and preconfigures two routers to connect SPPNet to the remote entity's network. This connection is accomplished via a small DMZ segment. The only devices on the DMZ are the two SPPNet routers provided and the firewall which is provided by the entity. All communication is accomplished via SPP assigned addresses. It is the responsibility of the remote entity to configure their router to listen and forward these addresses. Addresses will be provided by SPP to be configured on the remote entity's firewall. The SPPNet routers will connect to the remote entity's firewall appliances and provide the routing path back to SPP and all other entities as well as SPP's vendor if necessary. The SPPNet routers are configured as a redundant pair reducing data loss. No manual intervention is required. Southwest Power Pool is responsible for all configuration of the routers and assumes the cost of maintenance and repair for the duration of the connection.

7.3 Getting Connected to SPPNet

When a request for SPPNet connectivity is made, SPP will exchange site data with the requesting participant. The data exchanged includes location and demarc information as well as contact details. Once SPP receives this information, SPP will begin the order process and verification.
After the approval process has been completed SPP will begin the order process. Lead time for circuit orders is typically 45 to 60 business days. During this time SPP will order the routers and configure them. Also, during the order process SPP will discuss with the requesting participant the technical details of the connectivity. The requesting participant is responsible for their firewall configuration during this time. SPP will ship the routers so that they will arrive at roughly the same time as the circuits are provisioned. It is then the responsibility of the requesting participant to rack and power the routers and connect them to their firewalls. Once the circuits are up and all hardware is connected SPP and the requesting participant will test connectivity with the SPP staff.
Testing passes from the network group after successful network connectivity testing. Applications groups are responsible for testing server to server connectivity.

8 Synchrophasor Data Exchange Requirements

Synchrophasor data is transmitted to SPP by SPP Members as well as other ISOs and RTOs to support uses listed in the Introduction section of this document. SPP considers this data CEII and to be shared under the NERC ORD.

8.1 Synchrophasor Data Exchange Standards

- All data items and related quality codes should be transmitted at a rate of 30 frames per second in compliance with IEEE C37.118 communication standards.
- SPP Members are responsible for the accuracy of the data transmitted to SPP. A target of no more than 5% overall inaccuracy or loss of data from SPP Members to SPP is preferred for instantaneous monitored values.
- Planned outages for SPP Member PDC systems should be reported to SPP by sending an email to pmusupport@spp.org prior to taking the equipment out of service. This includes the PDC and associated Member PDC - SPP PDC communications equipment.
- Unplanned outages of the SPP Member PDC system should be reported by sending an email to pmusupport@spp.org.

8.2 Synchrophasor Data Format

The data format minimum requirements for transmitting data to SPP are defined in the following table.

Parameter	Value

Data Format	C37.118-2011/C37.118-2005 (PDC to PDC) SIEGate Gateway Exchange Protocol (SIEGate to SIEGate) STTP Protocol
SPP Data Requirement	Positive Sequence (3-Phase not required)
Data Rate	30 Samples/Second
PMU to SPP PDC Latency (maximum)	Maximum 3 seconds
Communication Protocol	TCP or UDP (**Note**: TCP is preferred)

8.3 Synchrophasor ID Codes

The C37.118 data frame format is used to transmit synchrophasor data from a PMU to a PDC. The C37.118 data frame contains a header and phasor/analog data, ending with a CRC error check. Inside the header exists the device identifier. This identifier is 2 bytes long, meaning the identifier can hold an integer value from 0 to 65,535. It is important for this number to be unique for each and every PMU to prevent system overlap. The NERC Data Exchange Working Group (DEWG) has assigned specific ranges to each ISO/RTO.

For western PMUs, the allowed values are 34001 to 36000.
For eastern PMUs in SPP's footprint, the allowed values are 27001 to 29000.

When setting up new PMUs, it is important that each new assigned PMU have a unique ID code. SPP will provide this number until an automatic registration system is available. Please send an email to pmusupport@spp.org to have SPP provide unique PMU ID codes for new PMU installations.

9 Synchrophasor Network Data Quality

Applications that consume PMU data require accurate and reliable data that is delivered on time. The overall quality of the input data used by these applications will significantly impact the quality of the output of these applications.

Data quality is a broad term that includes data:

- Availability
- Bad Data

Data quality issues may develop from:

- Latency
- Repeated values
- Measurement bias
- Bad/missing timestamps
- Loss of GPS synchronization

- Incorrect signal meta data
- Planned/Unplanned outage
- Poor hardware performance
- Improper device configurations
- The PMU itself ceases to operate properly
- Communication link issues between a properly operating PMU and the member datacenter (latency, bandwidth limitations, communication device hardware failure)
- Data aggregator issues at the Member datacenter and/or PMU location

Several areas along the path of PMU signal origination to final destination can affect the overall data quality, including:

- At the PMU itself (including GPS equipment and satellite signal used to timestamp the data)
- Within the communications network from the PMU to the Member datacenter aggregation site (latency, loss of communication, etc.)
- At the Member datacenter aggregator (Members PDCs/SIEGate instance, historians, etc.)
- Within the communications network from the Member datacenter to SPP (SPPNet, EInet, Internet/VPN connections)
- At the point of use by SPP applications

SPP runs a monthly data quality report using EPG GridSmarts based on requirements from the WECC DDMWG (Data Delivery Management Working Group). These requirements are described below.

9.1 Data Availability %

Data Availability % is defined as the number of data frames received divided by the number of data frames expected multiplied by the integer constant 100. It is inverse-analogous to data dropout %. This figure of merit reflects quality of PDC setup and network integrity.

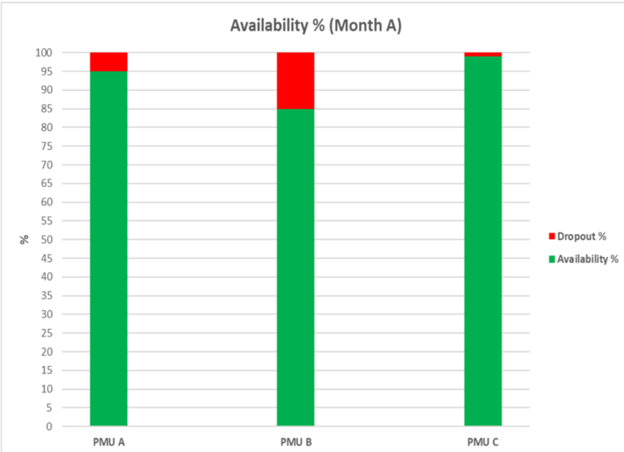
9.2 Bad Data %

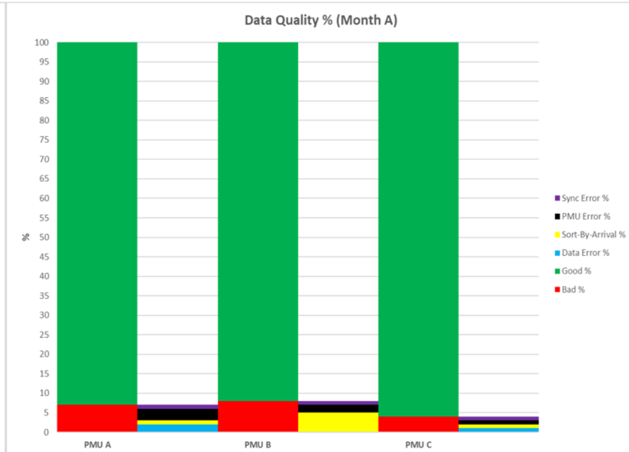
Bad Data % is defined as the number of frames received with status errors divided by the number of data frames received. In the C37.118 standard, the four main status errors (excluding dropout errors) are:

- Data Error
- Sort-By-Arrival Error
- PMU Error
- Sync Error

If any of these errors are raised in a data frame, the entire data frame is considered bad. This figure of merit reflects the average monthly data fidelity for a given PMU.

Below is an example of three different PMU, each with their own mix of data availability % and bad data %. It should be emphasized that bad data % *only operates on received data* from a PMU.





10 Appendix

10.1 SPP Eastern Interconnection [EI] EMS Model Area Names

Area Identifier	Company Name
CSWS	American Electric Power
BEPC	Basin Electric Power Cooperative
EDE	Empire District Electric
EVRG	Evergy (Replaces KCPL & WR)
GRDA	Grand River Dam Authority
INDN	Independence Power and Light
KACY	Kansas City Board of Public Utilities
LES	Lincoln Electric System
MPS	Missouri Public Service
NPPD	Nebraska Public Power District
OKGE	Oklahoma Gas and Electric
OPPD	Omaha Public Power District
SECI	Sunflower Electric Cooperative Inc.
SPA	Southwestern Power Administration
SPRM	City Utilities of Springfield, Missouri
SPS	Southwestern Public Service Company
WAUE	Western Area Power Administration - Upper Great Plains East
WFEC	Western Farmers Electric Cooperative

10.2 SPP Western Interconnection [WI] Area Names

Area Identifier	Company Name
W106	AESO (Alberta Electric System Operator)
W066	APS (Arizona Public Service Company)
W030	BCH (BC Hydro)
W001	BPA (Bonneville Power Administration)
W034	IPCO (Idaho Power Company)
W068	LADWP (Los Angeles Dept of Water and Power)
W017	NVE (Nevada Power Company)
W036	NEW (Northwest Energy)
W042	PAC (Pacific Corp)
W080	PGAE (Pacific Gas & Electric)
W075	PNM (Public Service Company of New Mexico)
W012	PSCO (Public Service of Colorado)
W092	SCE (Southern California Edison)
W084	SDGE (San Diego Gas & Electric)
W073	SRP (Salt River Project Agricultural Improvement and Power District)
W074	TEP (Tucson Electric Power Company)
W010	TSGT (Tri-State Generation and Transmission)
W071, W077, W087	WAPA (Western Area Power Administration)