2750 Monroe Blvd.
Audubon, PA 19403

PJM Technical Guidelines for

Installation of Synchrophasor Measurements at

Generation Facilities

2750 Monroe Blvd.
Audubon, PA 19403

Introduction

The technical requirements and guidelines presented here are for reference to aid new generation facilities in early planning to design and install synchrophasor measurement system that is compliant and interoperable with PJM. The requirements are consistent with the governing text in the PJM Tariff[1] and PJM Manuals[2]. These requirements and guidelines can be used for initial plans, which should then be shared and reviewed with PJM during the Interconnection process.

This document is comprised of three main sections:

1. **Technical Specifications**, which detail the required measurements, networking, protocols, data storage, and other details pertinent to the design of the synchrophasor system. Items that are preferred but not strictly required are identified as "preferred". The preferred items are in addition to the base requirements, not a replacement of the requirements.

2. **Example One-line Drawings and Point Lists**, which illustrates a typical generation electrical drawing indicating PMU measurement location for a traditional generator and solar farm facility. Required and preferred measurements and related equipment are color coded. Additional guidance is also provided.

3. **Naming Convention**, which explains the PJM naming convention for the phasor data station and channel naming. The resulting names will be configured into the site PMUs.

The PMU registry template will typically be provided as part of this package. The registry template will be filled out by the site with PJM's assistance, and included in the PJM Phasor Registry, which will make future maintenance and administration easier.

[1] PJM OPEN ACCESS TRANSMISSION TARIFF, Effective Date 12/28/2013, Section 8.5.3
[2] PJM Manual 01: Control Center and Data Exchange Requirements, current R30, Section 3.3

2750 Monroe Blvd.
Audubon, PA 19403

Technical Specifications

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 PJM. The requirements are consistent with the governing text in the PJM Tariff[1] and PJM Manuals[2]. These requirements and guidelines can be used for initial plans, which should then be shared and reviewed with PJM during the Interconnection process. Specifications noted as "required" must be satisfied, specifications noted as "preferred" are not required but add additional operational value and should be satisfied wherever possible.

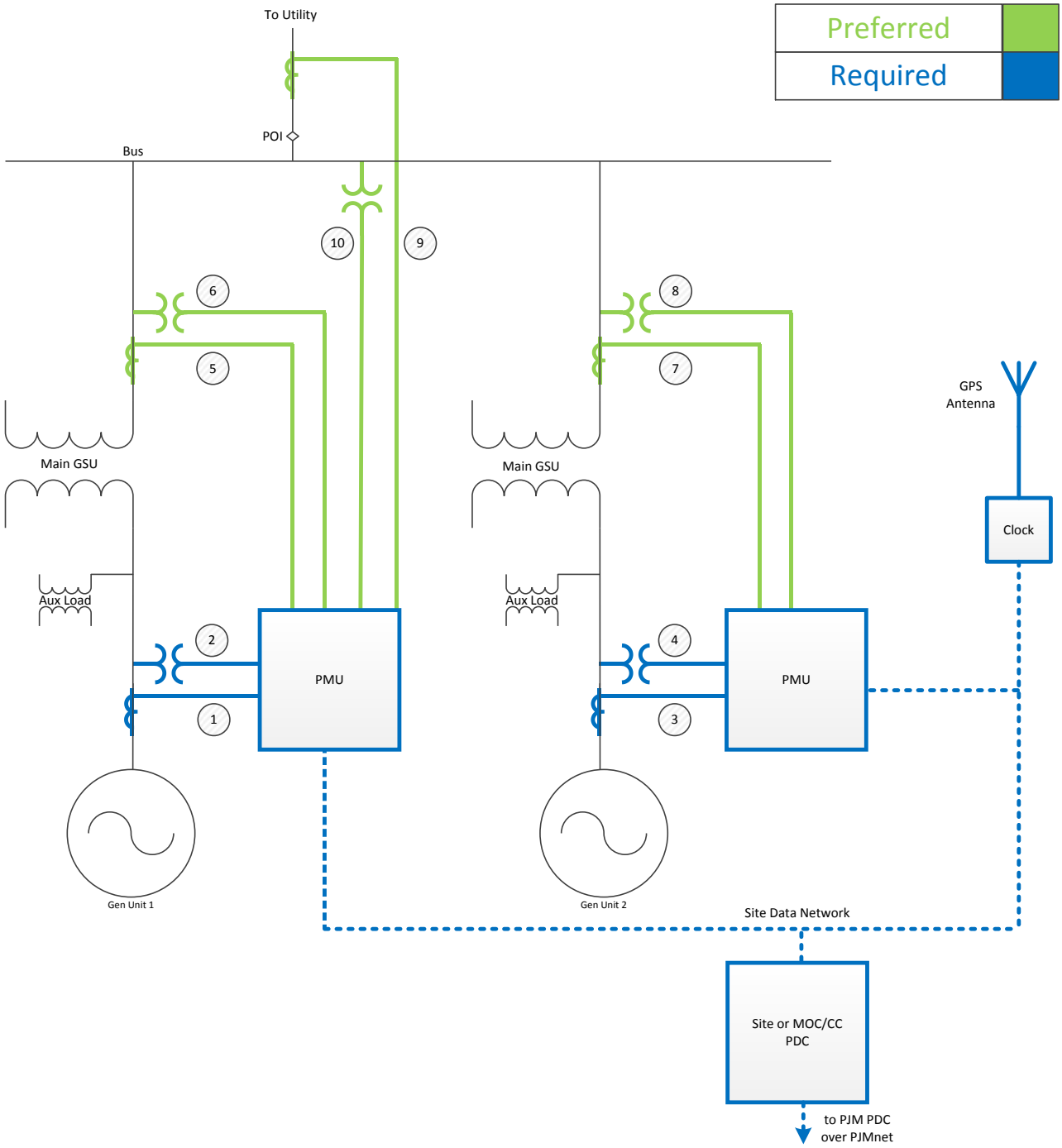
Measurement Point	***Required:*** PMU(s) shall measure at the Customer Facility low-side of each generator step-up transformer, unless it is a non-synchronous generation facility in which case the PMU(s) shall measure at the Customer Facility side of each Point of Interconnection.
	Preferred: Additional measurement point at any Point of Interconnection (usually high-side of a main step-up transformer).
	Note: With both low-side and high-side measurements, the impact of GMD on the transformer (reactive power as a function of GIC flow) can be monitored.
Measured Phases	***Required:*** Voltage and current Signals are required to be streamed to PJM as the Positive Sequence component. Actual measurement of all 3 phases is required for calculation of Positive Sequence.
	Preferred: Separate phase current and voltage measurements (each phase as a separate Signal), stored locally.
	Note of Interest: Separate phase measurements are valuable for handling power phase balance problems.
Signals	***Required:*** For each measurement point: Voltage, Current, Voltage Angle, Current Angle, Frequency, df/dt (rate of change of frequency).
Measurement Coordinate System	***Required:*** All phasors must be reported in polar coordinates.
Scan Rate	***Required:*** 30 samples per second, streaming to PJM PDC client.
	Preferred: 60 samples per second, only stored locally (per the Local Storage Compression preferred storage).
	Note of Interest: The accuracy of PMU-based Generator Model Validation improves significantly with 60 samples/sec data.

[1] PJM OPEN ACCESS TRANSMISSION TARIFF, Effective Date 12/28/2013, Section 8.5.3
[2] PJM Manual 01: Control Center and Data Exchange Requirements, current R30, Section 3.3

Network Interface	***Required***: TCP/IP traffic. Configurable IP address (or equivalent NATing) and listening port number. Firewall to allow connection from PJM client.
	Note of Interest: At some Facilities the PJMnet circuit that supports the ICCP SCADA or DNP SCADA data between PJM and the Facility will also support the C37.118 Synchrophasor data. If there is a Market Operation Center or Control Center separate from the Facility that already has a PJMnet circuit installed, then the customer may be required to connect between the site PMU/PDC and a Market Operation Center or Control Center PDC. Network design should be part of the review process with PJM Interconnection Coordination.
Data Protocol	***Required***: C37.118-2005 communicating via TCP/IP.
	Preferred: C37.118.2-2011 communicating via TCP/IP.
PDC	***Required***: A local PDC for data concentration, data storage, and support of PJM C37.118 connection.
	Note: A PDC is often useful for data concentration, ease of data storage, and as a gateway for applications using phasor data. The PDC may be located at the facility or at the corresponding control center. A control center that operates more than one facility with PMUs would concentrate all facility PMUs at the CC PDC. Other architectures are considered on a case by case basis.
Local Storage Amount	***Required***: Storage amount - 30 days-worth of rolling local data storage of all Signals.
	Preferred: Storage amount – additional storage up to 90 days-worth of rolling local data storage of all Signals.
Local Storage Compression	***Required***: Storage compression - data storage preserving lossless 30 samples per second.
	Preferred: Storage compression – data storage with additional granularity preserving lossless 60 samples per second.

2750 Monroe Blvd.
Audubon, PA 19403

Example One-Line Drawing and Point List, Synchronous Generation

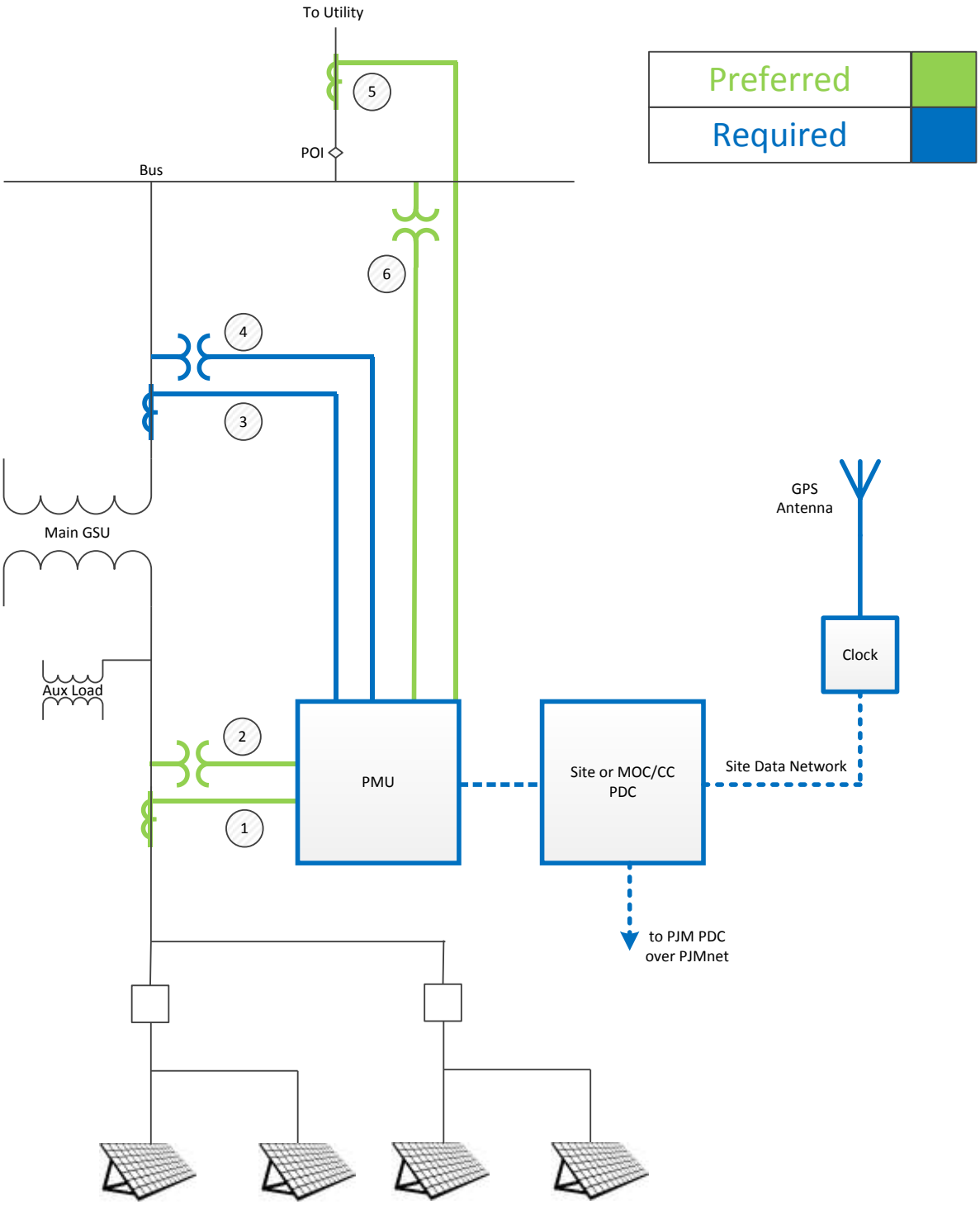


2750 Monroe Blvd.
Audubon, PA 19403

#	Measurement Description	Signal
1	Unit 1 low side	Current Magnitude and phase angle (positive seq.)
2	Unit 1 low side	Voltage Magnitude and phase angle (positive seq.)
3	Unit 2 low side	Current Magnitude and phase angle (positive seq.)
4	Unit 2 low side	Voltage Magnitude and phase angle (positive seq.)
5	Unit 1 high side	Current Magnitude and phase angle (positive seq.)
6	Unit 1 high side	Voltage Magnitude and phase angle (positive seq.)
7	Unit 2 high side	Current Magnitude and phase angle (positive seq.)
8	Unit 2 high side	Voltage Magnitude and phase angle (positive seq.)
9	Site POI line	Current Magnitude and phase angle (positive seq.)
10	Site POI line	Voltage Magnitude and phase angle (positive seq.)

2750 Monroe Blvd.
Audubon, PA 19403

Example One-Line Drawing and Point List, Non-synchronous Generation (Solar , Wind, etc.)



2750 Monroe Blvd.
Audubon, PA 19403

#	Measurement Description	Signal
1	Low side	Current Magnitude and phase angle (positive seq.)
2	Low side	Voltage Magnitude and phase angle (positive seq.)
3	High side	Current Magnitude and phase angle (positive seq.)
4	High side	Voltage Magnitude and phase angle (positive seq.)
5	Site POI line	Current Magnitude and phase angle (positive seq.)
6	Site POI line	Voltage Magnitude and phase angle (positive seq.)

2750 Monroe Blvd.
Audubon, PA 19403

Additional Guidance

- Many devices already incorporated in the typical generator facility design, for example protective relays, can often also serve as a PMU. These devices will often already be connected to the necessary Potential Transformers and Current Transformers. In some cases, only relatively minor changes will have to be made. These changes may include additional configuration of the device, installation of a PDC, and local data storage.
- The number of PMUs or physical location of the PMU is not strictly set by PJM requirements. A PMU can have one, many, or all of the required measurements, depending on the device capabilities and connected instrument transformers. First consider the required measurement points per these guidelines, and then select the best set of devices to obtain those measurements.
- For network Quality of Service (QOS), prioritize SCADA data over PDC data.
- Validate the final GPS coordinates of the PMU prior to providing the information to PJM.
- Ensure a strong GPS signal to the clock by using a shielded coax antenna and (for example) Schweizer SEL/Arbiter clock.
- Ensure firmware is kept up to date on all involved systems and assets. This helps prevent operational issues, such as logic on handling leap seconds, as well as provides the latest security enhancements.

2750 Monroe Blvd.
Audubon, PA 19403

Naming Convention

The C37.118 data protocol used to send and receive synchrophasor data has specific built-in fields for identifying measurements. This naming and identification data will typically be configured in each PMU and automatically passed downstream to all PDCs and data clients. 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. A single substation can commonly have more than one PMU. Each PMU will generally have several data points, or CHNAM channels. All STN and CHNAM can be a maximum of 16 characters (bytes) long.

The PMU owner must use appropriate one-lines, facility names, substation names, or identifying information to determine the STN and CHNAM names. The STN used should be based on the B1 station name in PJM's EMS model. This information can be provided by PJM.

PJM has a naming convention for STN and CHNAM that defines all characters. That convention is detailed in this document and explained by example here, with two channels under a single station.

STN, Station Name Example:

AAG_GOODRIVR_01

AA is an example identifier of the transmission zone the asset is located in. The two-letter identifier for every transmission zone in PJM is provided in the "Company Identifier in STN" tab in the PMU registry template file.

AA**G**_GOODRIVR_01

The "G" character designates that the PMU is owned by a generation company. The other option for this character is "T", which designates that the PMU is owned by the Transmission Owner.

AAG_**GOODRIVR**_01

GOODRIVR is an example STN name. STN names shorter than 9 characters are acceptable and should not be padded for length. The STN name should be based on the B1 value associated with this generator in the PJM EMS model. The STN name should begin and end with an underscore.

AAG_GOODRIVR_**01**

A PMU identifier number, starting at 01 and increasing to the number of PMUs at the station.

CHNAM, Channel Name Example:

Frequency signals may simply be named "Frequency," and Status signals may simply be named "Status".

For Voltage and Current signals, the following convention should be followed:

T013GEN1_1V1

T06901BROADST_1I1

The first character designates the location of the measurement point and should be one of the following values:

Character	Description
A	Non-phasor analog
B	Bus
D	Digital
L	Line
T	Transformer

T**013**GEN1_1V1

T**069**01BROADST_1I1

The next three digits state the nominal voltage level at the measurement in kV, padded with zeroes at the front if below 100kV. Decimals should be rounded to the nearest whole number. For example, 12.5 kV should be rounded to 13 kV.

T013**GEN1**_1V1

T069**01BROADST**_1I1

Up to the next 9 characters should describe the equipment being measured. For voltage signals and transformer current signals, this should be the B3 equipment name from the PJM EMS model. For line current signals, this should be the STN name representing the station at the opposite end of the line, and should be based on PJM's EMS model. STN names shorter than 9 characters are acceptable here and should not be padded. The STN name must be terminated with a single underscore character.

T069**01BROADST_**1I1

Following the underscore, a single digit number must be included and will be an incremental counter number used to differentiate multiple signals that measure the same piece of equipment. For example, a single PMU monitoring the line current of two parallel transmission lines will use this identifier. In most scenarios, this will be 1.

T06901BROADST_1**I1**

Finally, the type of measurement is identified here, with most importantly V1 and I1 meaning positive sequence voltage and positive sequence current respectively. Note that within the C38.118 protocol this will include magnitude and angle. There are other identifiers for generic digital or analog data, if needed.