



North American SynchroPhasor Initiative

Performance Requirements Task Team (PRTT)

A Guide for PMU Installation, Commissioning and Maintenance

Part I

**PMU Acceptance Test Checklist
for Connecting to TVA SuperPDC**

April 28, 2006

Last Updated: April 16, 2009

Performance Requirements Task Team Leader:

Damir Novosel, KEMA

Task Force Contributors:

Ken Martin, BPA – Task Force Leader

Ritchie Carroll, TVA

Paul Trachian, TVA

Henry Huang, PNNL, CERTS

Virgilio Centeno, Virginia Tech

Damir Novosel, KEMA

Yi Hu, KEMA

Revision History

Date	Rev. #	Description
04/24/06	1	• Development started. & added some 4/28/06
05/05/06	1.1	• Reviewed and revised per teleconference 5/5/06
04/16/09	1.2	• Reviewed and revised for accuracy

Table of Contents

1. Glossary of Terms.....	4
2. Preface.....	5
3. PMU Acceptance Test for Connecting to TVA SuperPDC.....	5
4. Checklist of PMU Acceptance Test for Connecting to TVA SuperPDC	5
5. Concluding Remarks.....	6
6. Appendix I: TVA PMU Connection Tester	7
7. Appendix II: TVA IEEE C37.118 Proxy Service	9

List of Figures

Figure 1 PMU Connection Test Tool with IEEE C37.118 selected	7
Figure 2 PMU Connection Test Tool with IEEE 1344 selected	8
Figure 3 Data flow diagram of the Proxy Service	9

1. Glossary of Terms

BPA/PDCStream – An extension of IEEE 1344, widely used by the BPA PDC and human-machine interface software on the West Coast.

GPS – Global Positioning System. A satellite based system for providing position and time. The accuracy of GPS based clocks can be better than 1 microsecond.

IEEE 1344 – A highly efficient protocol for real time SynchroPhasor data. Typically data is streamed in this format over UDP/IP or across a serial link.

IEEE C37.118 – Related to IEEE 1344, but adds much needed capability. This protocol and its associated standard are intended to replace IEEE 1344 and the BPA/PDCStream protocols. Typically data is streamed in this format over UDP/IP or across a serial link.

NERC – North American Electricity Reliability Corporation

PDC – Phasor Data Concentrator. A logical unit that collects phasor data, and discrete event data from PMU's and possibly from other PDC's, and transmits data to other applications. PDC's may buffer data for a short time period but do not store the data.

PMU – Phasor Measurement Unit. A device that samples analog voltage and current data in synchronism with a GPS-clock. The samples are used to compute the corresponding phasors. Phasors are computed based on an absolute time reference (UTC), typically derived from a built-in GPS receiver.

SuperPDC – The PDC which is implemented to collect all the phasors of the Eastern Interconnection for the NASPI. It is physically located at TVA.

TCP/IP – TCP/IP is 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.

TVA – Tennessee Valley Authority

UDP/IP – UDP/IP is 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.

UTC – Coordinated Universal Time (initials order based on French). UTC represents the time-of-day at the Earth's prime meridian (0° longitude).

2. Preface

This document intends to serve as a guide for connecting PMUs to TVA's SuperPDC. Before a PMU can be connected to the SuperPDC and function properly, several tests need to be performed as detailed in the remainder of this document.

3. PMU Acceptance Test for Connecting to TVA SuperPDC

This document is focused only on the series of tests performed prior to connecting a PMU to the SuperPDC. Actually the PMU acceptance test is a broad topic and the checklist in this document is only a subset of it. Acceptance tests should be performed when a PMU is commissioned to service. The PMU acceptance tests include normal hard wiring check, insulation test, calibration and functional tests to ensure that hard wire connections are good, insulation meets substation requirements, input signals are properly calibrated and the device is operational. For PMU devices, there are several additional things need to be checked: designated A phase (it should be the same across the whole NASPI system), phase sequence (ABC, not ACB), and GPS reception. All these are beyond the scope of this document. But this document can evolve to become a PMU commissioning guide which will address PMU acceptance more broadly.

4. Checklist of PMU Acceptance Test for Connecting to TVA SuperPDC

The intention of this section is to list the tests which need to be performed before connecting the PMU to the SuperPDC. Examples of test methods are introduced but they are not the only methods and this list does not intend to provide detailed test methods and test setup. Users should apply the checklist to their respective situations with their own available resources.

Network Connectivity Test

This refers to the data link between a PMU and the SuperPDC. The data link can be a dedicated data line, a dial-up link, LAN-LAN VPN, etc. Tests in this section will include using the "ping" command to determine connection and presence of devices at each end and a data rate test to assure that the connection has sufficient capacity to carry the required data.

Protocol Test (TCP/IP or UDP)

The PMU-PDC communication will be by TCP/IP or UDP. Once the parameters are determined, the connection with the SuperPDC can be tested. If it works, the protocol is determined to be acceptable. If not, further investigation is required. In both cases, a monitor, such as Ethereal (free download at www.ethereal.com) should be used to be sure the protocol guidelines are implemented correctly. The TVA PMU Connection Tester (see Appendix I) can be used to test protocols and data formats. If the Tester is used, this protocol test can be combined with the data format test below.

Data Format Test (IEEE 37.118, PDCStream, IEEE 1344, OPC, etc.)

Once the format is determined, the connection with the SuperPDC can be tested. All commands used in the IEEE protocol should be tested with a close examination of the data to be sure it fully

conforms. A monitor, such as Ethereal, provides a good tool to allow precise examination of the data to assure conformance. Ritchie Carroll of TVA developed a PMU Connection Tester (see Appendix I), which can be used to test both protocols and data formats. This tool can be downloaded from the NASPI Tools website http://phasors.pnl.gov/resources_tools.html. For IEEE C37.118 data format, configuration frames are sent when requested if TCP/IP is used. For UDP, TVA developed an IEEE C37.118 Proxy Service application, which requests configuration frames at the top of the minute. The communication paradigm used makes the transmission itself secure. Details about this Service application can be found in Appendix II. This Proxy Service application is free for download at the NASPI Tools website http://phasors.pnl.gov/resources_tools.html.

Reporting Data Rate Test

Verify the reporting rate as it is supposed to be (e.g. 30 samples-per-second). It is suggest to use the PMU Connections Tester (see Appendix I) for this test.

Data Coherency Test

The data being received from the device, though perhaps at the correct rate and packaged correctly, must also conform to what values are to be expected. Using the PMU Connection Tester the data streaming in should be verified to be real-world values which match the desired output of the device. Examples of a mismatch would be a voltage magnitude being reported in a channel that is identified via the metadata as containing current or the misconfiguration of the PMU's PT or CT ratios to output a value which does not match the rating of the line it is measuring. It is suggested that communication between the sender and the receiver of data be established to make sure that the data values are in fact those which are anticipated.

Latency Test

Latency can be roughly determined from the difference between the timestamp and the time when the data arrives at the SuperPDC. Currently for NASPI PMUs, latency is typically 1~5 seconds. It is suggested to use the PMU Connection Tester (see Appendix I).

5. Concluding Remarks

This checklist was developed in the intention of facilitating PMU connection to the SuperPDC. There are often questions about how to connect PMUs to the SuperPDC and it has been a critical path for NASPI to bring phasor data into NASPI real-time data stream. Hopefully this checklist can serve as a starting point. This checklist is by no means a complete one, and it will be updated when new situations come up. Comments and suggestions are welcome and should be directed to:

Paul Trachian, Operations, pbtrachi@tva.gov

Or Ritchie Carroll, Management and Development, jrcarrol@tva.gov

Or Matt Crocker, Networks, cmcrocker@tva.gov

PMU data communication involves many aspects. The NASPI Data Management Task Team led by Paul Myrda maintains a frequently asked questions (FAQ) site at http://phasors.pnl.gov/resources_data.html. Please refer to that site for more information on data communication.

6. Appendix I: TVA PMU Connection Tester

This tool is developed by Ritchie Carroll of TVA for testing connections between PMUs and PDCs. It can test various data formats including IEEE C37.118, IEEE 1344, BPA PDCStream, etc. This tool can be downloaded from the NASPI Tools website http://phasors.pnl.gov/resources_tools.html.

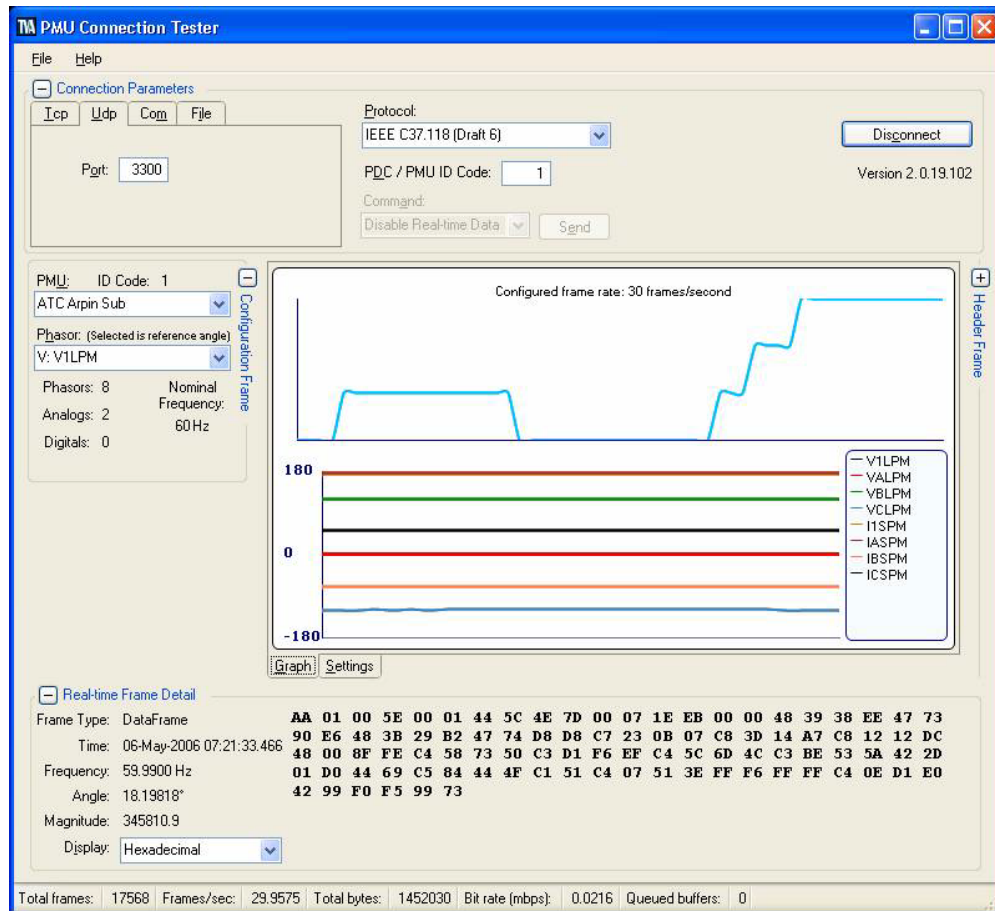


Figure 1 PMU Connection Test Tool with IEEE C37.118 selected



Figure 2 PMU Connection Test Tool with IEEE 1344 selected

7. Appendix II: TVA IEEE C37.118 Proxy Service

This IEEE C37.118 Proxy Service is developed by Ritchie Carroll of TVA. The purpose of this Windows service based application is to provide a “proxied” data stream in native IEEE C37.118 format from a PMU or PDC device at a utility without having to expose its internal substation devices through an external connection. Figure 3 shows the data flow of this Proxy Service. This service application can be downloaded at the NASPI Tools website http://phasors.pnl.gov/resources_tools.html. The source code is also included to allow utilities and vendors to establish trust in what data processing steps the application is performing, but is solely owned and copyrighted by TVA and is being provided exclusively for purposes in conjunction with the Eastern Interconnect Phasor Project, any other use of source code would have to be approved by TVA.

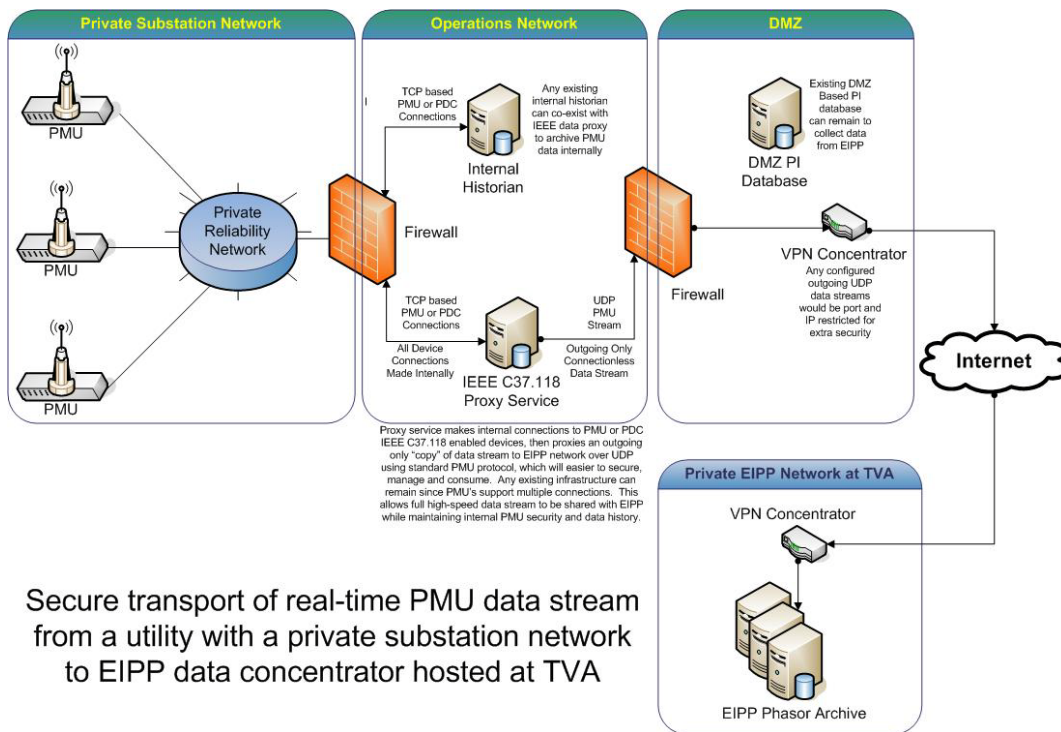


Figure 3 Data flow diagram of the Proxy Service

After installation, the service will need to be started to create the initial configuration file (“C37.118 Proxy Service.exe.config”) – make sure to stop the service before making modifications to the configuration file. The configuration file defines the settings needed for rebroadcast of the PDC/PMU data streams. Below is an example – note that you can define as many connections as needed (i.e., one per PMU or PDC). Note that the destination port per given IP will need to be unique – you will need to work with TVA to select an appropriate non-used port number for destinations pointing into the private NASPI hosting network:

- **Example configuration file for the Proxy Service**

```
<?xml version="1.0" encoding="utf-8"?>
<configuration>
  <appSettings file="">
    <clear />
    <!-- Define the total number of connections handled by proxy service -->
    <add key="TotalProxyConnections" value="2" />

    <!-- The section below begins definition of first connection -->
    <add key="ProxyConnection1.Name" value="Example PDC Connection" />
    <add key="ProxyConnection1.Host" value="165.233.31.32" />
    <add key="ProxyConnection1.Port" value="5000" />
    <add key="ProxyConnection1.PmuID" value="1" />
    <!-- This example defines two destinations for PDC output, allowing data transmission to
more than one location -->
    <add key="ProxyConnection1.Destinations" value="127.0.0.1:3200,152.85.98.5:3200" />
    <add key="ProxyConnection1.LogFileName" value="D:\apps\IEEE C37.118 Data Proxy Service\My
PDC Connection.log" />

    <!-- The section below begins definition of second connection -->
    <add key="ProxyConnection2.Name" value="Example PMU Connection" />
    <add key="ProxyConnection2.Host" value="165.233.31.15" />
    <add key="ProxyConnection2.Port" value="4712" />
    <add key="ProxyConnection2.PmuID" value="3" />
    <add key="ProxyConnection2.Destinations" value="152.85.98.5:3300" />
    <add key="ProxyConnection2.LogFileName" value="D:\apps\IEEE C37.118 Data Proxy Service\My
XYZ PMU Connection.log" />
  </appSettings>
</configuration>
```