TOOLS AND TECHNIQUES FOR OFF-LINE ANALYSIS OF PHASOR DATA

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DSI Toolbox File Reading Formats

PDC- Phasor data concentrator (BPA format)
PPSM- Portable Power System Monitor (BPA format)
SWX- Various ASCII formats related to BPA Swing Export

- PSMT ASCII-Standard ASCII format for data export from PSM Tools and DSI Toolbox. (Excel compatible, with special header)
- PSLF/PSDS- GE software output
- PTI PRNT- PTI software output
- PTI RAWC- PTI software output
- DFR Comtrade (Digital Fault Recorder)

PDC Special- Mimics intermediate export from PDC. Provided for AEP and others.
PMU- Phasor measurement unit- Macrodyne A, Macrodyne B, VA Tech, Arizona Public Service. Involves several legacy formats that are no longer in active service.
DCU- Data Capture Unit. PNNL device similar to PPSM. Data saved as .mat files.
PSAM- Power System Analysis Monitor (BPA legacy system)
Special- Special options under keyboard control
PSMT- Standard Matlab format for data export from PSM Tools and DSI Toolbox. (formats converted to *.mat)
PSDM- Power System Disturbance Monitor (BPA legacy system)
F08- ASCII data exported from FORTRAN predecessor to DSI Toolbox.
PPSM Special- Portable Power System Monitor. BPA's high speed point on wave. Similar to digital fault recordings, but stored as Matlab data.

DSI Toolbox File Writing Formats

PSMT- Standard PSM Tools format used in DSI Toolbox workspace. Files to be merged must first be translated into this format.
SWX- Excel compatible ASCII format, with header information developed at BPA for Swing Export.

DSI Toolbox Features for Merging Files

PSMreload (matching files together and then merging)

- T**imestamp editing-** Manual signal alignment. Important for merging mismatched files covering the same event
- **Signal resampling**- Required before merging files, adjusting timesteps etc.
- **Automatic renaming of signals to facilitate sorting-**
- **Parallel merging of multiple files**
- **Saving merged data**

DSI Toolbox Modules for Phasor Data Processing and Analysis

Suggested Priority	Module
1.	**Batch Plots**- Plot all or selected signals, control axes, send to printer, save to file, manipulate, etc. Can plot any signal against any other, including sample number.
2.	**Angle/Freq Refs**- Select angle or frequency signal as reference, and subtract from all other signals of that type; estimate frequency from angle signals. At user option, data from this operation overstore or are appended to original data.
4.	**Filter/Decimate**- Input data are filtered and/or decimated. Filter types include high-pass, low-pass, and band-pass Butterworth, several kinds of moving average, the BPA "activity filter" for oscillation detection, and filters defined by the user under keyboard control.
5.	**Backload Filtered**- Data from the filter operation overstore or are appended to present data. Decimated data must overstore present data, due to change in sample rate.
3.	**Fourier**- Fast Fourier Transforms (FFT), Inverse FFT, windowing, autospectra vs. frequency, coherency vs. frequency, waterfall plots, calculate transfer function using non-parametric gain and phase vs. frequency.
7.	**Histograms-** Provides statistical information concerning signal activity within their frequency bands. One or more cycles of bandpass filtering are done first.
6.	**Ringdown GUI-** Calculate mode frequencies, damping ratios, mode shapes, and transfer functions from ringdown signals using Prony analysis.
7.	**Ringdown Utilities-** Provides tabular and graphical display for Ringdown GUI, constructs linear models for control system design.
10.	**AutoCorrelations-** Time domain counterpart to the Fourier processing option. Experimental code seeks modes and damping from system noise response.
*.	**ModeMeter-** Custom codes for estimating mode frequencies, damping ratios, mode shapes, and transfer functions from ambient noise and other signals. Several codesets under development by universities in DOE/EPSCoR project, BPA, PNNL, perhaps others. Some codesets build upon proprietary codes distributed by the Math Works, other National Laboratories, and the NASA Langley Research Center.
*.	**EventScan-** Custom codes that open and scan long file sequences for dynamic events. None have been integrated into the DSI Toolbox as yet.
*.	**Phasor Utilities-** Custom codes for deriving phasors from point-on-wave signals. Undocumented toolset for expert users.
*.	**Backload Phasor Results-** Replaces original point-on-wave signals by derived phasors.

*. **Special Displays**- Custom display codes provided by or for special users. Experimental versions are under development at BPA, perhaps elsewhere.

9. **DownSelect Signals**- Sorts and/or downselects the signals in active memory.

8. **Load new data**- Loads a new data set for analysis, with optional restart of the automatic processing log.

*. **Save results**- Saves analysis results and processing log to output file. User can reduce data time span, select between PSMT and SWX output formats; future option will provide extended .dst format compatible with PDC utilities.

*. **Keyboard**- Provides direct access to MATLAB Command Window (MCW) during a DSI toolbox session.

*. **Defaults on/off-** Toggles the default settings that customize processing for efficient performance of pre-defined task sequences.

Summary of Off-Line Software Tools Used Within the WECC Visualization and Analysis Tools

Software	WECC Utility	Functionality	How To Obtain
DSI Toolbox	Bonneville Power Admin., others	See above	Free at http://phasors.pnl.gov/ or ftp://ftp.bpa.gov/outgoing/WAMS%20Information/. Requires MATLAB; Signal Processing and Control System Toolboxes suggested.
Proprietary, SCE	Southern California Edison	Plotting and frequency domain analysis.	Barat Bhargava, SCE. Compiled code is offered free to utilities after signing a non-disclosure agreement.
CyberPower MSU (Note 1)	None	DSI toolbox within a Windows environment.	The company will shortly be offering the compiled package to the EIPP members at reduced cost. (Note 2) http://www.cyberpower.us/
PhasorFile	BPA, Idaho Power, New Mexico, others	Display and interactive examination of PDC data (.dst files) captured at PDC or PDC StreamReader. Can export data as Matlab or ASCII.	Ken Martin, BPA. PhasorFile is a standard part of the PDC technology suite.
StreamPlayer	BPA,PNNL others	Playback of PDC data (.dst files) captured at PDC or PDC StreamReader. Emulates real-time display from PDC StreamReader.	Greg Stultz, BPA. StreamPlayer is a standard part of the PDC technology suite.
Spectrum Analysis Tool for StreamReader	BPA,PNNL others	Continuous spectral analysis & display for the PDC StreamReader, in either real time or playback mode.	Jeff Johnson, PNNL. The Spectrum Analysis Tool is distributed by BPA & PNNL as a standard add-on to the PDC technology suite.
BPA's ATP/EMTP Analyzer	Idaho Power	Used to process data from ATP or EMTP. Can also be used for Phasor data and is very powerful. Does filtering and frequency domain analysis.	BPA (free)
DADiSP	California ISO	Spreadsheet and GUI counterpart to MATLAB's signal processing package	About $3k per license. http://www.dadisp.com/

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Note 1: CyberPower consists of a team of software engineers that have placed a windows frame around a portion of the DSI toolbox. The software is not yet available, although it is expected to be ready soon. I have some reservations about using this software: 1. It was not validated by power system engineers after it was ported over to a windows environment, and likely was not validated at all. 2. CyberPower employs software engineers, so technical help they offer will lack insight into power system applications for which

the tool will be used. 3. Currently, an older version of the DSI toolbox is being used, although they have discussed upgrading the tool (if technically feasible).

Note 2: Since some of the under-layer applications are freeware, CyberPower has decided not to charge for MSU. However, for those who would like to receive MSU support and maintenance from CyberPower, CyberPower will charge $3K/per seat per year to cover cost. For EIPP members who would like to evaluate a trial version of the MSU software and work with CyberPower to fine tune the application, CyberPower is offering one seat with free support and upgrade for one year.

Summary of Off-Line Software Tools Used Within the WECC Planning and Model Calibration Tools

Software	WECC Utility	Functionality	How To Obtain
PSLF/PSDS	All	Version 14.1 allows PMU data as boundary condition(s) for analysis. This functionality is currently being used by BPA, PNNL, and others within the WECC.	GE
Proprietary AESO	Alberta Electric Systems Operator (AESO)	MATLAB based software. PMU visualization, modal identification, and model validation.	Software is not available to the general public or other utilities at this time.
MATLAB Simulink Power System Blockset	Idaho Power	Various modeling, signal processing	MATLAB
PST (Power System Toolbox)	PNNL, Various Universities	Load flow and Dynamic Power System Modeling	Graham Rogers, Cherry Tree Software http://www.eagle.ca/~cherry/

Summary of Off-Line Software Tools Used Within the WECC Other Tools

Software	WECC Utility	Functionality	How To Obtain
Psymetrix Storm Minder	None	On- line visualization, storage, retrieval, and analysis	Psymetrix will provide a comprehensive and integrated solution only. Tools within Storm Minder software are not separately available. www.psymetrix.com.

WECC Survey (Conducted June, 2004)

The following senior planning engineers within the WECC were surveyed regarding their use of phasor data and the software tools they employ for power system analysis using phasor data. The following questions were asked:

1. Do you or does your organization use phasor data ?
2. If so, what software tools do you use to analyze phasor data?
3. Do you use the DSI toolbox? If so, what features within the DSI toolbox do you find the most useful?

Name:	Barat Bhargava
Title:	Senior Planning Engineer, PhD
Organization:	Southern California Edison, Member WECC Model and Validation Working Group
Tools Used:	PSLF, SCE owned software tools (compiled software is free, but not raw code).
PMU Data Used:	Yes
DSI Toolbox:	Yes, some, but mainly SCE in-house software tool.

Name:	Peter Mackin
Title:	Principal Engineer
Organization:	Navigant Consulting, formerly with the California ISO, Chair WECC Disturbance Modeling Working Group, Member WECC Model and Validation Working Group.
Tools Used:	PSLF/ Excel
PMU Data Used:	Neither he nor anybody at Navigant uses PMU data.
DSI Toolbox:	He has downloaded the DSI toolbox but he hasn't used it. Peter would use the DSI toolbox if frequency based information or damping information was needed, but he just hasn't needed it.

Name:	Mark Willis
Title:	Senior Operations Engineer
Organization:	California ISO (Operations and Disturbance Analysis), Member WECC Model and Validation Working Group
Tools Used:	PSLF, DADISP http://www.dadisp.com/ (spreadsheet based software similar to MATLAB ~$3k), MATLAB (used very little)
PMU Data Used:	Yes- look at data only if an event has occurred. Look at both time and frequency domain.
DSI Toolbox:	Has it, but doesn't use it

Name:	Irena Green
Title:	Senior Grid Planning Engineer
Organization:	California ISO, Member WECC Model and Validation Working Group.
Tools Used:	PSLF
PMU Data Used:	No (nobody in planning)
DSI Toolbox:	No (nobody in planning)

Name:	Les Pereira
Title:	Director, Transmission Planning and Design
Organization:	Northern California Power Agency, Member (former Chair) WECC Model and Validation Working Group.
Tools Used:	PSLF, BPA tool to read DTS data
PMU Data Used:	Occasionally, but only for time domain plots, not for frequency based analysis.
DSI Toolbox:	Yes, used occasionally. Used primarily for plots in time domain analysis. No frequency domain analysis is done.

Name:	Abraham Ellis
Title:	Senior Planning Engineer, PhD.
Organization:	Public Service Company of New Mexico, Member, WECC Model and Validation Working Group.
Tools Used:	PSLF, BPA's 'PhasorFile' for visualization and remote PDC data capture in comma delimited format. Abraham suggests that modifying 'phasor file' to output polar coordinates instead of rectangular would be very helpful. He currently does this conversion using his own software.
PMU Data Used:	Yes, used extensively for local analysis such as determining the severity of local oscillations or voltage regulation problems. Not used for inter-area oscillations.
DSI Toolbox:	He has it, and has gone to the training, but the software is not installed, and not used by anybody at PSNM.

Name:	Baj Agrawal
Title:	Principal Planner, PhD
Organization:	Arizona Public Service, Member WECC Model and Validation Working Group.
Tools Used:	PSLF. APS just started using the DSI toolbox. They previously used spreadsheets. Doug Selin is the main user at APS.
PMU Data Used:	Yes.
DSI Toolbox:	None of the advanced features within the DSI toolbox are used (e.g. no modal analysis, no Prony analysis, only plots etc).

Name:	John Kehler
Title:	Engineering Operations and Reliability
Organization:	Alberta Electric System Operator, Chair, WECC Model and Validation Working Group.
Tools Used:	PSLF, AESO Proprietary MATLAB based tools. AESO is putting more effort and money into enhancing their own proprietary toolset. This toolset might not be available to others as freeware, but a decision has not yet been made.
PMU Data Used:	Yes, model validation, modal identification.
DSI Toolbox:	Used for modal identification and damping, but primarily for visual analysis of PMU signals.

Name:	Orlando Ciniglio
Title:	Planning Engineer, PhD
Organization:	Idaho Power, Member WECC Model and Validation Working Group.
Tools Used:	PSLF, MATLAB, Simulink, Simulink's Power System Blockset, ATP analyzer (Software by BPA used to process data from ATP or EMTP that is very powerful, free, and does filtering).
PMU Data Used:	Yes, line monitors. Time signals only are reviewed… no damping or modal analysis is done.
DSI Toolbox:	Installed, but doesn't know how to use. Wants to attend a workshop, but is unaware of where to find one.

Name:	Bill Miller
Title:	Operations and Disturbance Analysis Engineer.
Organization:	PG&E
Tools Used:	DSI Toolbox, MATLAB
PMU Data Used:	Yes, some.
DSI Toolbox:	Using only basic features of DSI toolbox. They are not using Ringdown tool or any advanced features such as frequency based analysis.

Name:	Anatoly Meklin
Title:	Planning Engineer
Organization:	PG&E
Tools Used:	PSLF, EPRI's LoadSym
PMU Data Used:	None
DSI Toolbox:	Doesn't have it

Name:	Bill Middlestadt
Title:	Principal Planning Engineer
Organization:	PBA, Chair, WECC Technical System Studies Group.
Tools Used:	PSLF, DSI Toolbox, BPA's 'PhasorFile', BPA's WASC Package (Wide Area Stability Control- an open loop real-time control tool that uses PMU data). Streamreader (real-time tool).
PMU Data Used:	Yes
DSI Toolbox:	Yes. Modemeter, special functions to find the slope of the power-angle relationship, PV and QV curves from system noise, and the power angle curve (Some of these are beta versions of special functions under development by John Hauer. John does not distribute these special functions within the DSI toolbox until they've been validated.). Uses plotting ringdown GUI, and modemeter. Does *NOT* use: no autocovariance, no filters, no FFT, no histograms.

Name:	Dmitri Kosterev
Title:	Principal Planning Engineer
Organization:	BPA, Member WECC Model and Validation Working Group, Chair, Load Modeling Task Force.
Tools Used:	PSLF, DSI toolbox
PMU Data Used:	Rarely
DSI Toolbox:	Yes. Used for time and frequency analysis on model data, modeshapes, generator participations. Prony analysis is much preferred to Eigenanalysis within other small signal stability (sss) packages because you can't be sure that the linearization is correct within those packages. Also, Dmitry wants post disturbance analysis, not small signal stability analysis (even though both are linear), and sss packages may not provide a proper representation of a linearized system during post disturbance.

Name:	John F. Hauer
Title:	Laboratory Fellow
Organization:	PNNL; Member WECC Disturbance Monitoring Work Group (DMWG), WECC Model and Validation Working Group (M&VWG)
Tools Used:	DSI toolbox & Matlab toolsets; Excel; stability studies performed by others upon request (e.g., Henry Huang at PNNL)
PMU Data Used:	Extensively, from across entire WECC & sometimes from EIPP. Also data from other monitor types, plus stability programs
DSI Toolbox:	Extensive use for repair/integration/analysis/archiving of monitor data (all WECC sources & monitor types), outputs from stability programs, data from PMU performance tests. Use all time domain and frequency domain tools, specialized Matlab toolsets from MathWorks, custom code developed as needed. Develop DMWG report materials for all significant WECC events, annual summary of WECC system performance, ongoing work group activities.