**Actual Power System Events of Sustained Oscillations**

**Requirements for PMU data collection**

**IEEE PES Oscillation Source Location Task Force**

1. **Objective**

The objective of the efforts is to collect a set of system-wide PMU measurements capturing the representative real-life events of sustained oscillations including poorly damped natural and forced oscillations. The data set is intended to be used for the research, development and testing of PMU-based applications and particularly for the development of algorithms to identify the source of sustained oscillations suitable for practical implementation in control centers.

1. **Event Selection Criteria**

Sustained oscillations in power systems can have a broad variety of attributes in terms of frequency, spreading and observability in the system, nature of forced signal, presence of such signal in one or simultaneously in several locations and presence of resonance conditions. The collection of real-life events intends to **representatively cover the variety of attributes of sustained oscillations**. Practically meaningful algorithms for locating the source of sustained oscillations and especially designed for online applications must correctly work in a broad range of practically feasible scenarios. The collected set of real-life events intents to facilitate the development and testing of new algorithms and applications.

1. **Event Description**

Each submitted oscillatory event should contain a description including the following:

* The **size** of the power system and what portion of the system is covered by the set of collected PMU data
* If available, the description of the **sequence of events** resulting in sustained oscillations
* If available, **location of the source** for the forced oscillations up to a specific power plant or specific generator and, if known, the nature of actual reason of forced oscillation signal.
* If source is provided, indication of the **confidence** level (low, medium or high) for the accuracy of provided information about the **source**. The confidence level in the accuracy of this information is very important in making conclusions while testing algorithms. If the source of oscillations is unknown or at a low confidence level, this should be clearly stated in the event description.

1. **PMU Location and Naming Convention Requirements**

All names should be **anonymous** and the data set should be made appropriate for public use.

The set of PMU data and corresponding event description are mandatory information to be submitted for an event. Topological information or one-line diagram can be provided if deemed appropriate. If topological information is not available, at a minimum, the proposed PMU naming convention should indicate the metered component as Line or Bus within meshed network or measurement at the radial element – Point of Interconnection (POI) of a power plant, individual generator within power plant, load center or FACTS.

There are no strict requirements for the location of PMU measurements but the following is a guideline.

* PMU measurements should represent a system-wide coverage which can be viewed as a set of PMU measurements available in a control center.
* PMU measurements should include voltages and frequencies in selected major substations; currents on selected major transmission lines; voltage and current measurements at the Point of Interconnections (POIs) of representative radially connected components: for example, power plant, individual generators within power plant, load center, HVDC, FACTS devices, etc.
* The voltage and current signals closest to the source (if case of forced oscillation) should be included in the data set.

1. **Data Quality Requirements**

PMU data quality should be consistent with applicable standards.

At a minimum, any one of the IEEE C37.118 Status Word bits as non-zero is considered bad data. C37.118 Status Word is not provided in submitted data files. Instead, corresponding individual points should be corrected. Any individual data point with bad or missing data should be reported as ‘NaN’ in the submitted data files.

No other bad data should be removed or replaced to mimic a realistic data quality.

1. **Time Interval Requirements**

The time interval of measurements should be reasonable minimal to minimize the size of collected data but covering the oscillation period, and, if applicable, both the pre- and post- event periods. Oscillatory event can last from few seconds to minutes or hours.

* If an oscillatory event is shorter than 1-5 minutes then the data set should include the entire event plus up to 1-3 minutes before and up to 1-3 minutes after the event.
* If the oscillatory event has clear inception time and lasts longer than 5 minutes then the data set should include up to 1-3 minutes before and up to 1-10 minutes of oscillations depending on the frequency of oscillations. The oscillatory period should preferably cover at least 10-20 cycles of the lowest frequency of oscillations in case of multi-frequency process.
* If an oscillatory event does not have clear start and end points, then the oscillation period should cover at least 10-20 cycles of the lowest frequency of oscillations in case of multi-frequency process.

1. **Data Formatting Requirements**

A data set of oscillatory event consists of the following files:

* Case description per the above requirements in “3. Event Description”: text, Word or PDF formats
* PMU data set: one or several .csv files per description below. A data set could be reasonably split into several files for consequential periods of time to limit the size of each individual file. Each file should repeat the same header. ***One single file for an event is preferable***.
* Current-voltage mapping for calculation of MW and MVAR in transmission elements with current measurements. Naming convention described below provides sufficient information on pairs of currents and voltages to be used for calculation of MW and MVAR flow. If provided data follows the below naming convention, additional current-voltage mapping is not needed.
  1. **PMU data set .csv file**

The .csv PMU data structure and format follows, with some modifications, the *Guideline for Data Format Used in Engineering Analysis Applications of Disturbance and Simulated Data[[1]](#footnote-1) and SMS - Interconnection-Wide Oscillation Baselining and Data Collection Instructions [[2]](#footnote-2)*.

* Voltages and currents should be reported as positive sequence values or single phase values consistent with the positive sequence
* Voltage magnitude should be reported in units of kV (i.e. 345 kV) and contain phase-to-neutral values
* Phase angles should be reported in units of degrees (bounded by +/- 180 degrees), and should be the raw phase angle reported by the PMU (not a referenced phase angle difference)
* Frequency should be reported in units of Hertz (i.e. 60.00000 Hz), with the highest resolution available (at least three trailing decimal places).
* Data rate should be 30 frames or higher per second

PMU signal names should be anonymized. Anonymizing the actual names could be arbitrary; however the following unification is recommended.

* All actual substation names are replaced by sequential numbers starting from 1.
* All actual transmission component IDs (lines or transformers) are replaced by sequential numbers starting from 1.
* ID for a transmission line having PMU measurements from both sides is assigned as numbers of terminal substations separated by dash character (Example: 6-4).
* IDs of parallel transmission lines connecting the same substations and having measurements from both sides are distinguished by adding a “circuit” number at the end of ID separated by dash character.
* All transmission components radially connecting power plants, individual generators of load centers to the system are labeled as ‘Gen’ or ‘Load’ with unique IDs for each substation.
  + 1. **Header Lines**

The header structure consists of four (4) rows, as shown in Figure 1.

• **Line 1: Signal Names**

Signal name has the following structure: **Sub:<substation number>:<type>:<component number>**

* **<substation number>** is a sequential number.
* **<type>** is a type of the system component. Possible types are:
  + **Bus** for a bus bar within a substation
  + **Ln** for a transmission component connecting buses in a meshed network
  + **Gen** for a transmission component radially connecting generator or power plant
  + **FACTS** for a transmission component radially connecting a FACTS device
  + **Load** for a transmission component radially connecting load center
  + **HVDC** for a connection to HVDC line
  + Any other types can be added as necessary.
* **<component number>** is a unique number of a power system component within***Ln*** category; for other categories*,* that is a unique number for each category within a substation.

*Examples:*

Sub:17:Ln:26 means Line 26 at substation 17;

Sub:17:Ln:17-4 and Sub:17:Ln:17-4-1 mean two parallel lines connecting substations 17 and 4;

Sub:17:Bus:1 means bus bar 1 at substation 17;

Sub:17:Gen:Gen1 means radial connection to generator 1 attached to substation 17;

Sub:17:Load:Load1 means radial connection to load 1 attached to substation 17;

Signal name for voltage and current phasor should be the same for a pair of voltage and current phasors to be used for MW and MVAR flow calculation.

Signal names should not contain commas or spaces; use semicolon (:) to separate the fields.

• **Line 2: Signal Type**

Acceptable signal types include:

|  |  |
| --- | --- |
| **Signal Type** | **Acceptable TYPE** |
| Positive sequence RMS value of voltage | VM |
| Positive sequence voltage phasor angle; phase-to- neutral | VA |
| Positive sequence RMS value of current | IM |
| Positive sequence current phasor angle | IA |
| Frequency | F |

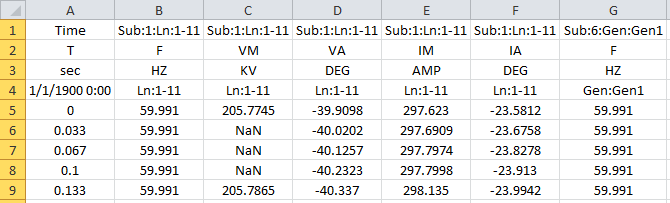
• **Line 3: Units**

Acceptable units include:

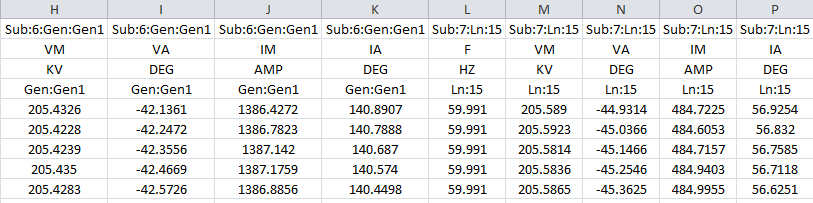
|  |  |
| --- | --- |
| **Signal** | **Acceptable UNITS** |
| Time | sec (Seconds) |
| Voltage Magnitude; phase-to- neutral | KV (Kilovolts) |
| Voltage Phase Angle | DEG (Degrees) |
| Current Magnitude | AMP (Amperes) |
| Current Phase Angle | DEG (Degrees) |
| Frequency | HZ (Hertz) |

* **Line 4: Description**

Description of the signal can contain any alphanumerical values (except commas or spaces) to clearly describe the signal and location of measurement. The recommended Description should contain a copy of the last part of Signal name: **<type>:<component number>.**



(a)



(b)

Fig.1 Sample .csv file format (opened in Microsoft Excel for clarity). (a) Columns A-G, (b) Columns H-P.

* + 1. **Data Lines**

The data lines should be formatted to the following requirements:

• Times will monotonically increase, with no missing times (i.e., “don’t skip time stamps”).

• Times will be equally spaced, with at least 4 trailing decimal places (e.g., 0.0167, 0.0333, etc.).

• Frequency measurements should have at least 3 trailing decimal places; 5 trailing decimal places is preferable.

1. **Submission and Testing Requirements**
   * 1. **Naming of Data**

Regarding submission of the data files as described above, please package all files as a single compressed .ZIP file. It is suggested that the compressed file be named in the following format for ease of identification. A readme file in the TXT format be provided with the same file name as the data file, i.e.:

* [Case Name]\_[Last Name of the sender]\_[Organization of the sender].ZIP
* [Case Name]\_[Last Name of the sender]\_[Organization of the sender].TXT

Please replace “[ ]” by proper information. A sample name is for the two files is

* ISO-NE-case1\_MASLENNIKOV\_ISO-NE.ZIP
* ISO-NE-case1\_MASLENNIKOV\_ISO-NE.TXT
  + 1. **Delivery of Data**

There are two options to send the compressed ZIP file and the TXT file:

Option 1:For a ZIP file <10MB, you may email it and the TXT file as attachments to both of the following addresses

* + Dr. Slava Maslennikov (ISO New England) at smaslennikov@iso-ne.com
  + Dr. Kai Sun (University of Tennessee) at kaisun@utk.edu

Please begin the subject line of the email with “OSCILLATION DATA COLLECTION” and provide a brief note on the data in the email including, e.g., the date and time of recording/simulation, description of events, etc.

Option 2:You may also upload the ZIP file and TXT file to a data exchange media (like FTP of ShareFile) by using the following steps

* + Send a message to the two email addresses listed in the Option 1 requesting an instructions for data uploading.
  + In the response, you will receive detailed instructions on how to upload files.

After you upload the files, please inform us of your submission of data by sending a message to the above two email addresses.

Option 2 is preferable because emails with attached zipped file could be automatically filtered out by anti-spam filters and not delivered.

* + 1. **Testing and Posting of Data**

The quality of each submitted data set will be tested by a Moderator using the aforementioned data requirements as guidelines. Dr. Kai Sun or Dr. Slava Maslennikov or any other assigned in the future person will act as a Moderator.

For testing, a Moderator will be using the following Matlab code as a primary procedure - ***Read\_AnalysisPMU\_IEEEformat\_v1.m***. This code provides:

* Verification of data consistency with above requirements
* Verification of the completeness of data
* Sanity check on reasonable ranges for voltage and current magnitudes and frequency
* Plots the graphs for all magnitudes and phases of provided data
* Calculates the spectra of oscillations for frequency, voltage and current magnitudes

All detected deficiencies or anomalies are reported with clear identification of an issue.

It is highly recommended to use this code before submitting data to verify the data quality and consistency with the requirements and to improve the efficiency of data submission process.

Only the data passing the test will be posted onto the Test Cases Library of Power System Sustained Oscillations under this IEEE PES Task Force at this link:

http://web.eecs.utk.edu/~kaisun/Oscillation/

For the data that failed in the test, suggestions will be provided for improving the quality of the data.

1. WECC Joint Synchronized Information Subcommittee (JSIS). “Guideline for Data Format Used in Engineering Analysis Applications of Disturbance and Simulated Data”. August 2013. Salt Lake City, UT. Available: https://www.naspi.org/File.aspx?fileID=1210*.*  [↑](#footnote-ref-1)
2. http://www.nerc.com/comm/PC/Synchronized%20Measurement%20Subcommittee/SMS%20-%20Interconnection-Wide%20Oscillation%20Baselining%20and%20Data%20Collection%20Scope%20Document%20-%2012-14-2015.pdf [↑](#footnote-ref-2)