# Schema for Phasor Data Using the COMTRADE File Standard

## 1. Introduction

Synchrophasor data is used both in real-time from direct transmission and after the fact as recorded data. The SYNCHROPHASOR standard, C37.118, describes a real-time data transmission format but does not define a format for recorded data storage or exchange. Several formats have been used for synchrophasor data, most notably the PhasorFile (also known as 'dst') data format pioneered in the WECC and supported by Bonneville Power Administration users. While a number of users have created recording and reading software for this format, it is not supported as a recognized standard by a standards organization. It is preferable that data be recorded in a recognized standard format so that tools, methods, and data can be exchanged world wide.

The IEEE COMTRADE standard is a file format designed for time series data that is established world wide and is supported by standards making bodies. It has a significant number of recording parameters that can be adapted for phasor data. This document presents a schema for using the COMTRADE format for recorded phasor data by making synchrophasor specific assignments to the standard COMTRADE parameters. The parameters are used in the standard, prescribed manner, but with specific uses which allow some automatic (machine) processing. This recommendation is for use with COMTRADE starting with the 1999 version. This schema can be readily adapted to the new COMTRADE version currently near completion.

The focus is on the configuration file portion which defines the data. Nothing in this recommendation is outside of the COMTRADE format, so all present and future methods are applicable, including ASCII and binary data file types.

In the following descriptions, the terms phasor value, analog value, and digital value refer to phasor, analog, and digital values that are referenced in the synchrophasor standard, C37.118.

## 1.1 COMTRADE Configuration file

The COMTRADE standard configuration file is given below for reference and introduction.

```
station_name,rec_dev_id,rev_year <CR/LF>
TT,##A,##D <CR/LF>
An,ch_id,ph,ccbm,uu,a,b,skew,min,max,primary,secondary,PS <CR/LF>
An,ch_id,ph,ccbm,uu,a,b,skew,min,max,primary,secondary,PS <CR/LF>
An,ch_id,ph,ccbm,uu,a,b,skew,min,max,primary,secondary,PS <CR/LF>
An,ch_id,ph,ccbm,uu,a,b,skew,min,max,primary,secondary,PS <CR/LF>
…
Dn,ch_id,ph,ccbm,y <CR/LF>
Dn,ch_id,ph,ccbm,y <CR/LF>
…
lf <CR/LF>
nrates <CR/LF>
samp,endsamp <CR/LF>
samp,endsamp <CR/LF>
dd/mm/yyyy,hh:mm:ss.ssssss <CR/LF>
dd/mm/yyyy,hh:mm:ss.ssssss <CR/LF>
ft <CR/LF>
timemult <CR/LF>
```

PSRC H8 Application of COMTRADE for Synchrophasor Data
Approved by IEEE PSRC Subcommittee H on July 31, 2009 as a PSRC Report

The first line is the station name, recording device ID, and version of the standard. For synchrophasor use, the station name will usually be the recording location. The device ID identifies the recording device and this is left to the user. The version year of the standard is critical. The earliest version useable for synchrophasor data is 1999.

## 1.2 Channel type count

The second line of the configuration file is the count of channels by type.

TT,##A,##D **<CR/LF>**

TT = sum of total channels = ##A + ##D
##A = number of analog channels. There will be 2 channels for each phasor value and 1 channel for each analog value. The 2 channels representing phasor values will be explicitly identified as described under channel information below.
##D = number of status or digital channels. In synchrophasor data, digital values come in blocks of 16 channels; the same data is represented in COMTRADE in binary format. The channel name and type information may be read from the synchrophasor configuration and parsed into the COMTRADE configuration file as described below. Synchrophasor data also includes time and data quality information that is not normally included in COMTRADE type data. This information needs to be included in the recorded file, and the method is also described below.

## 2. Analog channel information overview

The next block of configuration file entries is the analog channel descriptions. Analog channel information includes both phasor data and analog data as defined in the SYNCHROPHASOR standard. Phasors are always represented as a complex number either using rectangular components with a real and imaginary value, or polar components with a magnitude and angle value. These two values will be recorded as successive analog channels (channel pairs) with rectangular values ordered real first, imaginary second and polar values ordered magnitude first, angle second. The first channel of the pair may be an even or odd numbered channel depending on what channels have preceded it. The overall order of analog channels in the file can be set by the user, though it is suggested following the same general order used by the synchrophasor standard for data transmission. Details are provided in the descriptions below.

## 2.1 Analog channel information

**An,ch_id,ph,ccbm,uu,a,b,skew,min,max,primary,secondary,PS** <CR/LF>

    **An**       analog channel index number 1 to 999999, sequential from 1.

    **ch_id**    alphanumeric channel name 0 to 64 char. This should be a combination of the station name and the channel names as given in C37.118. Those names are restricted to 16 bytes, so they will occupy 33 bytes (with colon) in the 64 byte field. They will be written as station name followed by channel name connected with a colon. That is, station_name:channel_name. Note that the same name will be applied to two channels since each phasor has two number values that are recorded in different analog channels. The channel phase identification field (ph) is used to designate which component is represented in each channel. Channel names must be unique as they are used to link the two components of the phasor together. If other information is to be added to this name, it must be added after the channel name delimited by an underscore or other character. Since the colon delimits the station to channel name, it cannot be used in any channel name and should not be used in any other name. With this convention, phasor data names (ch_id) will always start with the station_name:channel_name.

    **ph**       channel phase identification, 0 to 2 char. Each phasor is represented in two analog channels. The channels are identified by the 2 characters XY as follows:

**X = Phase where**        A => A phase, single phase
B => B phase, single phase
C => C phase, single phase
R => R phase, single phase
S => S phase, single phase
T => T phase, single phase
1 => 1 phase, single phase
2 => 2 phase, single phase
3 => 3 phase, single phase
P or + => positive sequence
N or - => negative sequence
Z or 0 => zero sequence

**Y = Phasor component where**    r => real for rectangular components
i => imaginary for rectangular components
m => magnitude for polar components
a => angle for polar components

**ccbm**    circuit component being monitored, 0 to 64 char. This is a freeform field that will be left to the user except that keyword quantities may be included. The key words defined below are used for machine identification of the defined parameters and should not be used in this field for any other purpose. The key word quantities should be separated from other words by spaces and should be used as shown below (case sensitive). These key word values can easily be identified and recorded by machine methods. A key word is a 4 character mnemonic followed by the equals (=) sign followed by the identified parameter. There are to be no spaces between characters; that is, no spaces before or after the = sign. Inclusion of key words is not required. Note that a machine parser should scan the entire field for key words since they may be located anywhere in the text, in any order, and more than one may be included. Key words and their usage:

**Vref**    this is used for a current phasor to designate the voltage channel, An, that is required for computing power, $\mathbf{P} = \mathbf{EI}$*. Since voltage and current phasors occupy two channels, this key word shall be included with the real or magnitude channel of the current phasor pair and refer to the real or magnitude channel of the voltage phasor pair. Phasors are represented as real and imaginary components in a rectangular coordinate system and as magnitude and phase in a polar coordinate system. For example,

Vref=1123 indicates the channel 1123 is the real or magnitude component of a voltage phasor that voltage will be used with the given current to compute power

**Vnom**    this is used for a voltage phasor to indicate that the phasor represents a voltage and the nominal voltage in kV. This key word must accompany the first channel of the voltage phasor pair. For example,

Vnom=345 indicates the nominal voltage is 345 kV.

**Inom**    this is used for a current phasor to indicate that the phasor represents a current and the nominal current in Amperes. This key word must accompany the first channel of the current phasor pair. For example,

Inom=3000 indicates the nominal current is 3000 Amps..

Add other key words as required, keeping care that the field is limited to 64 characters which could rarely be more than 3 key words per quantity.

**uu**    alphanumeric channel units, 0 to 32 char. Use as described in the COMTRADE standard.

**a**    channel multiplier, 1 to 32 char. According to the 1999 standard, the contents of the ".dat" file must be in integer counts. For real, imaginary, and magnitude component channels, this field is the integer PHUNIT value with the $10^{-5}$ scaling applied. That is, this is PHUNIT x $10^{-5}$ as described in the SYNCHROPHASOR standard. For angle component channels this number should be $10^{-4}$ since the (integer) angle should be given radians x $10^4$.

> **b**      channel offset, 1 to 32 char. The offset is normally used to define the zero level for channels that are single ended or have floating references. For angle component channels this number can be used to adjust angle offsets, such as Y-Delta connections and inter-area differences.

Scaling and offset are applied ax + b where x is the integer value stored in the ".dat" file. b must be in the same units as ax.

> **skew**      time skew between channels, 1 to 32 char. Phasor data is by definition synchronized within microseconds and theoretically to within less than one microsecond, so this value should be set accordingly as described in the COMTRADE standard.
>
> **min**      data range minimum value, 1 to 6 char. Use as described in COMTRADE standard.
>
> **max**      data range maximum value, 1 to 6 char. Use as described in COMTRADE standard.
>
> **primary**      PT/CT primary ratio factor, 1 to 32 char. Use as described in COMTRADE standard.
>
> **secondary**      PT/CT secondary ratio factor, 1 to 32 char. Use as described in COMTRADE standard.
>
> **P/S**      primary or secondary PT/CT scaling identifier, 1 char. Enter P or S and use as described in COMTRADE standard.

## 3. Status (digital) channel information overview

Following analog channel definitions, the next block of configuration file entries are the digital channel descriptions. In the COMTRADE standard, Boolean channels represented by a single bit set to 1 or 0 are called status channels. In the SYNCHROPHASOR standard they are called digital channels. In this latter standard, digital channels are always grouped in blocks of 16 channels while in COMTRADE they are represented singly in the ASCII file type but as 16 channel blocks in binary files. The data blocks will often contain unused channels. When SYNCHROPHASOR data is stored as ASCII files it is permissible to drop the unused channels provided the recording device has provided a means to sort those used from those unused. With binary file types the recording will be the same for both types. It is permissible to only list the channels that are being used in the COMTRADE configuration file. Viewing devices or programs that convert file data back to the SYNCHROPHASOR data stream format should provide default information for the unrepresented digital channels. A sample is given below for this purpose.

## 3.1 Status (digital) channel information

**Dn,ch_id,ph,ccbm,y** <CR/LF>

> **Dn**      digital channel index number 1 to 999999, sequential from 1.
>
> **ch_id**      alphanumeric channel name 0 to 64 char. This should be a combination of the station name and the channel names as given in C37.118. Those names are restricted to 16 bytes, so they will easily fit in this up to 64 byte field. They will be written as station name followed by channel name connected with a colon. That is, station_name:channel_name.
>
> **ph**      channel phase identification, 0 to 2 char. Use as defined in the COMTRADE standard.
>
> **ccbm**      circuit component being monitored, 0 to 64 char. Use as defined in the COMTRADE standard.
>
> **Y**      normal state of the channel, 1 character. Always either 1 or 0 as defined in the COMTRADE standard.

The first 8 digital channels are reserved for bits of the time quality byte included in the fractional time (FRACSEC) long word contained in the C37.118 time stamp. The next 8 digitals are reserved for future use, and for the purpose of keeping the individual PMU station status indications on even 16-bit words. The next 16 digital channels are reserved for bits of the status word for the first station represented in the data sample. If there is more than 1 station

included in the frame of data that is represented, the status of each station is to be represented as 16 channel groups in the same order as they appear in the data frame. The binary form of COMTRADE data files allocates digital status information into 16-bit (or larger) blocks; the status for each station can be written directly into a binary formatted file since digital status is allocated to 16-bit words. Each status bit is to be named by the station name with an extension identifying the bit. This is the same station name used in identifying the signals, so the status of each signal is identifiable. Any digital status data included in the synchrophasor data should follow after the time quality and PMU status indications. The exact mode of representation is shown below.

| | |
|---|---|
| D1, TQ_CNT0, T0,,0 | first 8 bits are the Time Quality from the FRACSEC word |
| D2,TQ_CNT1, T1,,0 | |
| D3,TQ_CNT2, T2,,0 | |
| D4,TQ_CNT3, T3,,0 | |
| D5, TQ_LSPND, T4,,0 | |
| D6, TQ_LSOCC, T5,,0 | |
| D7, TQ_LSDIR, T6,,0 | |
| D8, TQ_RSV, T7,,0 | The next 8 bits are skipped to preserve 16-bit word structure for station status |
| D17, <station1>:TRG1, S0,,0 | next 16-bits are the status for the first station in the data message |
| D18, <station1>:TRG2, S1,,0 | |
| D19, <station1>:TRG3, S2,,0 | |
| D20, <station1>:TRG4, S3,,0 | |
| D21, <station1>:UNLK1, S4,,0 | |
| D22, <station1>:UNLK2, S5,,0 | |
| D23, <station1>:SEC1, S6,,0 | |
| D24, <station1>:SEC2, S7,,0 | |
| D25, <station1>:SEC3, S8,,0 | |
| D26, <station1>:SEC4, S9,,0 | |
| D27, <station1>:CFGCH, SA,,0 | |
| D28, <station1>:PMUTR, SB,,0 | |
| D29, <station1>:SORT, SC,,0 | |
| D30, <station1>:SYNC, SD,,0 | |
| D31, <station1>:PMUERR, SE,,0 | |
| D32, <station1>:DTVLD, SF,,0 | |
| D33, <station2>:TRG1, S0,,0 | next 16-bits are the status for the second station in the data message |
| D34, <station2>:TRG2, S1,,0 | |
| … | |
| D(16(n+1)), <stationn>:DTVLD, SF,,0 | end of last status of last for station in message with n stations |
| D(16(n+1)+1), name, etc,,0 | start of all digital status indications contained in data |

## 4. Fixed parameter overview

There are 12 additional parameters that are specified in the COMTRADE configuration. These are used in their standard manner, but for completeness they are reviewed here in relation to synchrophasor data.

**lf** <CR/LF>

   **lf**    line frequency in Hz, 0 to 32 char. This should always be 50 or 60 to indicate the system frequency.

**nrates** <CR/LF>

   **nrates**   number of sampling rates in the file, 1 to 3 char. A file of phasor data will normally be made using a single sampling rate, so this will usually be 1. It can be > 1 in accordance with COMTRADE variable rate recording.

**samp,endsamp** <CR/LF>

       **samp**            sample rate in samples per second (Hz), 1 to 32 char (can be a value < 1). This is the sample or frame rate of phasor data and there will normally be only one rate. However, in accordance with COMTRADE variable rate recording, there can be more than one entry with several rates in the file.

       **endsamp**       number of the last sample recorded using the given samp rate, 1 to 10 char. With a single sample rate, this number is the last sample in the file. With multiple rates in the file, several samp, endsamp pairs will indicate the relevant blocks.

**dd/mm/yyyy,hh:mm:ss.ssssss** <CR/LF>
**dd/mm/yyyy,hh:mm:ss.ssssss** <CR/LF>

       **timestamps**     two timestamps are given (identical in format). The first one is the time of the first data item in the file. the second is the point at which the file was triggered (trigger point). Details of the required characters are available in the standard. For these purposes, these times and times in the data should be expressed in unoffset UTC, that is, with neither local time zone offset nor daylight saving offset.

**ft** <CR/LF>

       ft              file type, 5 to 6 char. This parameter can only be ascii or ASCII for a data file using the ascii format, or binary or BINARY for a data file using the binary format

**Timemult** <CR/LF>

       **timemult**       is a time multiplication factor, 1 to 32 char. This factor is used to multiply all the time stamps given in the data file to achieve a different time scale. Time stamps in the data file are given in microseconds in a 10 character field which limits the time span of the file to 9999999999 microseconds or about 10000 seconds. Multiplying these time stamps by a scale factor allows storing a much longer time record. Since the data interval between samples for phasor data is usually 16667 microseconds or larger, timemult can be increased to allow exchange of longer data records. For example, if timemult = 1000 then data for a time period of 10000000 seconds (over 115 days) can be represented in a single record.

## Data File Information

Data files follow the exact description provided in the COMTRADE standard, so they are not detailed here. Using the binary format is recommended, due to the size of these files. However any file format can be used.