Summary of the Proposed Revisions to IEEE Standard C37.111-1999, COMTRADE

Common Format for Transient Data Exchange

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Sponsored by:

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Power System Relaying Committee (PSRC) of the
Power Engineering Society (PES) of the
Institute of Electrical and Electronics Engineers (IEEE)

Presented before the

36th Annual
Western Protective Relay Conference
Spokane, Washington
October 20th-22nd, 2009

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ABSTRACT

The COMTRADE standard includes a number of restrictions that were designed for the computing technologies of the eighties and nineties. A number of these restrictions have become obsolete or incompatible with current technology. The restrictions include, but are not limited to, file names and extensions, storage and exchange media, time stamps and time quality, and data types. The proposed revisions are aimed at addressing these restrictions while realizing the benefits of the latest in data management technology. The benefits include: simplifying the process of archiving, exchanging, and synchronizing COMTRADE records, and supporting a wide range of data types.

The object of this paper is to brief users on the proposed revisions and to provide a short tutorial for new comers. The paper describes the reasons behind the proposed revisions followed by an overall description of the revisions and the resulting improvements. The paper also addresses the key issues of using COMTRADE for saving synchronous phasor data (as in IEEE Std. C37.118-2005).

BACKGROUND

The subject of this section is the story of COMTRADE, a brief review from a historical perspective with special emphasis on practice and development. The COMTRADE story can be related in four basic stages of evolution: the first stage is represented by the 1991 standard, the second stage is represented by the 1999 revisions, the third stage is the consequences of the 2003 blackout, and the fourth stage is represented by the proposed revisions. The four stages are:

1) 1991 Standard: The need for a common format for transient data exchange became clear in the late eighties when we had multiple providers of digital fault recorders (DFRs). Each provider supplied their own brand of proprietary formats, programs and operating nuances. To that extent, the COMTRADE standard was produced in 1991 specifically aimed at realizing a common format which all providers can follow. Within a few years, most of the major providers developed new programs for converting their own proprietary data into COMTRADE. This was a considerable step forward but resulted in

more programs for users to operate and produced new compatibility issues which opened up the field to third party providers who, in turn, develop “universal programs” for working with various types of DFR formats from a common platform.

2) 1999 Revisions: During the nineties, large numbers of digital relays were being installed and most of them were capable of recording transient data. Subsequently, the field of transient data recording was now open to providers of digital relays too and a considerable number of new operating nuances were introduced. To that extent, the PSRC kept close track of this evolution and delivered a revised COMTRADE standard in 1999. The main objective of the revised standard was to reinforce the basic concepts of transient data representation and to accommodate a growing set of innovative discoveries such as “dynamic sampling” and “information files”.

International acceptance of COMTRADE was achieved throughout the community of users and providers (including DFR, digital relay, and third party providers) around the turn of the century. This acceptance led to another considerable number of new providers joining the community including, but not limited to, providers of digital meters, phasor measurement units, and remote terminal units. This in turn added another considerable number of derivatives, deviations, and interpretations of the standard. For example, some providers are now using COMTRADE to exchange non-transient information such as steady state data.

3) 2003 Blackout: As a consequence of the northeast blackout of Aug 14th, 2003, the North American Electric Reliability Corporation (NERC) began an investigation into the root causes behind the blackout with the aim of making recommendations to help avoid such events in the future. To that extent, NERC collected thousands of transient data files from many of the involved utilities. The collected files revealed two fundamental problems that could seriously hinder any investigative process. The problems were:

- The collected files were in multiple formats, many of them were in proprietary form. The investigation team had to use multiple types of display and analysis programs which slowed the analysis process and hindered the ability of synchronizing data files and performing end to end studies.

- The collected files did not share a common naming convention and it became difficult to discern which files came from which utilities and which ones were captured by which devices. The lack of a common naming practice became a serious hindrance confronting the investigation process.

Fortunately, the investigation team had the tools needed to successfully convert the files into COMTRADE and to rename them under a common naming convention (as now defined in IEEE Std. C37.232-2007, Recommended Practice for Naming Time Sequence Data Files, COMNAMES).

The use of COMTRADE and COMNAMES helped the investigation team resolve many of the problems associated with managing and analyzing large quantities of transient data records. The usefulness of these formats was duly noted by NERC and by NPCC (the Northeast Power Coordinating Council) as being invaluable during the investigation process. Today, both formats are required under NERC Std. PRC-002-2 (Proposed Standard for Disturbance Monitoring and Reporting Requirements). Nonetheless, the

investigation did expose a number of weaknesses in the COMTRADE standard. The main weaknesses are enumerated below:

- The lack of a formatted field for specifying whether the time tags were based on local time or were based on UTC without offset (UTC stands for Universal Coordinated Time, and UTC without offset is called Greenwich Mean Time or "Zulu" time).

- The lack of a common set of formatted fields for specifying whether the time tags were properly synchronized or not.

- The lack of a combined file format for resolving the added complications of managing and keeping track of up to 4 separate files for each COMTRADE record.

These weaknesses are directly addressed by the 2009 proposed revisions as described in the following sections.

4) Proposed Revisions: Since 2002, a number of PSRC working groups (first HTF1, then H5D and now H4) have been actively collecting lessons learned, developing solutions, and carefully revising the original text of the 1991 and 1999 standards. The latest draft of the standard contains a number of useful additions and revisions including:

- A number of new fields and data types designed to support the standard's growing use and expanding scope,

- A new file structure designed to simplify the management and tracking of large quantities of COMTRADE records, and

- A new revised text that removes a number of obsolete restrictions such as the one on filenames being restricted to 8 characters which is very difficult to use when trying to implement a common naming practice. Current naming practices, such as the COMNAMES format, allow for filenames of up to 253 characters in length but recommend the use of no more than 64 characters to ensure compatibility across various types of operating systems.

The proposed revisions are enumerated in the following sections. The latest draft is being prepared for ballot and the aim of the H4 working group is to complete their work in 2010. To that extent, enumerating and discussing the proposed changes at this time should prove of benefit for both users and developers of the standard.

THE NEW FIELDS

A number of new fields have been added to the configuration file and a number of new data types have been added to the data file. The new fields are:

Time Code: The Time Code field is used to specify the time difference between local time and UTC without offset. The field is restricted to a maximum of 7 formatted characters. The first character is a sign character and is followed by up to 5 characters for indicating the time difference (which includes up to 2 digits for the hours followed by the letter "h" followed by 2 digits for the minutes). A few examples are shown below:

"-4" means the time difference is minus 4 hours,
"-7h15" means the time difference is minus 7 hours and 15 minutes,
"+10h30" means the time difference is plus 10 hours and 30 minutes, and
"0" means the time difference is 0 (local time is UTC).

The time difference should also reflect whether standard time or daylight savings time was in affect at the time of the recording.

Local Code: In the event that the date and time stamps in the COMTRADE record are set to UTC without offset (meaning Time Code is 0), then the Local Code field can be used to identify the local time zone where the record was captured. The Local Code format is in the same format as the Time Code field. The code "x" or "X" means such information is not available.

Time Quality: The Time Quality field is used to indicate the maximum time error between the recorded time stamps and the time from the synchronizing source (such as a GPS clock). The field corresponds to the Time Quality indication code defined in IEEE Std. C37.118. The field is composed of a single hexadecimal digit. Some of the possible values are:

"F" means clock failure, time is not reliable,
"B" means clock unlocked, time is within 10 seconds,
"A" means clock unlocked, time is within 1 second,
"7" means clock unlocked, time is within 1 millisecond,
"4" means clock unlocked, time is within 1 microsecond,
"1" means clock unlocked, time is within 1 nanosecond, and
"0" means clock locked onto its source (such as a satellite in the case of a GPS Clock).

Leap Second: The Leap Second field is used to indicate that a leap second may have been added or deleted during the recording resulting in either two segments of data having the same Second of Century time stamp or having a missing second.

"3" means the time source does not have the capability to address leap seconds,
'2" means a leap second was subtracted in the record,
"1" means a leap second was added in the record, and
"0" means the record does not contain a leap second adjustment.

THE NEW DATA TYPES

The proposed standard supports 2 new types of binary data formats for use with the COMTRADE data file. The new data types are named "Binary32" and "Float32". The "ASCII" data type was also revised accordingly and the "Binary" data type remains unchanged. The new and revised data types are:

ASCII Data: The ASCII data type was revised from a maximum of 5 integer digits to a maximum of 12 numeric digits (integer or floating point notation format).

Binary32 Data: Is a new Binary data type format designed to represent 32 bit integer numbers according to the 2's complement system.

Float32 Data: Is a new Binary data type format designed to represent 32 bit real numbers according to the ANSI/IEEE Std. 754-1985.

At this point it is worthwhile to mention that the original intent of the 1991 standard was to preserve the raw A/D counts (analog to digital conversion counts) in the data file. To that extent, the original text restricted the data file contents to 16 bit values. However, modern technologies that produce 24 bit counts or more are commonly used today. In addition, files that are created manually or by automated analysis applications could also contain real numbers.

The new and revised data types represent a change that is in line with modern day technologies and provide more flexibility in representing data in its original form without having to convert to 16 bit values. The data file contents are no longer restricted to only 16 bit values.

THE NEW FILE STRUCTURE

The current file structure defines 4 types of files for each COMTRADE record. The 4 files are: header, configuration, data, and information. The files share the same name but have different extensions (HDR, CFG, DAT, and INF respectively). The header and information files are optional and the header file is frequently used. It is difficult to keep track of, manage or exchange, COMTRADE records when each record is composed of multiple files. It is especially difficult when dealing with massive amounts of records.

The proposed file structure defines one file for each COMTRADE record. The new structure combines the original 4 files (as is) under one file. The combined or single file format is identified by the CFF extension. The use of the new CFF format is strongly recommended in the proposed standard. The use of the 4 original files is also allowed. The new file structure has a number of advantages including:

- Simplifying the management, archiving, and exchange of COMTRADE records,
- Reducing the total number of files by an average factor of 3, and
- Allowing for the potential use of COMTRADE as a standard format for recording transient records and not just for exchanging them.

The CFF format is composed of four separate sections. The sections are separated by XML tags (Extensible Markup Language). The sections are organized in the following order with XML tags encapsulating each section:

<RECORD: SINGLE-FILE-EXAMPLE.CFF>
  <CONFIG>
    The configuration file contents (.CFG file)
  </CONFIG>
  <INFORMATION>
    The information file contents (.INF file)
  </INFORMATION>
  <HEADER>
    The header file contents (.HDR file)

```
   </HEADER>
   <DATA>
      The data file contents (.DAT file)
   </DATA>
</RECORD>
```

OBSOLESCENCE

The current text includes a number of obsolete statements and recommendations. For example, consider the following text (from section A.6.2):

"The most commonly used computer systems today are personal computers equipped with floppy disk drives. The double-sided, high-density 1.44 MB 3.5" floppy diskettes are the most popular form of file transfer. They can be placed easily in padded envelopes and sent by mail from one location to another. Because of the widespread use and the convenience with which they can be sent to another location by mail, it is recommended that 1.44 MB 3.5" floppy diskettes be used for exchanging fault data."

Clearly, the above statements and recommendations are no longer applicable. Because of frequent changes and enhancements in "state of the art technologies", the proposed standard uses a more generic text. For example, the above text now reads:

"The most commonly used computer systems today are personal computers equipped with CD, DVD and USB drives. Any one of these mediums can be effectively used for exchanging data. However, some other devices may be available in the future which may be more advanced both in terms of amount of data storage capability and the size of the device. Users should adopt the latest available technology that is popular without waiting for the next revision of the standard."

The above scenario is repeated multiple times throughout the standard. The full extent of the proposed additions and revisions can only be appreciated by reading the actual text of the proposed standard. Nonetheless, one of the most significant revisions is the one concerning filenames. Here is an example of the original text:

"Filenames are in the form xxxxxxxx.yyy. The xxxxxxxx portion is the name used to identify the record and the .yyy portion is used to identify the extension. The filenames must follow the IBM compatible DOS (Version 6 Operating System) conventions for legal characters within the filenames (e.g., periods and spaces are not allowed as part of the filename). The names are limited to eight characters and the extensions are limited to three characters."

Clearly, and as indicated in the Background section, it is very difficult to implement a common filing system with only 8 DOS characters for naming transient data files. Here is an example of the revised text:

"Filenames are in the form "name.extension". The filenames should follow the IEEE Std. C37.232-2007 (COMNAMES). However, users and manufacturers should take appropriate care to restrict the filename length so that files can be copied using available operating systems and CD/DVD writing technologies."

The COMNAMES filename includes key portions of the information in the file content (such as the name of the circuit, the name of the substation, the name of the recording device, and the date and time of event occurrence). The COMNAMES standard is rapidly gaining popularity and is now being used by a nontrivial number of users including utilities, system operators, manufacturers, and third party providers.

COMTRADE EXAMPLES

The following template example shows the basic structure of the configuration file. The 1999 revisions are underlined and the proposed revisions and additions are bold faced and underlined:

- station_name, rec_dev_id, rev_year
- TT, #A, #D
- An, ch_id, ph, ccbm, uu, a, b, skew, min, max, primary, secondary, PS
- Dn, ch_id, ph, ccbm, y
- line_freq
- nrates
- samp, endsamp
- start_date, start_time
- trigger_date, trigger_time
- **file_type**
- timemult
- **base_time, time_code**
- **tmq_code, leapsec**

An example configuration file containing the proposed changes is provided below:

- SMARTSTATION, IED123, 2009
- 8, 4A, 4D
- 1, IA , A, Line123, A, 0.113891, 0.056945, 0, -32768, 32767, 933, 1, s
- 2, IB , B, Line123, A, 0.113891, 0.056945, 0, -32768, 32767, 933, 1, s
- 3, IC , C, Line123, A, 0.113891, 0.056945, 0, -32768, 32767, 933, 1, s
- 4, 3I0, N, Line123, A, 0.113891, 0.056945, 0, -32768, 32767, 933, 1, s
- 1, 51A, A, Line123, 0
- 2, 51B, B, Line123, 0
- 3, 51C, C, Line123, 0
- 4, 51N, N, Line123, 0
- 60
- 1
- 1200, 240
- 12/01/2009,05:55:30.75011
- 12/01/2009,05:55:30.78261
- **ASCII**
- 1.00
- **-5h30, X**
- **B, 3**

An example of the associated data file is provided next (lines 87 to106 are shown):

- 87,72500,-83,68,7,-8,0,0,0,0
- 88,73333,-15,5,4,-6,0,0,0,0
- 89,74167,55,-53,0,2,0,0,0,0
- 90,75000,122,-96,-2,24,0,0,0,0
- 91,75833,182,-119,-7,56,0,0,0,0
- 92,76667,228,-121,-11,95,0,0,0,0
- 93,77500,260,-104,-14,142,0,0,0,0
- 94,78333,271,-68,-17,186,0,0,0,0
- 95,79167,260,-19,-18,223,0,0,0,0
- 96,80000,228,39,-19,248,0,0,0,0
- 97,80833,178,100,-19,260,0,0,0,1
- 98,81667,113,158,-16,255,0,0,0,1
- 99,82500,43,206,-12,236,0,0,0,1
- 100,83333,-30,236,-5,202,1,1,0,1
- 101,84167,-95,249,2,156,1,1,0,1
- 102,85000,-150,243,6,98,1,1,0,1
- 103,85833,-187,218,11,42,1,1,0,1
- 104,86667,-202,176,16,-10,1,1,0,1
- 105,87500,-195,123,18,-54,1,1,0,1
- 106,88333,-165,61,19,-85,1,1,0,1

FUTURE TRENDS

In addition to the proposed revisions described in the previous sections, the COMTRADE working group considered a number of other suggestions. Chief among these suggestions were: support for Synchrophasors, support for user defined channels, and support for a new format based on XML descriptions of COMTRADE fields and data types. The following is a brief description of these suggestions and the corresponding actions taken by the working group members are also summarized:

Synchrophasors: The COMTRADE and Synchrophasors working groups coordinated and worked together and had extensive discussions trying to determine how to best support Synchrophasors in COMTRADE. The definition of the new Time Quality field is based on Synchrophasors, and the new ASCII, Binary32 and Float32 data types were designed to also support Synchrophasors. In addition, a task force was formed in 2008 to develop “A Schema for Synchrophasors Data Using the COMTRADE Standard”. The task force developed the schema based on the 1999 format (mainly because the 2009 format is still in the “proposed” state). Their final report was published in 2009 and is included in it’s entirety in the proposed standard as an informative annex.

User Channels: The suggestion to support user channels was first presented to the COMTRADE working group in 2003. The concept is to provide users with a common format for adding channels to the configuration file without having to add corresponding columns to the data file. The channels are programmed by the user based on some standard language for scripting transient data formulas. User channels are useful, they can be used to reconstruct a missing phase (by subtracting the monitored phases from the neutral phase), or they can be used to calculate sequence components, frequency, fault impedance, active and/or reactive power, harmonics and so forth. Clearly, the suggestion requires the development of a new script language which is an extensive effort and is best addressed by the formation of a new working group that is dedicated to

this issue. To that extent, the issue is currently being considered by the H10 working group whose mission is to develop a common format for scripting device and channel names. Their final report is due in 2010.

XML Format: The suggestion to support a new format based on XML was first considered by the COMTRADE working group in 2005. This suggested format is similar to the single file format (CFF extension) as discussed in the previous sections except that it uses formal definitions for each of the COMTRADE fields and data types based on XML version 1.0 and is identified by the XSD extension. The suggested format defines an XML schema (formal definitions) based on IEC Std. 61850-6 (Configuration Description Language for Communication in Electrical Substations Related to Intelligent Electronic Devices). The main intent of the working group is to realize 2 basic advantages by organizing COMTRADE records into XML format. The advantages are:

- Compatibility with modern database applications (most of which support XML) allowing for direct importing and exporting of COMTRADE records, and

- Compliance verification which provides users with access to an array of available XML tools for automatically validating whether a given COMTRADE record adheres to the standard or not.

The working group worked diligently over a long period of time and produced a 25 page report listing the details for representing COMTRADE in XML. Initial attempts at using the new format exposed 2 basic concerns. The concerns are:

- The size of the resulting XML file is much larger than the size of an equivalent data file saved in the standard format. The difference in the data file size is more than 116 additional characters per line, and the difference in the total number of lines is 5 fold.

- The readability and editability of the configuration file is substantially degraded when using an ASCII editor. However, if an XML editor is used then the opposite is true.

Clearly, defining an efficient and agreeable XML format requires an extensive effort and is best addressed by the formation of a new working group dedicated to this issue. To that extent, a new working group is on schedule to being proposed in 2010 to address the COMTRADE in XML issues using the 25 page report as their starting point.

CONCLUSIONS

In conclusion, the development of the COMTRADE standard has spanned almost 2 decades of work and the standard is considered as the premier format worldwide for exchanging transient data records. The proposed standard provides a number of advantages over the current standard. Chief among these advantages is the simplified management and tracking of COMTRADE records (courtesy of applying the standard for naming files along with the use of the single file format, CFF). Other advantages of the proposed standard include, but are not limited to: support for a wider range of applications (courtesy of the new fields and data types), and an expanded scope that may lead to the use of COMTRADE as a standard format for recording transient data records and not only for exchanging them. In the future, and judging by the ongoing

efforts, more advantages will also be realized especially in the areas of naming methodologies, scripting languages, Syncrophasors, and XML.

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[B6] IEEE Std. C37.111-1991, IEEE Standard Format for Transient Data Exchange

[B7] IEEE Std. C37.111-1999, IEEE Standard Format for Transient Data Exchange