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Summary Changes in 2013 IEEE/IEC Dual Logo COMTRADE Standard

Working Group H4 of the Relaying Communications Subcommittee,
Power System Relaying Committee of the Power Engineering Society (PES) of
the Institute of Electrical and Electronics Engineers (IEEE)

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Abstract: The globally used COMTRADE standard was initially developed by IEEE and later adopted by IEC. The first IEEE version was published in 1991 and was later revised in 1999. The IEC version was adopted in 2001. The 2013 revision of the COMTRADE standard is an IEEE/IEC Dual Logo standard planned for publication during the first quarter of 2013. The main motivations for the current revisions are: 1) to remove restrictions that were only relevant for computing technologies of the 1990s and 2) to satisfy the requirement of universal time information in COMTRADE files. The second need was identified during the 2003 Northeast Blackout analysis to time synchronize data from different substations. The working group has also addressed other issues, including the availability of a single file. Industry users feel very strongly about this need to easily exchange and manage COMTRADE files, and the working group's recommendations address these concerns.

Keywords: COMTRADE, Relay, IED, PMU, UTC, Filename, file name, file extension, file content, single file format, combined file, configuration file, data file, header file, information file, transient data, transient data record, time sequence data, start date, start time, trigger date, trigger time, base time, time code, file type, time quality, and leap second.

I – INTRODUCTION

The history of the COMTRADE standard can be narrated in many different ways. However, the common themes are innovation, cooperation and success over the last twenty years. The COMTRADE standard evolved in four stages: the first stage is represented by the IEEE 1991 standard, the second stage is represented by the IEEE

1999 revision, the third stage is represented by the consequences of the 2003 Northeast blackout, and the fourth stage is represented by the 2013 IEEE/IEC Dual Logo COMTRADE standard. The goal of the first COMTRADE standard [1] was to assist relay engineers in evaluating the relay performance based on Digital Fault Recorder data. The first standard was quite successful: it was accepted by many relay manufacturers and utility engineers who recognized the value in sharing and using data from many devices scattered over a large geographical area, including simulation laboratories, test laboratories, and field installations. Noting the success of the COMTRADE standard in North America, users in other countries also began using the standard, resulting in a COMTRADE version of the standard coming from European manufacturers with 1993 identified as the standard year. Users were attracted to the simplicity and the interoperability provided by the standard. One critical focus of future power system development is interoperability; the COMTRADE standard is identified as a key SMART Grid standard for such development.

II – EVOLUTION OF COMTRADE STANDARD

A) The 1991 Standard

The need for a common format for transient data exchange became clear in the late 1980s, as different providers of digital fault recorders (DFRs) continued to develop proprietary formats, programs, and methods of operation. The COMTRADE standard developed in 1991 specifically aimed to realize a common format for all providers. 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, developed “universal programs” for working with various types of DFR formats from a common platform.

B) The 1999 Standard

During the 1990s, many digital relays capable of recording transient data were installed for the first time. 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. The Power System Relaying Committee kept close track of this evolution and delivered a revised IEEE COMTRADE standard in 1999 [2]. 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 millennium. 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 began using COMTRADE to exchange non-transient information. IEC adopted the revised COMTRADE standard in 2001 [3].

C) The 2003 Northeast Blackout

On August 14, 2003, a large part of the northeastern United States and part of Canada experienced a blackout that affected over 50 million people and required several days for full restoration of the system. North American Electric Reliability Corporation (NERC) began an investigation into the root causes behind the Northeast blackout, with the aim of making recommendations to help avoid such events in the future. NERC collected thousands of transient data files from many of the utilities involved. The collected files revealed two fundamental problems that seriously affected the investigative process:

- the collected files were in multiple formats, many of which were proprietary. The investigative team had to use multiple types of display and analysis programs which slowed the analysis process and hindered their ability to synchronize data files and perform end-to-end studies, and
- the collected files did not share a common naming convention: which made it difficult to discern both which files came from particular utilities and also which files were captured by particular devices. The lack of a common naming practice became a serious hindrance in the investigation.

Fortunately, the investigative 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 [4]) COMNAMES.
The use of COMTRADE and COMNAMES helped the investigative 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 (Standard for Disturbance Monitoring and Reporting Requirements). Nonetheless, the investigation did also expose a number of weaknesses in the COMTRADE standard. The main weaknesses are:

- the lack of a formatted field for specifying whether the time tags were based on local time or were based on UTC (UTC stands for Coordinated Universal Time, and UTC without offset is called “Zulu” time),
- the lack of a common set of formatted fields for specifying whether the time tags were properly synchronized or not, and
- the lack of a combined file format resulting in added complications of managing and keeping track of up to 4 separate files for each COMTRADE record.

These weaknesses are addressed by the 2013 IEEE/IEC Dual Logo COMTRADE Standard, described in the following section.

III – 2013 IEEE/IEC DUAL LOGO COMTRADE STANDARD

Since 2002, two Power System Relaying Committee working groups (H5D and H4) have been actively collecting lessons learned, developing solutions, and carefully revising the original text of the 1991 and 1999 standards, an effort which has resulted in the 2013 IEEE/IEC Dual Logo COMTRADE Standard [5]. 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 single file structure designed to simplify the management and tracking of large quantities of COMTRADE records;
- revised text that removes a number of obsolete restrictions, such as the restriction of filenames to 8 characters (Current naming practices, such as the COMNAMES format, allow for filenames of up to 253 characters in length, but the use of no more than 64 characters is recommended to ensure compatibility across various types of operating systems); and
- some of the non-critical fields in the configuration section have been made critical for better understanding and use of the data in the COMTRADE file.

A) The New Fields in the Configuration Section

A number of new fields have been added to the configuration 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 will also reflect whether standard time or daylight saving time was in effect 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" means such information is not applicable.

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 [6]. 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,
'**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.

B) The New Data Types

The standard supports two new types of binary data formats for use with the COMTRADE data file. The new data types are named "Binary32" and "Float32". Characters from the Unicode UTF-8 Standard are also allowed. Any occurrence of the terms ASCII or Text in the standard also inherently implies Unicode UTF-8. The new data types are:

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 IEEE Std. 754-2008 [7].

The additional data types represent a change that is in line with modern technologies and provide more flexibility in representing data in its original form, eliminating a conversion step.

C) The New File Structure

The 1999 COMTRADE standard 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, although 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 2013 IEEE/IEC Dual Logo COMTRADE standard file structure supports a single file for each COMTRADE record, although the four separate files are still maintained for backward compatibility. The single file structure combines the original 4 files (as is) under one file. The combined or single file format is identified by the CFF file extension. The use of the new CFF format is strongly recommended in the 2013 IEEE/IEC Dual Logo COMTRADE standard. 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 organized in the following order with a one-line separator between sections:

--- file type: CFG ---

The configuration file contents (.CFG file)

--- file type: INF ---

The information file contents (.INF file)

--- file type: HDR ---

The header file contents (.HDR file)

--- file type: DAT ASCII **---**

OR

--- file type: DAT BINARY:702 ---

The data file contents (.DAT file)

The number '702' after the word 'BINARY' indicates the number of bytes in the BINARY data.

D) Obsolescence

The text of the 2013 Dual logo standard is updated to match with technologies of today relating to digital data storage and transfer media. Also, restrictions related to the number of characters in filenames have been improved to match with the IEEE C37.232 standard of 2007.

IV – EXAMPLE FILE

The following template example shows the basic structure and evolution of the configuration file. The 1999 revisions are underlined and the 2013 revisions 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
- **time_code, local_code**
- **tmq_code, leapsec**

An example configuration file containing the 2013 changes is provided below:

- SMARTSTATION, IED123, 2013
- 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, -5h30**
- **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

V – FUTURE TRENDS

In addition to the revisions described in the previous sections, the IEEE COMTRADE working group has considered a number of other suggestions, including support for Synchrophasors, support for user defined channels, and support for a new format based on XML descriptions of COMTRADE fields and data types.

Synchrophasors: The COMTRADE and Synchrophasors working groups have discussed extensively the best way to support Synchrophasors using COMTRADE. The definition of the new Time Quality field is based on Synchrophasors, and the new Binary32 and Float32 data types were designed also to support Synchrophasors. In addition, an IEEE Power System Relaying Committee (PSRC) task force was formed in 2008 to develop "A Schema for Synchrophasors Data Using the COMTRADE Standard". The task force developed schema is added as an informative annex (Annex H) to the 2013 IEEE/IEC Dual Logo COMTRADE standard.

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, 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 requires extensive effort. This suggestion is best addressed by the formation of a new working group that is dedicated to this issue.

XML Format: The suggestion to support a new format based on eXtensible Markup Language (XML) was first considered by the IEEE 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 two 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 has produced a 25 page report listing the details for representing COMTRADE in XML. Initial attempts at using the new format exposed two basic concerns:

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

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.

The development of the COMTRADE standard has spanned almost two decades of work and the standard is considered the premier format for exchanging transient data records. The 2013 IEEE/IEC Dual Logo COMTRADE standard provides a number of advantages over the earlier standard including the simplified management and tracking of COMTRADE records, due to the availability of single file format. Other advantages of the 2013 IEEE/IEC Dual Logo COMTRADE standard include the support for a wider range of applications, due to the new fields and data types. These new parameters may lead to the use of COMTRADE as a standard format for recording, and not only for exchanging, transient data records. In the future, more advantages will also be realized in a future standard for the global audience.

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