

IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems

Sponsor

**Power Systems Relay Committee
of the
IEEE Power Engineering Society**

Reaffirmed 2 February 2005

IEEE-SA Standards Board

Abstract: A common format for data files and exchange medium used for the interchange of various types of fault, test, or simulation data for electrical power systems is defined. Sources of transient data are described, and the case of diskettes as an exchange medium is recommended. Issues of sampling rates, filters, and sample rate conversions for transient data being exchanged are discussed. Files for data exchange are specified, as is the organization of the data. A sample file is given.

Keywords: configuration file, data file, header file, information file, transient data.

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Print: ISBN 0-7381-1666-1 SH94743
PDF: ISBN 0-7381-1667-x SS94743

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Introduction

[This introduction is not part of IEEE Std C37.111-1999, IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems.]

The increasing use of digital technology in devices such as protection, oscillograph, measurement, and control apparatus in electric power substations has created the potential for accumulating large numbers of digital records of power system transient events. In addition to these sources of digital data, analog and digital power-system simulators may be used to generate digital records. The users of these records are faced with the problem of having to cope with different formats used by each system to generate, store, and transmit records.

Differences between IEEE Std C37.111-1999 and IEEE Std C37.111-1991

[These differences are not a part of IEEE C37.111-1999, IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems.]

- a) The Header (.HDR) file is explicitly defined as optional.
- b) The Configuration (.CFG) file has been modified. A field containing the COMTRADE standard revision year has been added to distinguish files made under this or future revisions of the standard. If this field is not present, the data is assumed to comply with C37.111-1991. A field for a Time Stamp Multiplication Factor has been added to meet the need for long duration files. To assist in conversion of the data, three new scaling fields (primary, secondary, and primary-secondary) are added, defining the instrument transformer winding ratios, and whether the recorded data is scaled to reflect primary or secondary values. Configuration fields for Status (Digital) Channel Information have been expanded to five fields to allow the same level of definition as for analog channels. Line Frequency is now defined as a floating point field. Support for Event Triggered data has been added by the addition of a new mode for Sampling Rate Information when the sampling rate is variable. The Date/Time Stamps format has been modified with the day of month preceding the month entry field, and the year field now has all four numbers of the year. A requirement that at least one leading space shall be tolerated in the data fields, including those fields for which no data is available (previously specified as comma delimiters with no spaces in between) has also been added.
- c) A new format for a binary data (.DAT) file has been specified and the requirement for a user-supplied conversion program has been eliminated.
- d) A new optional Information file (.INF) has been added to provide for transmission of extra public and private information in computer-readable form.
- e) All field descriptions are explicitly defined with respect to: criticality, format, type, minimum/maximum length, and minimum/maximum value.

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IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems

1. Overview

1.1 Scope

This standard defines a format for files containing transient waveform and event data collected from power systems or power system models. The format is intended to provide an easily interpretable form for use in exchanging data. As such, it does not make use of the economies available from data encoding and compression that proprietary formats depend upon for competitive advantage. The standard is for files stored on physical media such as digital hard drives and diskettes. It is not a standard for transferring data files over communication networks.

1.2 Purpose

This standard defines a common format for the data files and exchange medium needed for the interchange of various types of fault, test, and simulation data.

The rapid evolution and implementation of digital devices for fault and transient data recording and testing in the electric utility industry have generated the need for a standard format for the exchange of data. These data are being used with various devices to enhance and automate the analysis, testing, evaluation, and simulation of power systems and related protection schemes during fault and disturbance conditions. Since each source of data may use a different proprietary format, a common data format is necessary to facilitate the exchange of such data between applications. This will facilitate the use of proprietary data in diverse applications and allow users of one proprietary system to use digital data from other systems.

2. Files and data storage

2.1 Categories of files

Files stored on digital devices and media consist of bytes representing a combination of alphabetic, numeric, symbol, punctuation, and other formatting characters. Depending on the format, a byte, part of a byte, or

more than one byte, may be represented by a letter, number, or symbol (e.g., “A,” “3,” or “+”). There are three general classes of files used on computer systems: executable files, text files, and data files. The use of the file determines the category.

2.1.1 Executable files

Executable files contain a sequence of instructions suitable for processing by a computer. Computer programs are stored as executable files (.EXE). COMTRADE does not define executable files.

2.1.2 Text files

Text files imply data in human-readable form. A text file may be used for control of a computer program if the format is rigidly specified. COMTRADE text files use the character representation specified in ANSI X3.4-1986 [B1].¹ This is often called “ASCII format” or “Text (.TXT) format” by word processor programs.

COMTRADE defines one freeform ASCII text file intended for strictly human interpretation, the Header file. COMTRADE also defines three files in which the format is rigidly controlled and which are both human- and computer-readable—the Configuration file and the Information file, and the ASCII form of the Data file.

Most word processors can save text files in two or more formats. The text format contains only the characters actually typed, including punctuation and standard formatting characters such as carriage return/line feed. Other formats contain special characters specific to the particular word processor being used. The text format shall be used for the text files in a COMTRADE record to eliminate word processor-specific characters or codes. Programs intended to read COMTRADE files only require use of the typed characters that most word processor programs can read or print.

If no command exists in the word processor to save the file in this format, an alternative method is to use the print functions to print the text to disk to create the file.

2.1.3 Data files

Data files may contain numerical data, text data, or both. The data may be stored in either binary or ASCII format. Fields within ASCII format data files use defined text separated by commas, or some other common delimiter. As such, they are both human- and machine-readable. Most word processors cannot format, read, or write data files in binary form. However, many spreadsheet and data processing programs can read binary data files, if the format is known. Binary numbers must be processed by application-specific software to be easily interpreted by humans. COMTRADE defines one binary file, the binary form of the data file. Binary data are generally used when large amounts of data are to be stored because this uses less storage space (e.g., three bytes of binary data can represent numbers from 0 to 16 777 215 whereas three bytes of ASCII data can represent the numbers from 0 to 999). ASCII numbers have the advantage of being interpreted by humans, and by standard computer hardware and software.

2.2 Critical/non-critical data

Some of the data in the configuration file are not absolutely necessary for reproduction of the sample data, and some variables provided for in the configuration file may not be relevant to a particular application. Such data may be described as non-critical and may be omitted. An example of such non-critical data is the recording device channel name. However, the position normally occupied by such variables must be maintained in order to maintain the integrity of the file. If data are described as non-critical in any clause of this

¹The numbers in brackets preceded by the letter B correspond to those of the bibliography in Annex F.

standard, the position may be left empty and the corresponding data separator retained following the preceding data separator with no intervening characters or spaces. Any data that are necessary for reproduction of the sample data are termed critical. If such data are missing, the file may be unusable.

2.3 Data representations

Data are stored in files as series of binary digits or “bits.” Each bit can be either a 1 or a 0. The bits are organized in groups of eight bits called bytes. When a computer reads the data in a file, it reads the data as a series of bytes.

2.3.1 Binary data

The eight bits in a byte can be organized in 256 different combinations. They can be used, therefore, to represent the numbers from 0 to 255. If larger numbers are needed, several bytes can be used to represent a single number. For example, 2 bytes (16 bits) can represent the numbers from 0 to 65 535. When the bytes are interpreted in this fashion, they are known as binary data. Several different formats are in common use for storage of numeric data in binary form.

2.3.2 ASCII data

As an alternative to a byte representing the numbers 0 to 255, a byte can be used to represent 255 different symbols. ASCII is a standard code of symbols that match 127 of the combinations of eight binary bits. For example, the byte 01000001 represents an uppercase “A” while 01100001 represents a lowercase “a.” With 127 different combinations, it is possible to represent all of the keys on the keyboard plus many other special symbols. The remainder of the 256 combinations available from an eight-bit format are used for drawing and other special application characters. To represent a number in ASCII format requires one byte for each digit of the number.

2.4 Data field delimiters and lengths

Data fields within a file or within a subset of data in a file must be separated from the other data fields so that they may be extracted for reading or manipulation. For instance, written text uses a space as a word delimiter. Computer files use a variety of delimiters. In the binary form of COMTRADE data files, the only delimiter is a strict definition of the length and position of each data variable, and a byte count of the position within the file is necessary to determine the limit of any data entry. The ASCII files defined by COMTRADE use the comma and the carriage return/line feed as data separators. This permits the use of variable field lengths, but means that these characters cannot be used within any data entry. Leading spaces or zeroes are allowed in ASCII numeric fields providing the permitted maximum character count is not exceeded.

2.4.1 Carriage return/line feed delimiter <CR/LF>

COMTRADE uses the symbol <CR/LF> to represent a data separator terminating the end of a line or a set of data. The delimiter is the combination of two ASCII formatting characters:

CR = carriage return takes the cursor or insertion point back to the beginning of the current line.

LF = line feed moves the cursor or insertion point to a new line below the current line.

The symbols “<” and “>” surrounding the CR/LF are used to delineate the delimiter from the nearby text within the standard and are not part of the delimiter. In most present-day computer programming or application environments, the two-character combination is automatically generated when the return or “ENTER” key is pressed.

2.4.2 Comma delimiter

The comma is used as a delimiter for data entries within a sample in COMTRADE configuration (.CFG), information (.INF), and ASCII format data (.DAT) files.

2.4.3 Field lengths

Field lengths are specified for many alphabetical or numerical variables in the COMTRADE standard. These limitations were specified to simplify reading lines of data containing many variables. For integer numeric variables, the maximum field length is one character longer than required to hold the maximum value for that field. This extra character space is allowed for a leading minus for signed numbers and to allow the application of simple programming techniques that automatically print the leading space, even for unsigned numbers. The 6-character and 10-character field lengths for data, time stamps, and sample numbers used in earlier revisions of COMTRADE are retained for backward compatibility.

2.5 Floating point notation

Real numbers may be stored in several ways. Numbers of limited range can be entered as a numeric string with a decimal point. For larger or smaller numbers, any reasonable limit on string length leads to a loss of resolution. In such cases, it is desirable to store the number in a format allowing use of a representation of the significant digits (mantissa) and a multiplier (exponent) format. Spreadsheets and other mathematical programs often use floating point notation to represent such numbers. COMTRADE allows the use of floating point notation (Kreyszig [B7]) to represent real numbers for conversion factors in the .CFG file. The terms exponential notation or scientific notation are sometimes used for this form and interpretations of the form vary. Since programs designed to read COMTRADE files must be able to recognize and interpret numbers represented in this format, one single format is defined here. The numbers shall be interpreted and displayed as follows.

A signed floating point value consists of an optional sign (+ or –) and a series of decimal digits containing an optional decimal point, followed by an optional exponent field that contains the character “e” or “E” followed by an optionally signed (+ or –) integer exponent. The exponent is a factor of base 10, so 3E2 means 3 multiplied by 100 (10^2) or 300. Correct interpretation of negative numbers and negative exponents requires the inclusion of the negative sign. For positive numbers or exponents the sign is optional and is assumed if absent.

The format shall be written as:

[±]dd[.]dddd[E[±]ddd]

where

- Square brackets surround any optional item.
- “d” represents any numeral between 0 and 9.
- At least one numeral must appear in the field.
- If the decimal point appears, at least one numeral must appear to the left and right.
- The character “e” or “E” represents “exponential” with base 10.
- If the exponential sign appears, it must be followed by at least one numeral, the intervening plus/minus sign is optional if positive, but must be “+” or “–” not “±.”
- The numeric value following “E” must be an integer.

Examples:

Acceptable

1E2 (= 100)

1.23E4 (= 12 300)

0.12345E-5 (= 0.0000012345)

−1.2345E2 (= −123.45)

Unacceptable

.123 (one numeral must precede decimal)

123E (at least one numeral must follow “E”)

±0.123E±4 (plus/minus signs make the value indeterminate)

0.123 E4 (space before “E” not allowed)

2.6 Methods of accessing data in files

The two different methods used to access text and data files are random access and sequential order.

2.6.1 Random access files

Data within random access files can be retrieved or stored in any random sequence. The access time for each record is independent of the location of the data. Each data field has a specific address that can be used for reading or writing. COMTRADE does not use random access files.

2.6.2 Sequential files

Sequential files are accessed by reading or writing each data field in sequence. Individual data fields have no specific address and their position in the file is relative to the other variables. The exact byte-count position in the file is dependent on the length of the preceding variables. COMTRADE uses sequential files.

2.7 Primary to secondary ratios

The devices used to measure and record events on a high voltage system are not capable of accepting the high voltage and high currents of the power system directly. These devices are built to accept inputs in more manageable and less dangerous levels, termed secondary quantities. Voltage transformers and current transformers are used to reduce the voltage and current signals on the power system to these lower values. The transformer ratios are chosen so that when the power system is running at the rated or nominal primary value, the secondary value is at the nominal secondary value. The ratio is specified in primary-secondary order, the convention being that the primary is closest to the source of power. Primary ratings are available for all common voltages and load values on the power system. Common values for the secondary values are in the region of 70 V line-to-ground, and 1 A or 5 A. IEEE Std C57.13–1993[B6] specifies the description and rating of these transformers.

Thus, for a current transformer applied to a feeder and rated at 800:5, the secondary current will be at the nominal 5 A value only when the primary load current is 800 A. Lower values of load result in correspondingly lower values of secondary current.

For three-phase applications, voltage transformers are normally rated in phase-to-phase voltage values rather than phase-to-ground. The output of a voltage transformer rated at 345 kV:120 V will be 120 V phase-to-

phase (70 V phase-to-ground) only when the primary system phase-to-phase voltage is 345 kV. The term line-to-line is used interchangeably with phase-to-phase, and similarly line-to-ground instead of phase-to-ground.

3. COMTRADE Files

Each COMTRADE record has a set of up to four files associated with it (see Clause 2.). Each of the four files carries a different class of information. The four files are as follows:

- a) Header;
- b) Configuration;
- c) Data; and
- d) Information.

All files in the set must have the same filename, differing only by the extensions that indicate the type of files.

File names are in the form xxxxxxxx.yyy. The xxxxxxxx portion is the name used to identify the record (e.g., FAULT1 or TEST_2). The .yyy portion of the file name is used to identify the type of file and is known as the extension: .HDR for the header file, .CFG for the configuration file, .DAT for data file(s), and .INF for the information file. The file names must follow the IBM compatible DOS (MS-DOS Version 6 Operating System User's Guide [B8]) conventions for legal characters within the file names (e.g., periods and spaces are not allowed as part of the file name). The file names are limited to eight characters and extensions are limited to three characters.

3.1 Header file (xxxxxxx.HDR)

The header file is an optional ASCII text file created by the originator of the COMTRADE data, typically through the use of a word processor program. The data is intended to be printed and read by the user. The creator of the header file can include any information in any order desired. Examples of information to include are given in subclause 4.1. The header file format is ASCII.

3.2 Configuration file (xxxxxxx.CFG)

The configuration file is an ASCII text file intended to be read by a computer program and, therefore, must be saved in a specific format. The configuration file contains information needed by a computer program in order to properly interpret the data (.DAT) file. This information includes items such as sample rates, number of channels, line frequency, channel information, etc.

One field in the first line of the configuration file identifies the year of the COMTRADE standard revision with which the file complies (e.g., 1991, 1999, etc.). If this field is not present or it is empty, then the file is assumed to comply with the original issue of the standard (1991). The configuration file also contains a field that identifies whether the companion data file is stored in ASCII or binary format. Details of the exact content and format of the configuration file are given in Clause 5.

The configuration file can be created with a word processing program or by a computer program that creates the configuration file from the data that is the source of the transient record. If a word processor is used to create the configuration file, it must save the data in ASCII text file format.

3.3 Data file (xxxxxxx.DAT)

The data file contains the value for each input channel for each sample in the record. The number stored for a sample is a scaled version of the value presented to the device that sampled the input waveform. The stored data may be either zero-based or it may have a zero offset. Zero-based data spans from a negative number to a positive number (e.g., -2000 to 2000). Zero-offset numbers are all positive with a positive number chosen to represent zero (e.g., 0 to 4000 , with 2000 representing zero). Conversion factors specified in the configuration file define how to convert the data values to engineering units. The data file also contains a sequence number and time stamp for each set of samples.

In addition to data representing analog inputs, inputs that represent on/off signals are also frequently recorded. These are often referred to as digital inputs, digital channels, digital sub-channels, event inputs, logic inputs, binary inputs, contact inputs, or status inputs. In this standard, this type of input is referred to as a status input. The state of a status input is represented by a number “1” or “0” in the data file.

The data files may be in either ASCII or binary format—a field in the configuration files indicates which format is used. A detailed description of the data file format is given in Clause 6.

3.4 Information file (xxxxxxx.INF)

The information file is an optional file containing extra information that, in addition to the information required for minimum application of the data set, file originators may wish to make available to users. The format provides for public information that any user can read and use, and private information that may be accessible only to users of a particular class or manufacturer. The information file will be described in detail in Clause 7.

4. Header file

The header file is an ASCII text file for the storage of supplementary narrative information, provided for the user to better understand the conditions of the transient record. The header file is not intended to be manipulated by an applications program.

4.1 Content

Examples of information that may be included in the header file are as follows:

- a) Description of the power system prior to disturbance;
- b) Name of the station;
- c) Identification of the line, transformer, reactor, capacitor, or circuit breaker that experienced the transient;
- d) Length of the faulted line;
- e) Positive and zero-sequence resistance and reactance, capacitance;
- f) Mutual coupling between parallel lines;
- g) Locations and ratings of shunt reactors and series capacitors;
- h) Nominal voltage ratings of transformer windings, especially the potential and current transformers;
- i) Transformer power ratings and winding connections;
- j) Parameters of the system behind the nodes where the data was recorded (equivalent positive- and zero-sequence impedance of the sources);

- k) Description of how the data was obtained, whether it was obtained at a utility substation or by simulating a system condition on a computer program such as an electro-magnetic transient program (EMTP);
- l) Description of the anti-aliasing filters used;
- m) Description of analog mimic circuitry;
- n) The phase sequencing of the inputs; and
- o) Number of discs on which the record is stored.

4.2 Filenames

Header filenames shall have the .HDR extension to distinguish them from the configuration, data, and information files in the same set and to serve as a convention that is easy to remember and identify.

4.3 Format

The header file shall be a freeform ASCII text file of any length.

5. Configuration file

The configuration file is an ASCII text file that provides the information necessary for a human or a computer program to read and interpret the data values in the associated data files. The configuration file is in a predefined, standardized format so that a computer program does not have to be customized for each configuration file.

5.1 Content

The configuration file shall have the following information:

- a) Station name, identification of the recording device, and COMTRADE Standard revision year;
- b) Number and type of channels;
- c) Channel names, units, and conversion factors;
- d) Line frequency;
- e) Sample rate(s) and number of samples at each rate;
- f) Date and time of first data point;
- g) Date and time of trigger point;
- h) Data file type; and
- i) Time Stamp Multiplication Factor.

5.2 Filenames

Configuration filenames shall have the .CFG extension to distinguish them from header, data, and information files in the same set and to serve as a convention that is easy to remember and identify.

5.3 Format

The configuration file is an ASCII text file in a standardized format. It must be included with every file set to define the format of the data file.

The file is divided into lines. Each line shall be terminated by a carriage return and line feed. Commas are used to separate fields within a line. The data separator comma is required even if no data is entered into a field. Since commas, carriage returns, and line feeds are used as data separators, they are not legal characters within any field. For example, a channel name such as “Pacific West, Line number two” shall be interpreted as two separate fields. The use of data separators allows the field length to be variable so that leading or padding zeroes, or spaces are not required. However, because some programming languages reserve a leading character position for a minus sign, programs intended to read COMTRADE files shall be written to tolerate at least one leading space in fields. The information in each line of the file must be listed in the exact order shown in subclauses 5.3.1–5.3.9. The lines must appear in the exact order shown in subclause 5.5. Deviations from this format will invalidate the file set.

5.3.1 Station name, identification, and revision year

The first line of the configuration file shall contain the station name, the recording device identification, and the COMTRADE Standard revision year.

station_name,rec_dev_id,rev_year <CR/LF>

where

- station_name** is the name of the substation location. Non-critical, alphanumeric, minimum length = 0 characters, maximum length = 64 characters.
- rec_dev_id** is the identification number or name of the recording device. Non-critical, alphanumeric, minimum length = 0 characters, maximum length = 64 characters.
- rev_year** is the year of the standard revision, e.g. 1999, that identifies the COMTRADE file version. Critical, numeric, minimum length = 4 characters, maximum length = 4 characters. This field shall identify that the file structure differs from the file structure requirement in the original IEEE Std C37.111-1991 COMTRADE Standard. Absence of the field or an empty field is interpreted to mean that the file complies with the 1991 version of the standard.

5.3.2 Number and type of channels

This statement contains the number and type of channels as they occur in each data record in the data file:

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

where

- TT** is the total number of channels. Critical, numeric, integer, minimum length = 1 character, maximum length = 7 characters, minimum value = 1, maximum value = 999999, TT must equal the sum of ##A and ##D below.
- ##A** is the number of analog channels followed by identifier A. Critical, alphanumeric, minimum length = 2 characters, maximum length = 7 characters, minimum value = 0A, maximum value = 999999A.
- ##D** is the number of status channels followed by identifier D. Critical, alphanumeric, minimum length = 2 characters, maximum length = 7 characters, minimum value = 0D, maximum value = 999999D.