CHAPTER SEVEN

7. CONCLUSION

This project outlined a simple and cost effective concept of remote reading of energy meters specially, via low voltage distribution lines. Main problem in the distribution system is the difficulty of data transmission through power transformers. In addition to that different line configurations, tapings and branches of distribution system also considerably affect the data transmission.

Features of the present concept is to use a series of pulses of voltage and current for outbound and inbound signals respectively for data transmission with a polling technique. Different code arrangements for address, data, ACK and NACK are used for exchanging of messages in between the substation and the consumers. The maximum time taken to collect data from a consumer is about 10 seconds. Therefore rate of metering is considerably higher than the traditional metering method.

A number of steps were taken to show the feasibility of pulse transmission over the distribution lines and transformers. One of the feeders from Ratmalana grid substation and its distribution parts were selected for this study. A simplified power distribution system was developed to prepare a prototype power distribution model in the laboratory for experimental works. It was also applied to a computer simulation to observe the pulse transmission and detection. A series of measurements were made on the selected feeder to analyze the existing disturbances on voltage and current.

Under ideal and steady-state conditions, the computer simulation clearly showed that the injected pulses at one end can be transferred through transformers (here two transformers) and detected at the other end by selecting suitable band pass filters. After analyzing the existing disturbances on current and voltages at the substation it showed that the feeder is free from disturbances during nighttime rather than daytime.

Therefore signal transmission is desirable during midnight period and detection can be done at frequencies above 2kHz. Pulses of below 100 micro second pulse widths is suitable for pulse transmission. Below 750Amp current and below 400V pulse heights can be used without disturbing the system. But the detection frequency band, pulse width and pulse height may slightly change from feeder to feeder and also day to day according to the connected loads.

The Total Harmonic Distortion was calculated by considering measured data of current and voltage waves. It is about 4.76% in current wave and 1.2% – 1.6% in voltage wave. According to the IEEE-519 recommended standards, Total Harmonic Distortion for current and voltage must be less than 8% and 5% respectively. Therefore data transmission for meter reading is possible by applying voltage and current pulses as outbound and inbound signals without disturbing the power system.

A computer system is used at the substation for collecting data and processing billing and other purposes. At the consumer end, microcontroller and other required components are equipped with battery backup. As the microcontroller is equipped with non-volatile memory that can retain its contents a sudden disruption to the supply power would not cause any unrecoverable losses to data.

Suitable pulse injection equipment must be designed at the substation. The pulse detection methods must be improved further in order to reduce the magnitude of injected pulses.

APPENDIX A

Recommendation T.50 [1]

INTERNATIONAL ALPHABET No. 5

(former Recommendation V.3, Mar del Plata, 1968;
amended at Geneva, 1972 and Malaga-Torremolinos, 1984)

Introduction

A seven-unit alphabet capable of meeting the requirements of private users on leased circuits and of users of data transmission by means of connections set up by switching on the general telephone network or on telegraph networks has been established jointly by the CCITT and the International Organization for Standardization (ISO).

This alphabet – International Alphabet No. 5 (IA5) – is not intended to replace International Telegraph Alphabet No. 2 (ITA2). It is a supplementary alphabet for the use of those who might not be satisfied with the more limited possibilities of International Telegraph Alphabet No. 2. In such cases it is considered as the alphabet to be used as common basic language for data transmission and for elaborated message systems.

International Alphabet No. 5 does not exclude the use of any other alphabet that might be better adapted to special needs.

1 Scope and field of application

1.1 This Recommendation specifies a set of 128 characters (control characters and graphic characters such as letters, digits and symbols) with their coded representation. Most of these characters are mandatory and unchangeable, but provision is made for some flexibility to accommodate national and other requirements.

1.2 This Recommendation specifies a 7-bit coded character set with a number of options. It also provides guidance on how to exercise the options to define specific national versions and application-orientated versions. Furthermore it specifies the International Reference Version (IRV) in which such options have been exercised.

1.3 This character set is primarily intended for the interchange of information among data processing systems and associated equipment, and within data communication systems. The need for graphic characters and control functions in data processing has also been taken into account in determining this character set.

1.4 This character set is applicable to all alphabets of Latin letters.

1.5 This character set includes control characters for code extension where its 128 characters are insufficient for particular applications. Procedures for the use of these control characters are specified in ISO Standard 2022.

1.6 The definitions of some control characters in this Recommendation assume that data associated with them are to be processed serially in a forward direction. When they are included in strings of data which are processed other than serially in a forward direction or when they are included in data formatted for fixed-record processing they may have undesirable effects or may require additional special treatment to ensure that they result in their desired function.

2 Conformance and implementation

2.1 *Conformance*

A coded character set is in conformance with this Recommendation if it is a version in accordance with § 6: Equipment claimed to implement this Recommendation shall be able to interchange information by means of a version of the 7-bit coded character set, this version shall be identified in any such claim.

[1] This Recommendation corresponds to International Standard ISO 646 (1983).

2.2 *Implementation*

The use of this character set requires definitions of its implementation in various media. For example, these could include punched tapes, punched cards, magnetic media and transmission channels, thus permitting interchange of data to take place either indirectly by means of an intermediate recording in a physical medium, or by local connection of various units (such as input and output devices and computers) or by means of data transmission equipment.

The implementation of this coded character set in physical media and for transmission, taking into account the need for error checking, is the subject of ISO publications.

3 Definitions

For the purpose of this Recommendation the following definitions apply.

3.1 bit combination

An ordered set of bits used for the representation of characters.

3.2 character

A member of a set of elements used for the organization, control or representation of data.

3.3 coded character set; code

A set of unambiguous rules that establishes a character set and the one-to-one relationship between the characters of the set and their bit combinations.

3.4 code extension

The techniques for the encoding of characters that are not included in the character set of a given code.

3.5 code table

A table showing the character allocated to each bit combination in a code.

3.6 control character

A control function the coded representation of which consists of a single bit combination.

3.7 control function

An action that affects the recording, processing, transmission or interpretation of data and that has a coded representation consisting of one or more bit combinations.

3.8 graphic character

A character, other than a control function, that has a visual representation normally handwritten, printed or displayed.

3.9 position

That part of a code table identified by its column and row co-ordinates.

4 Specification of the coded character set

The bits of the bit combinations of the 7-bit code are identified by b_7, b_6, b_5, b_4, b_3, b_2 and b_1, where b_7 is the highest-order, or most-significant, bit and b_1 is the lowest-order, or least-significant, bit.

The bit combinations may be interpreted to represent integers in the range 0 to 127 in binary notation by attributing the following weights to the individual bits:

Bit:	b_7	b_6	b_5	b_4	b_3	b_2	b_1
Weight:	64	32	16	8	4	2	1

In this Recommendation, the bit combinations are identified by notation of the form x/y, where x is a number in the range 0 to 7 and y is a number in the range 0 to 15. The correspondence between the notations of the form x/y and the bit combinations consisting of the bits b_7 to b_1 is as follows:

- x is the number represented by b_7, b_6 and b_5 where these bits are given the weights 4, 2 and 1 respectively;
- y is the number represented by b_4, b_3, b_2 and b_1 where these bits are given the weights 8, 4, 2 and 1 respectively.

The notations of the form x/y are the same as those used to identify code table positions, where x is the column number and y the row number (see § 7).

The 128 bit combinations of the 7-bit code represent control characters and graphic characters. The allocation of characters to bit combinations is based on the following principles:

- the bit combinations 0/0 to 1/15 represent 32 control characters;
- the bit combination 2/0 represents the character SPACE, which is interpreted both as a control character and as a graphic character;
- the bit combinations 2/1 to 7/14 represent up to 94 graphic characters as one or more of these bit combinations may be declared to be unused (see § 4.3);
- the bit combination 7/15 represents the control character DELETE.

The allocation of individual characters to the bit combinations of the 7-bit code is specified in §§ 4.1, 4.2 and 4.3 below.

This Recommendation assigns at least one name to each character. In addition, it specifies an acronym for each control character and for the character SPACE, and a graphic symbol for each graphic character. By convention, only capital letters and hyphens are used for writing the names of the characters, except for small letters. For acronyms only capital letters and digits are used. It is intended that the acronyms and this convention be retained in all translations of the text.

The names chosen to denote graphic characters are intended to reflect their customary meaning. However, this Recommendation does not define and does not restrict the meanings of graphic characters. Neither does it specify a particular style or font design for the graphic characters when imaged.

4.1 *Control characters*

The control characters of the 7-bit coded character set are classified in the following categories:

a) *Transmission control characters*

Transmission control characters are intended to control or facilitate transmission of information over telecommunication networks. Procedures for the use of the transmission control characters on telecommunication networks are the subject of other ISO publications.

b) *Format effectors*

Format effectors are mainly intended for the control of the layout and positioning of information on character-imaging devices such as printing and display devices.

c) *Code extension control characters*

Code extension control characters are used to extend the character set of the code. They may alter the meaning of one or more bit combinations that follow them in the data stream. Procedures for the use of the code extension control characters are specified in ISO Standard 2022.

d) *Device control characters*

Device control characters are intended for the control of local or remote devices or ancillary devices connected to a data processing or data communication system. These control characters are not intended to control data communication systems; this should be achieved by the use of transmission control characters.

e) *Information separators*

Information separators are used to separate and qualify data logically. There are four such characters. They may be used either in hierarchical order or non-hierarchically; in the latter case, their specific meanings depend on the application.

f) *Other control characters*

These are the control characters that fall outside the preceding categories.

The composition of each category, and the allocation of the individual control characters in each category to bit combinations of the 7-bit code are specified in §§ 4.1.1 to 4.1.6. Each of these sub-clauses contains a table consisting of three columns. The first column specifies the acronym of each control character, the second column specifies the standard name of the control character and the third column, labelled "Coded representation", specifies the bit combination representing the control character concerned.

Detailed functional descriptions of all control characters are given in § 8.

4.1.1 *Transmission control characters*

The transmission control characters and their coded representations are specified in Table 1/T.50.

TABLE 1/T.50

Transmission control characters – coded representation

Acronym	Name	Coded representation
SOH	Start of heading	0/1
STX	Start of text	0/2
ETX	End of text	0/3
EOT	End of transmission	0/4
ENQ	Enquiry	0/5
ACK	Acknowledge	0/6
DLE	Data link escape	1/0
NAK	Negative acknowledge	1/5
SYN	Synchronous idle	1/6
ETB	End of transmission block	1/7

4.1.2 *Format effectors*

The format effectors and their coded representations are specified in Table 2/T.50.

TABLE 2/T.50

Format effectors – coded representation

Acronym	Name	Coded representation
BS	Backspace	0/8
HT	Horizontal tabulation	0/9
LF	Line feed	0/10
VT	Vertical tabulation	0/11
FF	Form feed	0/12
CR	Carriage return	0/13

TABLE 6/T.50

Other control characters – coded representation

Acronym	Name	Coded representation
NUL	Null	0/0
BEL	Bell	0/7
CAN	Cancel	1/8
EM	End of medium	1/9
SUB	Substitute character	1/10
DEL	Delete	7/15

4.2 *Character SPACE*

The acronym of the character SPACE is SP and its coded representation is 2/0. This character is interpreted both as a graphic character and as a control character. As a graphic character, it has a visual representation consisting of the absence of a graphic symbol. As a control character, it acts as a format effector that causes the active position to be advanced one character position.

4.3 *Graphic characters*

The 94 bit combinations 2/1 to 7/14 are used for the representation of graphic characters as specified in §§ 4.3.1, 4.3.2 and 4.3.3 below. Each of the §§ 4.3.1 and 4.3.2 contains a table consisting of three columns. The first column is labelled "Graphic" and specifies the graphic symbol of each graphic character, the second column specifies the standard name of the graphic character and the third column, labelled "Coded representation", specifies the bit combination representing the graphic character concerned.

All graphic characters of any version of the 7-bit coded character set are spacing characters, i.e. they cause the active position to advance.

4.3.1 *Unique graphic character allocations*

A unique graphic character is allocated to each of the 82 bit combinations 2/1, 2/2, 2/5 to 3/15, 4/1 to 5/10, 5/15 and 6/1 to 7/10. These characters are specified in Table 7/T.50.

4.3.2 *Alternative graphic character allocations*

Two alternative graphic characters are allocated to each of the bit combinations 2/3 and 2/4. These characters are specified in Table 8/T.50.

Either the character POUND SIGN or the character NUMBER SIGN shall be allocated to bit combination 2/3 and either the character DOLLAR SIGN or the character CURRENCY SIGN shall be allocated to bit combination 2/4 (see § 6).

Unless otherwise agreed between sender and recipient, the graphic symbols £, $ and ¤ do not designate the currency of a specific country.

4.3.3 *National or application-oriented graphic character allocations*

No specific graphic character is allocated to the ten bit combinations 4/0, 5/11 to 5/14, 6/0, and 7/11 to 7/14. These bit combinations are available for national or application-orientated use. A unique graphic character shall be allocated to each of these bit combinations, or the bit combination shall be declared unused (see § 6).

5 Composite graphic characters

In any version of the 7-bit coded character set specified according to this Recommendation, all graphic characters are spacing characters which cause the active position to move forward. However, by using BACKSPACE or CARRIAGE RETURN, it is possible to image two or more graphic characters at the same character position.

For example, SOLIDUS and EQUALS SIGN can be combined to image "not equals". The character LOW LINE, that may be used as a free-standing character, can also be associated with other character(s) to represent the graphic rendition "underlined".

Diacritical marks may be allocated to the bit combinations specified in § 4.3.3 and be available for composing accented letters. For such composition, it is recommended to use a sequence of three characters, the first or last of which is the letter to be accented and the second of which is BACKSPACE. Furthermore, QUOTATION MARK, APOSTROPHE or COMMA can be associated with a letter by means of BACKSPACE for the composition of an accented letter with a diaeresis, an acute accent or a cedilla, respectively.

6 Versions of the coded character set

6.1 *General*

In order to use the 7-bit coded character set for information interchange, it is necessary to exercise the options left open in § 4:

- to each of the bit combinations 2/3 and 2/4 one of the alternative graphic characters specified in § 4.3.2 shall be allocated;
- each of the bit combinations 4/0, 5/11 to 5/14, 6/0, and 7/11 to 7/14 shall have a unique graphic character allocated to it, or be declared unused;
- the format effectors, if any, to which the facility of § 4.1.2.2 applies, shall be identified.

A graphic character allocated to a bit combination specified in §§ 4.3.1 and 4.3.2 shall not be allocated to any other bit combination. For example the POUND SIGN, if not allocated to bit combination 2/3, shall not be allocated to any other bit combination.

A character set completed in this way is called a "version of ISO Standard 646/CCITT T.50" (see Appendix I).

6.2 *National versions*

6.2.1 The responsibility for defining national versions lies with the national standardization bodies. These bodies shall exercise the options available and make the required selection (see Appendix I).

6.2.2 If so required, more than one national version can be defined within a country. The different versions shall be separately identified. In particular when for a given bit combination, for example 5/12, alternative graphic characters are required, two different versions shall be identified, even if they differ only by this single character.

6.2.3 If there is in a country no special demand for specific graphic characters, it is strongly recommended that the characters of the International Reference Version (IRV) (see § 6.4) be selected and allocated to the same bit combinations as in the IRV.

However, when graphic characters that are different from the characters of the IRV are required, they shall have distinct forms and be given distinctive names which are not in conflict with any of the forms or the names of any of the graphic characters in the IRV.

6.3 *Application-orientated versions*

Within national or international industries, organizations or professional groups, application-orientated versions can be used. They require precise agreement among the interested parties, who will have to exercise the options available and to make the required selection.

6.4 *International Reference Version (IRV)*

This version is available for use when there is no requirement to use a national or an application-orientated version. In information interchange, the IRV is assumed unless a particular agreement exists between sender and recipient of the data. The graphic characters allocated to the IRV are specified in Table 9/T.50.

TABLE 9/T.50

IRV graphic character allocations

Graphic	Name	Coded representation
#	Number sign	2/3
¤	Currency sign	2/4
@	Commercial at	4/0
[	Left square bracket	5/11
\	Reverse solidus	5/12
]	Right square bracket	5/13
^	Circumflex accent	5/14
`	Grave accent	6/0
{	Left curly bracket	7/11
|	Vertical line	7/12
}	Right curly bracket	7/13
~	Tilde, overline	7/14

It should be noted that no substitution is allowed when using the IRV and that the facility of § 4.1.2.2 does not apply to any format effector.

According to § 5 it is permitted to use composite graphic characters and there is no limit to their number. Because of this freedom, their processing and imaging may cause difficulties at the receiving end. Therefore agreement between sender and recipient of the data is recommended if composite characters are used.

7 Code tables

A 7-bit code table consists of 128 positions arranged in 8 columns and 16 rows. The columns are numbered 0 to 7, and the rows are numbered 0 to 15.

The code table positions are identified by notations of the form x/y, where x is the column number and y is the row number.

The 128 positions of the code table are in one-to-one correspondence with the bit combinations of the 7-bit code. The notation of a code table position, of the form x/y, is the same as that of the corresponding bit combination (see § 4).

Each code table position contains a symbol and/or a reference to a clause of this Recommendation. When a code table position corresponds to a bit combination that represents a control character or the character SPACE, the symbol is the acronym of the character allocated; otherwise it is the graphic symbol representing the character allocated, if any. A reference to §§ 4.1.2.2, 4.3.2 or 4.3.3 is denoted by ①, ② or ③ respectively.

Table 10/T.50 is the basic 7-bit code table. It shows the 7-bit coded character set specified in § 4 and indicates the options related to format effectors (§ 4.1.2.2), alternative graphic characters (§ 4.3.2) and national or application-orientated use (§ 4.3.3).

Table 11/T.50 is the code table for the IRV of the 7-bit coded character set. It shows the result of exercising the three identified options in the manner specified in § 6.4.

8 Description of the control characters

The control characters are listed below in the alphabetical order of their acronyms.

8.1 *ACK Acknowledge*

A transmission control character transmitted by a receiver as an affirmative response to the sender.

8.2 *BEL Bell*

A control character that is used when there is a need to call for attention; it may control alarm or attention devices.

8.3 *BS Backspace*

A format effector which causes the active position to move one character position backwards.

8.4 *CAN Cancel*

A character, or the first character of a sequence, indicating that the data preceding it is in error. As a result, this data shall be ignored. The specific meaning of this character shall be defined for each application and/or between sender and recipient.

8.5 *CR Carriage Return*

A format effector which causes the active position to move to the first character position on the same line.

8.6 *DC1 Device Control One*

A device control character which is primarily intended for turning on or starting an ancillary device. If it is not required for this purpose, it may be used to restore a device to the basic mode of operation (see also DC2 and DC3), or for any other device control function not provided by other DCs.

8.7 *DC2 Device Control Two*

A device control character which is primarily intended for turning on or starting an ancillary device. If it is not required for this purpose, it may be used to set a device to a special mode of operation (in which case DC1 is used to restore the device to the basic mode), or for any other device control function not provided by other DCs.

8.8 *DC3 Device Control Three*

A device control character which is primarily intended for turning off or stopping an ancillary device. This function may be a secondary level stop, for example wait, pause, stand-by or halt (in which case DC1 is used to restore normal operation). If it is not required for this purpose, it may be used for any other ancillary device control function not provided by other DCs.

8.9 *DC4 Device Control Four*

A device control character which is primarily intended for turning off, stopping or interrupting an ancillary device. If it is not required for this purpose, it may be used for any other device control function not provided by other DCs.

8.10 *DEL Delete*

A character used primarily to erase or obliterate an erroneous or unwanted character in punched tape. DEL characters may also serve to accomplish media-fill or time-fill. They may be inserted into, or removed from, a stream of data without affecting the information content of that stream, but such action may affect the information layout and/or the control of equipment.

8.11 *DLE Data Link Escape*

A transmission control character which will change the meaning of a limited number of contiguously following bit combinations. It is used exclusively to provide supplementary transmission control functions. Only graphic characters and transmission control characters can be used in DLE sequences.

8.12 *EM End of Medium*

A control character that may be used to identify the physical end of a medium, or the end of the used portion of a medium, or the end of the wanted portion of data recorded on a medium. The position of this character does not necessarily correspond to the physical end of the medium.

8.13 *ENQ Enquiry*

A transmission control character used as a request for a response from a remote station – the response may include station identification and/or station status. When a "Who are you" function is required on the general switched transmission network, the first use of ENQ after the connection is established shall have the meaning "Who are you" (station identification). Subsequent use of ENQ may, or may not, include the function "Who are you", as determined by agreement.

8.14 *EOT End Of Transmission*

A transmission control character used to indicate the conclusion of the transmission of one or more texts.

8.15 *ESC Escape*

A control character which is used to provide additional characters. It alters the meaning of a limited number of contiguously following bit combinations. The use of this character is specified in ISO Standard 2022.

8.16 *ETB End of Transmission Block*

A transmission control character used to indicate the end of a transmission block of data where data is divided into such blocks for transmission purposes.

8.17 *ETX End of Text*

A transmission control character which terminates a text.

8.18 *FF Form Feed*

A format effector which causes the active position to advance to the corresponding character position on a pre-determined line of the next form or page.

8.19 *HT Horizontal Tabulation*

A format effector which causes the active position to advance to the next pre-determined character position.

8.20 *IS1 (US) Information Separator One (Unit Separator)*

A control character used to separate and qualify data logically; its specific meaning has to be defined for each application. If this character is used in hierarchical order as specified in the general definition of IS, it delimits a data item called a unit.

8.21 *IS2 (RS) Information Separator Two (Record Separator)*

A control character used to separate and qualify data logically; its specific meaning has to be defined for each application. If this character is used in hierarchical order as specified in the general definition of IS, it delimits a data item called a record.

8.22 *IS3 (GS) Information Separator Three (Group Separator)*

A control character used to separate and qualify data logically; its specific meaning has to be defined for each application. If this character is used in hierarchical order as specified in the general definition of IS, it delimits a data item called a group.

8.23 *IS4 (FS) Information Separator Four (File Separator)*

A control character used to separate and qualify data logically; its specific meaning has to be defined for each application. If this character is used in hierarchical order as specified in the general definition of IS, it delimits a data item called a file.

8.24 *LF Line Feed*

A format effector which causes the active position to advance to the corresponding character position of the next line.

8.25 *NAK Negative Acknowledge*

A transmission control character transmitted by a receiver as a negative response to the sender.

8.26 *NUL Null*

A control character used to accomplish media-fill or time-fill. NUL characters may be inserted into, or removed from, a stream of data without affecting the information content of that stream, but such action may affect the information layout and/or the control of equipment.

8.27 *SI Shift-In*

A control character which is used in conjunction with SO and ESC to extend the graphic character set of the code. It may reinstate the standard meanings of the bit combinations which follow it. The effect of this character when using code extension techniques is described in ISO Standard 2022.

8.28 *SO Shift-Out*

A control character which is used in conjunction with SI and ESC to extend the graphic character set of the code. It may alter the meaning of the bit combinations 2/1 to 7/14 which follow it until a SI character is reached. The effect of this character when using code extension techniques is described in ISO 2022.

8.29 *SOH Start Of Heading*

A transmission control character used as the first character of a heading of an information message.

8.30 *STX Start of Text*

A transmission control character which precedes a text and which is used to terminate a heading.

8.31 *SUB Substitute character*

A control character used in the place of a character that has been found to be invalid or in error. SUB is intended to be introduced by automatic means.

8.32 *SYN Synchronous idle*

A transmission control character used by a synchronous transmission system in the absence of any other character (idle condition) to provide a signal from which synchronism may be achieved or retained between data terminal equipment.

8.33 *VT Vertical Tabulation*

A format effector which causes the active position to advance to the corresponding character position on the next pre-determined line.

TABLE 7/T.50

Unique graphic character allocations

Graphic	Name	Coded representation
!	Exclamation mark	2/1
"	Quotation mark	2/2
%	Percent sign	2/5
&	Ampersand	2/6
'	Apostrophe	2/7
(	Left parenthesis	2/8
)	Right parenthesis	2/9
*	Asterisk	2/10
+	Plus sign	2/11
,	Comma	2/12
–	Hyphen, minus sign	2/13
.	Full stop	2/14
/	Solidus	2/15
0	Digit zero	3/0
1	Digit one	3/1
2	Digit two	3/2
3	Digit three	3/3
4	Digit four	3/4
5	Digit five	3/5
6	Digit six	3/6
7	Digit seven	3/7
8	Digit eight	3/8
9	Digit nine	3/9
:	Colon	3/10
;	Semicolon	3/11
<	Less-than sign	3/12
=	Equals sign	3/13
>	Greater-than sign	3/14
?	Question mark	3/15
A	Capital letter A	4/1
B	Capital letter B	4/2
C	Capital letter C	4/3
D	Capital letter D	4/4
E	Capital letter E	4/5
F	Capital letter F	4/6
G	Capital letter G	4/7
H	Capital letter H	4/8
I	Capital letter I	4/9
J	Capital letter J	4/10
K	Capital letter K	4/11
L	Capital letter L	4/12
M	Capital letter M	4/13
N	Capital letter N	4/14
O	Capital letter O	4/15
P	Capital letter P	5/0
Q	Capital letter Q	5/1
R	Capital letter R	5/2
S	Capital letter S	5/3
T	Capital letter T	5/4
U	Capital letter U	5/5
V	Capital letter V	5/6
W	Capital letter W	5/7
X	Capital letter X	5/8
Y	Capital letter Y	5/9
Z	Capital letter Z	5/10
_	Low line, underline	5/15
a	Small letter a	6/1
b	Small letter b	6/2
c	Small letter c	6/3
d	Small letter d	6/4
e	Small letter e	6/5
f	Small letter f	6/6
g	Small letter g	6/7
h	Small letter h	6/8
i	Small letter i	6/9
j	Small letter j	6/10
k	Small letter k	6/11
l	Small letter l	6/12
m	Small letter m	6/13
n	Small letter n	6/14
o	Small letter o	6/15
p	Small letter p	7/0
q	Small letter q	7/1
r	Small letter r	7/2
s	Small letter s	7/3
t	Small letter t	7/4
u	Small letter u	7/5
v	Small letter v	7/6
w	Small letter w	7/7
x	Small letter x	7/8
y	Small letter y	7/9
z	Small letter z	7/10

TABLE 8/T.50

Alternative graphic character allocations

Graphic	Name	Coded representation
£	Pound sign	2/3
#	Number sign	2/3
$	Dollar sign	2/4
¤	Currency sign	2/4

TABLE 10/T.50

Basic 7-bit code table

b_7	0	0	0	0	1	1	1	1
b_6	0	0	1	1	0	0	1	1
b_5	0	1	0	1	0	1	0	1
b_4 b_3 b_2 b_1	0	1	2	3	4	5	6	7
0 0 0 0	0	NUL	DLE	SP	0	③	P	③	p
0 0 0 1	1	SOH	DC1	!	1	A	Q	a	q
0 0 1 0	2	STX	DC2	"	2	B	R	b	r
0 0 1 1	3	ETX	DC3	#/£ ②	3	C	S	c	s
0 1 0 0	4	EOT	DC4	¤/$ ②	4	D	T	d	t
0 1 0 1	5	ENQ	NAK	%	5	E	U	e	u
0 1 1 0	6	ACK	SYN	&	6	F	V	f	v
0 1 1 1	7	BEL	ETB	'	7	G	W	g	w
1 0 0 0	8	BS	CAN	(	8	H	X	h	x
1 0 0 1	9	HT	EM	)	9	I	Y	i	y
1 0 1 0	10	LF ①	SUB	*	:	J	Z	j	z
1 0 1 1	11	VT ①	ESC	+	;	K	③	k	③
1 1 0 0	12	FF ①	IS4	,	<	L	③	l	③
1 1 0 1	13	CR ①	IS3	-	=	M	③	m	③
1 1 1 0	14	SO	IS2	.	>	N	③	n	③
1 1 1 1	15	SI	IS1	/	?	O	_	o	DEL

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① See § 4.1.2.2.

② See § 4.3.2.

③ See §§ 4.3.3 and 6.2.3.

TABLE 11/T.50

International Reference Version (IRV)

b_4	b_3	b_2	b_1		0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	DLE	SP	0	@	P	`	p
0	0	0	1	1	SOH	DC1	!	1	A	Q	a	q
0	0	1	0	2	STX	DC2	"	2	B	R	b	r
0	0	1	1	3	ETX	DC3	#	3	C	S	c	s
0	1	0	0	4	EOT	DC4	¤	4	D	T	d	t
0	1	0	1	5	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	6	ACK	SYN	&	6	F	V	f	v
0	1	1	1	7	BEL	ETB	'	7	G	W	g	w
1	0	0	0	8	BS	CAN	(	8	H	X	h	x
1	0	0	1	9	HT	EM	)	9	I	Y	i	y
1	0	1	0	10	LF	SUB	*	:	J	Z	j	z
1	0	1	1	11	VT	ESC	+	;	K	[	k	{
1	1	0	0	12	FF	IS4	,	<	L	\	l	|
1	1	0	1	13	CR	IS3	-	=	M	]	m	}
1	1	1	0	14	SO	IS2	.	>	N	^	n	~
1	1	1	1	15	SI	IS1	/	?	O	_	o	DEL

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APPENDIX B

IEEE 519

American standards regarding harmonics have been laid out by the IEEE in the 519 Standard: IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems. There is a combined effect of all nonlinear loads on utility systems that have a limited capability to absorb harmonic current. Further, utilities are charged with the responsibility to provide a high quality supply in terms of voltage level and waveform. IEEE 519 recognizes not only the absolute level of harmonics produced by an individual source but also their size relative to the supply network.

It should be noted that IEEE 519 is limited to being a collection of Recommended Practices that serve as a guide to both suppliers and consumers of electrical energy. Where problems exist, because of excessive harmonic current injection or excessive voltage distortion, it is incumbent upon supplier and consumer to resolve the issues within a mutually acceptable framework.

The purpose of IEEE 519 is to recommend limits on harmonic distortion according to two distinct criteria, namely:
There is a limitation on the amount of harmonic current that a consumer can inject into a utility network.
A limitation is placed on the level of harmonic voltage that a utility can supply to a consumer.

Guidelines for Individual Customers

The primary limit on individual customers is the amount of harmonic current that they can inject into the utility network. The current limits are based upon the size of the consumer relative to the size of the supply. Larger customers are restricted more than smaller customers. The relative size of the load with respect to the source is defined as the short circuit ratio (SCR), at the point of common coupling (PCC), which is where the consumer's load connects to other loads in the power system. The consumer's size is defined by the total fundamental frequency current in the load, IL, which includes all linear and nonlinear loads. The size of the supply system is defined by the level of short-circuit current, ISC, at the PCC.
These two currents define the SCR:

A high ratio means that the load is relatively small and that current limits will not be as strict as limits that pertain to a low ratio. This is demonstrated in 1, which lists recommended, maximum current distortion levels as a function of SCR and harmonic order. The table also identifies total harmonic distortion levels. All of the current distortion values are given in terms relative to the maximum demand load current. The total distortion is in terms of total demand distortion (TDD) instead of the more common THD term.

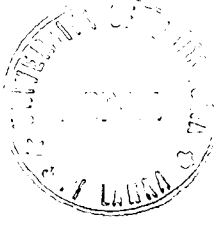

Table 1 shows current limits for individual harmonic components as well as total harmonic distortion.

For example a consumer with an SCR between 50 and 100 has a recommended limit of 12.0% for TDD, while for individual odd harmonic components with orders less than 11, the limit on each is 10%. It is important to note that the individual harmonic current components do not add up directly so that all characteristic harmonics cannot be at their individual maximum limit without exceeding the TDD.

Table 1. IEEE 519 Current Distortion Limits.

For conditions lasting more than one hour. Shorter periods increase limit by 50%)

Harmonic Current Limits for Non-Linear Load at the Point-of-Common-Coupling with Other Loads, for voltages 120 - 69,000 volts

Maximum Odd Harmonic Current Distortion in % of Fundamental Harmonic Order

ISC/IL	<11	11<=h<17	17<=h<23	23<=h<35	35<=h	TDD
<20*	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

Even harmonics are limited to 25% of the odd harmonic limits above.

*All power generation equipment is limited to these values of current distortion, regardless of actual ISC/IL.
Where ISC = Maximum short circuit current at point-of-common-coupling.

And IL = Maximum demand load current (fundamental frequency) at point of common coupling.

TDD = Total demand distortion (RSS) in % of maximum demand

It is important to note that Table 1 shows limits for odd harmonics only. IEEE 519 addresses even harmonics by limiting them to 25% of the limits for the odd orders within the same range. Even harmonics result in an asymmetrical current wave (dissimilar positive and negative waveshapes) which may contain a dc component that will saturate magnetic cores.

For power generation equipment, IEEE 519 does not recognize relative size. The limits are more strict in that the harmonic injections are limited to the lowest levels shown in the table.

Guidelines for Utilities

The second set of criteria established by IEEE 519 is for voltage distortion limits. This governs the amount of voltage distortion that is acceptable in the utility supply voltage at the PCC with a consumer. The harmonic voltage limits recommended are based on levels that are low enough to ensure that consumers' equipment will operate satisfactorily. Table 3 lists the harmonic voltage distortion limits from IEEE 519.

Table 3. Voltage Distortion Limits from IEEE 519

(For conditions lasting more than one hour. Shorter periods increase limit by 50%)

Bus Voltage at Point of VoltageDistortion Common Coupling	Individual Voltage Distortion (%)	Total THD (%)
Below 69 kV	3.0	5.0
69 kV to 137.9 kV	1.5	2.5
138 kV and above	1.0	1.5

Note: High Voltage systems can have up to 2.0% THD where the cause is a High Voltage DC terminal which will attenuate by the time it is tapped for a user.

As for current, limits are imposed on individual components and on total distortion from all harmonic voltages combined (THD). What is different in this table, however, is that three different limits are shown. They represent three voltage classes, up to 69 kV, 69 to 161 kV, and equal to or greater than 161 kV. Note that the limits decrease as voltage increases, the same as for current limits.

Again only odd harmonic limits are shown in the table. The generation of even harmonics is more restricted since the resulting dc offset can cause saturation in motors and transformers. Negative sequence current can cause heating in generators. Individual even harmonic voltage is limited to 25% of the odd harmonic limits, the same limit as currents.

Often utility feeders supply more than one consumer. The voltage distortion limits shown in the table should not be exceeded as long as all consumers conform to the current injection limits. Any consumer who degrades the voltage at the PCC should take steps to correct the problem. However, the problem of voltage distortion is one for the entire community of consumers and the utility. Very large consumers may look for a compromise with the utility over resolution of a specific problem, and both may contribute to its solution.

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