

Performance and testing of teleprotection equipment of power systems —

Part 1: Specification for narrow-band
command systems —

(Implementation of
CENELEC HD 543.1 S1)

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- BEAMA Ltd.
- EEA (the Association of Electronics, Telecommunications and Business Equipment Industries)
- Electricity Supply Industry in United Kingdom
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- North of Scotland Hydro-Electric Board
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Foreword

This Part of BS 7494 has been prepared under the direction of the Power Electrical Engineering Standards Policy Committee. It is based on IEC 834-1:1988 “*Performance and testing of teleprotection equipment of power systems*” Part 1 “*Narrow-band command systems*” published by the International Electrotechnical Commission (IEC), which has been endorsed by CENELEC as HD 543.1 S1.

For the sake of clarity, the CENELEC common modifications have been incorporated at the appropriate places in the IEC text and are marked by a vertical line at the left-hand margin. The foreword of IEC 834-1:1988 and the deleted parts of the original IEC text have been quoted in Appendix Z.

IEC Publication 834 is divided into two Parts. Part 2 “*Analogue systems*” (IEC Publication 834-2) is under consideration by IEC and may be published as Part 2 to this British Standard.

Cross-references

International Standard	Corresponding British Standard
IEC 50 (151):1978	BS 4727 <i>Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour terms</i> Part 1:Group 02:1980 <i>Electrical and magnetic devices terminology</i> (Technically equivalent)
IEC 255-5:1977	BS 5992 <i>Electrical relays</i> Part 3:1983 <i>Specification for the insulation testing of electrical relays</i> (Identical)

The Technical Committee has reviewed the provisions of IEC 50(448):1987, IEC 255-4:1976, and IEC 495:1974, to which reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard. There are no equivalent British Standards.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 32, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1 Scope

This standard applies to narrow-band single-signal and multi-signal equipment for teleprotection.

It also applies to voice frequency equipment which is used in connection with various telecommunication systems, such as power line carrier (PLC), radio link, rented circuits, leased or owned cables.

Narrow-band systems include audio frequency systems operating within a 4 kHz maximum band, and PLC channels within a maximum of 4 kHz bandwidth (for one direction of transmission).

2 Object

The object of this standard is to establish performance requirements and recommended methods for testing channels used for transmitting signals related to the command information required by the protective devices in power systems, and to give the associated terminology.

Both the power supply belonging to the equipment and the performance of the teleprotection equipment shall be tested. All the tests should be considered as type tests (see IEC Publication 50(151), International Electrotechnical Vocabulary (IEV), Chapter 151):

Type test (151-04-15)

A test of one or more devices made to a certain design to show that the design meets certain specifications.

3 Service conditions

3.1 Ambient conditions

The stated performance requirements shall be satisfied for the following conditions:

- Temperature range $-5\text{ }^{\circ}\text{C}$ to $+40\text{ }^{\circ}\text{C}$
- Maximum rate of change $10\text{ }^{\circ}\text{C/h}$
- Relative humidity 5 % to 95 %
- Maximum water content 28 g/m^3

3.2 Supply voltage with battery operation

The stated performance requirements shall be satisfied for the following conditions:

- Voltage tolerances $+15\text{ }%$ to $-20\text{ }%$

NOTE The variation figures quoted are typical for lead-acid batteries, the nominal voltage being taken as 2.1 V per cell.

3.3 Supply voltage with a.c. mains operation

The stated performance requirements shall be satisfied for the following conditions:

- Voltage tolerance $+10\text{ }%$ to $-15\text{ }%$
- Frequency tolerance $\pm 5\text{ }%$
- Harmonic content $< 10\text{ }%$

3.4 Storage conditions

The equipment, during shipment or storage, shall not suffer any damage when the ambient temperature lies between $-40\text{ }^{\circ}\text{C}$ and $+70\text{ }^{\circ}\text{C}$ unless otherwise agreed upon between user and manufacturer.

4 Telecommunication circuit used

Figure 1 shows the configuration of teleprotection equipment working at an audio frequency band (using part of a 4 kHz baseband). The signals are conveyed from the transmitter to the receiver via a telecommunication circuit.

The telecommunication circuit can be:

- a) cable link for audio frequency transmission;
- b) carrier frequency links for cables and overhead lines;

- c) carrier frequency links on aerial cables on power lines;
- d) power line carrier links (PLC);
- e) point-to-point radio-links (microwave);
- f) rented circuits;
- g) optical wave guides (fibre optics).

The telecommunication circuits should be chosen with care, as they will be influenced by noise, change of parameters and any kind of interference which may cause maloperation or nonoperation of the teleprotection equipment.

Figure 2 shows the configuration when the guard and command signals are generated and received at power line carrier frequencies.

Figure 1 and Figure 2 apply to both frequency shift and normally quiescent systems.

Section 2. Terminology

5 Terminology

The following terms, derived from Chapter 448 of International Electrotechnical Vocabulary (IEV) [IEC Publication 50(448)] are given for the sake of understanding. Figure 3 is intended to clarify the concepts and the relations among terms in use.

5.1 Protection (448-01-01)

5.2 Protection equipment (448-01-04)

5.3 Protection system (448-01-06)

5.4 Selectivity (for a protection system) (448-01-07)

5.5 Absolutely selective protection system (448-01-08)

5.6 Relatively selective protection system (448-01-09)

5.7 Distance protection system (448-03-01)

5.8 Underreaching (for a distance protection system) (448-03-02)

5.9 Overreaching (for a distance protection system) (448-03-03)

5.10 Teleprotection equipment

Equipment specially designed to be used in conjunction with a protection system requiring a telecommunication link between the ends of the protected circuit, to transform the information given by the protection equipment in a way suitable for transmission.

a) *Teleprotection system*

System composed by the teleprotection equipment and associated telecommunication system needed, in a protection system requiring a telecommunication link, between the ends of the protected circuit.

b) *Teleprotection channel*

- 1) The frequency band at disposal on the telecommunication system in order to permit the transmission of protection signals in both directions.
- 2) System composed, for testing purposes, by teleprotection equipment connected back-to-back without the associated telecommunication system.

c) *Telecommunication system — Telecommunication link*

System composed by telecommunication equipment and the associated physical link needed to transmit information signals over the distance.

- 5.11 Pilot wire protection system (448-01-16)
- 5.12 Power line carrier pilot protection system (448-01-17)
- 5.13 Microwave pilot protection system (448-01-18)
- 5.14 Communication aided distance protection system
- 5.15 Permissive protection system (448-03-04)
- 5.16 Permissive underreach distance protection system (448-03-06)
- 5.17 Permissive overreach distance protection system (448-03-09)
- 5.18 Accelerated distance protection system (448-03-07)
- 5.19 Blocking protection system (448-03-05)
- 5.20 Blocking overreach distance protection system (448-03-08)
- 5.21 (Longitudinal) differential protection system (448-03-11)
- 5.22 Phase comparison protection system (448-03-13)
- 5.23 Directional comparison protection system (448-03-14)
- 5.24 Intertripping (448-01-20)

Section 3. Definitions of teleprotection systems

6 General

The following clauses deal with the terms used in the description and/or specification of teleprotection systems (see also Sub-clause 19.1).

7 Types of teleprotection schemes

a) *Permissive trip schemes* (reference Section 2)

This term denotes channels operating in an audio frequency band, or in a PLC frequency band. The channel is designed with the premise that the dependability of operation is high even under conditions when, due to a power system disturbance, the telecommunication medium may be adversely affected. Frequency shift signalling with or without coding techniques is usually employed.

b) *Intertripping schemes (Direct trip)* (reference Section 2)

Intertrip channels are similar in operation to permissive trip channels with the exception that security against unwanted operation and dependability of correct operation are prime requirements. Speed of operation is usually sacrificed to meet security and dependability requirements.

c) *Blocking protection schemes* (reference Section 2)

These channels are similar to permissive trip channels, except in the more stringent requirement for dependability of operation and in the speed requirements.

8 Overall operating time of teleprotection systems (telecommunication circuit included)

Overall operating time T is the time elapsed between the moment of change of state at the transmitter input and the moment of the corresponding change of state at the receiver output including propagation time and additional delay due to noise.

Overall operating time is part of the fault clearance time (see Figure 4).

NOTE Fault clearance time T_c is shown in Figure 4 as typical only.

9 Transmission time (telecommunication circuit excluded)

The transmission time of a teleprotection channel is the time elapsed between the moment of change of state at the transmitter input and the moment of the corresponding change of state at the receiver output excluding propagation time. The nominal transmission time is normally specified for a noise-free transmission path and implies zero loss probability.

The transmission time of a particular change of state can be related to a specified loss probability, which is the same as specifying the probability that a certain delay is exceeded.

The transmission time is then measured with continuous white noise applied to the transmission path; for various S/N (signal-to-noise) ratios it is determined as the delay corresponding to a specified loss rate (typically 7 ms–65 ms). See also Sub-clause 22.3.

This method corresponds to reality to a certain extent, since the probability of excessive delay is crucial to the user.

a) T_o = *nominal transmission time for a teleprotection channel*

This is the time elapsed from the initiating of the input of a teleprotection transmitter until the teleprotection receiver has given an output, measured under noise-free conditions.

b) T_{ac} = *maximum actual transmission time for a teleprotection channel*

This is the maximum time elapsed from the initiating of the input of a teleprotection transmitter until the teleprotection receiver has given an output, measured under noisy conditions for a defined dependability and S/N ratio (clamping action will influence the additional delay due to noise).

10 Security

Security means the ability to prevent interference and noise from generating a command state at the receiving end when no command signal is transmitted.

For practical reasons the probability of unwanted command P_{uc} is normally measured (see Sub-clause 22.1).

Security is then given by:

$$1 - P_{uc}$$

An unwanted command is a command that occurs at the receiving end for a time longer than a specified duration when no such command has been transmitted.

With tripping schemes, if the duration of an unwanted command state (T_{uc}) is longer than a specified duration, it will be considered as an actual command by the protection relay. With permissive trip schemes, the risk of an unwanted tripping action is generally low, while in direct trip application each unwanted command will lead to an unwanted tripping action.

With blocking schemes, an unwanted command may lead, according to its duration (T_{uc}), either to a delay to trip or to prevent a necessary tripping action from taking place.

The probability of unwanted command is measured by applying bursts of white noise to the transmission path; for various S/N ratios the unwanted command rate is then determined as the ratio of the number of received commands to the number of noise bursts of specified duration applied. This method also corresponds to some extent to reality (breaker and isolator operations, arcing noise, etc.) and allows comparison of results obtained with different equipment (see also Clause 22). It is essential that the unwanted command rate is measured in this way, i.e. with bursts of noise, since the receiver under test may block its output after a certain time in the presence of continuous noise.

11 Dependability

Dependability broadly means the ability to issue a valid command in the presence of interference and/or noise.

For practical reasons the probability of missing command P_{mc} is normally measured (see Sub-clause 22.2). Dependability is then given by:

$$1 - P_{mc}$$

When a command occurs at the transmitting end, it is considered as a missing one in the three following cases:

- a) total absence of command state at the receiving end;
- b) command state at the receiving end taking place with an excessive delay;
- c) too short or interrupted command state at the receiving end.

Cases a) and b) will obviously give a missing command for both tripping and blocking schemes.

Concerning case c):

For a tripping scheme, if the received command is shorter than a minimum duration, the command is considered to be missing.

For a blocking scheme, a too short or interrupted command may lead to an unwanted trip on a healthy line.

The probability of missing command is measured by applying continuous white noise to the transmission path; for various S/N ratios the missing command rate is then determined from the number of commands not received within the specified time (and of specified minimum duration) divided by the number of transmitted commands.

To a certain extent this method corresponds to reality; it offers further the advantage that results obtained with different equipment can be easily compared.

12 Nominal frequency band

The nominal frequency band is the bandwidth required by the teleprotection signalling equipment to perform its stated function, including any noise sensing requirement. It affects the transmission time and the relationship between the equipment and other services using the same signalling channel.

13 Nominal impedance

The nominal impedance of teleprotection equipment is defined as the input and output impedance of the equipment measured within its nominal frequency band. This impedance is normally 600 Ω and shall rise outside the nominal frequency band to permit parallel operation of other signals on the same telecommunication medium. In the case of protection channels operating at carrier frequencies the nominal impedance shall be the same as that for other power line carrier equipment (see IEC Publication 495).

14 Guard — Command signals

The guard signal is a signal being transmitted by the teleprotection equipment and is used to monitor the integrity of the telecommunication link as to level and S/N-ratio requirements, and when present inhibits any output of the teleprotection receiver. The command signal is that signal transmitted by the teleprotection equipment requiring action at the receiving end as noted in Clause 7.

15 Levels of guard signals

In the case of dedicated teleprotection equipment the level of a guard signal is related to the power output of the transmitter in order to comply with its peak envelope power (PEP). In the case of PLC voice frequency equipment, other services may be carried on the same link on a multi-purpose basis: when a starting relay is operating the guard signal may be boosted to the full power of the transmitter, cutting other signals for the short time of the teleprotection operation.

Boosting of the guard signal is also employed on some dedicated systems, such as quiescent systems or those employing PLC high frequency teleprotection equipment.

16 Levels of command signals

In the case of dedicated teleprotection equipment the level of the command signal, as for the guard signal, is related to the peak envelope power (PEP) of the transmitter.

In all cases, where power boosting is applied for guard signals, the same applies for command signals.

Section 4. Requirements

17 General equipment interface requirements

17.1 Insulation

All input and output circuits not connected to earth (power supply terminals included) must sustain for the duration of 1 min without any damage a sinusoidal voltage at a frequency of 50 Hz–60 Hz applied between the relative terminals in parallel and earth.

For transmit and receive terminals and power supply input terminals for voltages less than 60 V, a test voltage of 500 V r.m.s. shall be used. For d.c. supply voltages greater than or equal to 60 V and a.c. power supply input terminals, a test voltage of 2 000 V r.m.s. shall be used.

For d.c. signal terminals and alarm circuit terminals connected to the protection equipment, a test voltage as stated in series C of Sub-clause 6.2.3 of IEC Publication 255-5 shall be used as:

- a test voltage of 1 kV for operating voltage of ≤ 60 V;
- a test voltage of 1.5 kV for operating voltage of 127 V;
- a test voltage of 2.0 kV for operating voltage of 250 V.

The insulation resistance of the above-mentioned circuits, measured at the voltage of 500 V d.c., shall be not less than 100 M Ω for any temperature less than + 35 °C and relative humidity less than 75 %.

17.2 Impulse withstand level

All input and output circuits, power supply terminals included, must sustain without any damage or unwanted change of state from guard to command output, impulse voltages applied to the relative terminals both in differential and in common mode.

The peak value of the standard test impulse of wave form 1.2/50 shall be:

- 1 kV for transmit and receive terminals and for d.c. power supply terminals less than 60 V;
- 5 kV for d.c. power supply terminals greater than or equal to 60 V, for a.c. power supply terminals and for d.c. signal terminals and alarm circuit terminals connected to the protection equipment (see IEC Publication 255-4, Appendix E).

The test voltage levels are measured before the circuit to be tested is connected to the circuit terminals. In the case where the circuit under test presents appreciable current flows due to impulse testing (e.g. due to low impedance or surge arresters), the energy delivered by the generator must be equal to $0.5 \text{ J} \pm 10 \%$.

17.3 High-frequency disturbance level

All input and output circuits, power supply terminals included, must sustain, without any damage or unwanted change of state from guard to command output, damped oscillatory waveforms applied to the relative terminals both in differential and in common mode.

The frequency of the waveform shall be 1 MHz with the envelope decaying to 50 % of peak value at the end of three to six cycles. The repetition rate shall be 400 per second and the duration of the test shall be at least 2 s. Other repetition rates may be agreed upon between the user and the manufacturer.

The standard peak value of the test voltage shall be:

- for transmit and receive terminals and d.c. power supply input terminals for voltages less than 60 V:
 - 1.0 kV for common (longitudinal) mode;
 - 0.5 kV for differential (transverse) mode;

for d.c. signal terminals and alarm circuit terminals connected to the protection equipment, for d.c. power supply terminals for voltages greater than or equal to 60 V and the a.c. power supply terminals:

- 2.5 kV for common (longitudinal) mode;
- 1.0 kV for differential (transverse) mode.

(See IEC Publication 255-4, Appendix E.)

The test shall be carried out under operating conditions.