

Guide to

General considerations for telecommunication services for electrical power systems

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Power Electrical Engineering Standards Policy Committee (PEL/-) to Technical Committee PEL/89, upon which the following bodies were represented:

Association of Consulting Engineers
BAMEMA (BEAMA Ltd.)
BEAMA Ltd.
EEA (the Association of Electronics, Telecommunications and Business Equipment Industries)
Electricity Supply Industry in United Kingdom
GAMBICA (BEAMA Ltd.)
North of Scotland Hydro-Electric Board
Telecommunication Engineering and Manufacturing Association
Transmission and Distribution Association (BEAMA Ltd.)

This British Standard, having been prepared under the direction of the Power Electrical Engineering Standards Policy Committee, was published under the authority of the Standards Board and comes into effect on 15 September 1992

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The following BSI references relate to the work on this standard:
Committee reference PEL/89
Draft for comment 89/33070 DC

ISBN 0 580 21151 7

Amendments issued since publication

Amd. No.	Date	Comments

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National foreword

This British Standard has been prepared under the direction of the Power Electrical Engineering Standards Policy Committee and is identical with IEC Publication 1085:1992 *General considerations for telecommunication services for electric power systems*, published by the International Electrotechnical Commission (IEC).

The International Standard gives an overview of the telecommunication services needed to satisfy the operational, maintenance and administrative needs of electric power systems.

Cross-references

International Standard	Corresponding British Standard
IEC 50(371):1984	BS 4727 <i>Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour terms</i> Part 2 <i>Terms particular to power engineering</i> Group 12:1990 <i>Telecontrol terminology</i> (Technically equivalent)
IEC 801	BS 6667 <i>Electromagnetic compatibility for industrial-process measurement and control equipment</i> BS 7404 <i>Telecontrol equipment and systems</i>
IEC 870-1	Part 1 <i>General considerations</i> (Identical)
IEC 870-2	Part 2 <i>Operating conditions</i> (Technically equivalent)
IEC 870-3:1989	Part 3:1991 <i>Specification for interfaces (electrical characteristics)</i> (Identical)
IEC 870-4:1990	Part 4:1991 <i>Specification for performance</i> (Identical)
IEC 870-5	Part 5 <i>Transmission protocols</i> (Identical)
IEC 834-1:1988	BS 7494 <i>Performance and testing of teleprotection equipment of power systems</i> Part 1:1991 <i>Specification for narrow-band command systems</i> (Identical)

The Technical Committee has reviewed the provisions of IEC 353, IEC 481, IEC 495, IEC 663, IEC 834¹⁾ and IEC 1000 series to which reference is made in the text and has decided that they are acceptable for use in conjunction with this British Standard.

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 and ii, pages 1 to 28, 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.

¹⁾ In preparation.

Introduction

The size and complexity of electric power systems in both developed and developing countries is growing rapidly and increasingly requires adequate telecommunication services to satisfy the operational, maintenance and administration needs.

It is therefore useful to have a report giving an overview of what is required which will assist in the planning of such services.

These considerations are based on the CIGRÉ paper (see 2.1) and on the relevant publications of IEC Technical Committee No. 57.

As the technical possibilities and solutions for the provision of telecommunication services for electric power system depend very much on international and national standards, and there is also a need to satisfy the local PTT requirements as well as a need to co-exist with local radio/broadcasting services, this document is issued as a Technical Report and not as a standard.

1 Scope

This Technical Report is intended to give an overview of the specific problems and requirements for electric power utility telecommunication systems.

2 Normative references to related International Standards and reports

The following standards contains provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Technical Report are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

There are many International Standards and reports covering the topics considered in this report and the following subclauses detail those relevant to each aspect.

2.1 General

Guide for planning of power systems telecommunication systems (1985).²⁾

ANSI/IEEE STD 367:1987, *IEEE recommended practises for determining the electric power station ground potential rise and induced voltage from a power fault*.

2.2 Telecontrol

In the area of telecontrol the IEC Technical Committee No. 57 is in the process of producing a very useful publication. This publication, IEC 870, consists of six parts as follows:

IEC 870-1, *Telecontrol equipment and systems — Part 1: General considerations*.

IEC 870-2, *Telecontrol equipment and systems — Part 2: Operating considerations*.

IEC 870-3:1989, *Telecontrol equipment and systems — Part 3: Interfaces (electrical characteristics)*.

IEC 870-4:1990, *Telecontrol equipment and systems — Part 4: Performance requirements*.

IEC 870-5, *Telecontrol equipment and systems — Part 5: Transmission protocols*.

IEC 870-6, *Telecontrol equipment and systems — Part 6: Telecontrol protocols compatible with ISO and CCITT standards (under consideration)*.

The following two documents, published by the IEC and IEEE respectively, are also very useful:

IEC 50(371):1984, *International Electrotechnical Vocabulary (IEV) — Chapter 371: Telecontrol*.

IEEE P 565/D3 5-27-77, *Manual of automatic and supervisory station control data organisation*.

2.3 Teleprotection

IEC Technical Committee No. 57 has produced the following standards on performance and testing of teleprotection equipment:

IEC 834-1:1988, *Performance and testing of teleprotection equipment of power systems — Part 1: Narrow-band command systems*.

IEC 834-2, *Performance and testing of teleprotection equipment of power systems — Part 2: Analogue comparison systems* (in preparation).

2.4 Power line carrier (PLC)

IEC Technical Committee No. 57 has produced the following standards:

IEC 353:1989, *Line traps for a.c. power systems*.

IEC 481:1974, *Coupling devices for power line carder systems*.

IEC 495:1974, *Recommended values for characteristic input and output quantities of single sideband power line carrier terminals*.

IEC 663:1980, *Planning of (single sideband) power line carrier systems*.

²⁾ Published by CIGRE Working Group 04 of Study Committee 35.

2.5 Radio

Recommendations and reports of the CCIR, XVIth Plenary Assembly, 1986, Volume IX — Part 1: *Fixed service using radio-relay systems*.

Recommendations and reports of the CCIR, XVIth Plenary Assembly, 1986, Volume VIII — Parts 1-3: *Mobile services*.

2.6 CCITT

- FDM:

CCITT Blue Book (1988) — Volume III — Fascicle 111-2: *International analogue carrier systems. Transmission media characteristics*.

- TDM:

CCITT Blue Book (1988) — Volume III — Fascicle 111-3: *Digital Networks. Transmission system and multiplexing equipment*.

- CCITT Blue Book (1988) — Volume VIII — Fascicle VIII-7: *Data communication networks. Message handling systems. Recommendations X.400 – X.420*.

2.7 Electro-magnetic compatibility

Immunity tests (IEC 801 and IEC 1000 series).

3 General

An electric power system consists of a number of power stations (thermal and hydro) located in different parts of a country supplying electric power via a transmission and distribution network to feed loads which are spread across the territory and are remote from the power stations. The transmission network connects the power stations to substations where switching and transformation to lower voltages takes place and from where loads, domestic and industrial are supplied via a distribution network.

An electric power system is frequently referred to as an electrical public utility. In order to administer and operate the utility, in addition to the power stations, transmission and distribution substations, a number of other units can be identified (see Figure 1). These are:

- a headquarters to run the utility;
- one or more control centres to determine which power stations should operate and how the transmission and distribution network shall be used;
- one or more maintenance centres;
- one or more computing centres for support of the control centre(s) and for support of headquarters.

These units obviously cannot work in isolation and hence require telecommunication services. The following subclauses in clause 3 identify the functions to be executed and the consequent telecommunication services needed to satisfy the functions.

3.1 Functions

3.1.1 Administrative telephony (see Figure 2)

At the most basic level headquarters will need to communicate with all locations within the utility by voice, that is telephony, and may also wish to use telex and facsimile services and, increasingly, electronic mail services. The locations will also wish to communicate with one another.

Locations will also need telephone connections to outside of the utility, that is via the public switched telephone network (PSTN) and this may again include telex and facsimile services.

3.1.2 Operational telephony (see Figure 3)

The control centre(s) requires rapid and simple telephone access to the power stations, substations and the maintenance centre(s). Telephone access is also required to neighbouring power utilities for the purpose of scheduling the interchange of electrical power.

3.1.3 Telecontrol (SCADA) (see Figure 4)

In order that the control centre can carry out its function it needs to be provided with all the information about the power system, namely status positions (i.e. monitored information such as circuit-breakers, isolators, alarms), measurands, integrated totals, etc., from the power stations (thermal and hydro) and substations which are of course remote from the control centre. It is also necessary to control electrical and hydraulic plant. If load frequency control (LFC — also known as Automatic Generation Control) is used then remote control of the turbine-alternators at the power stations will also be required.

In the case of hydro-electric power stations hydraulic data, such as rainfall and water level, also needs to be returned to the control centre.

At the control centre(s) this information is used to drive a man-machine interface consisting of mimic diagrams and visual display units (VDU's).

The system used to handle all these aspects is known as a telecontrol system or SCADA (Supervisory Control and Data Acquisition) system.

3.1.4 *Load management* (see Figure 5)

An electrical power utility may wish to improve its system load factor throughout the day by offering incentives to customers to utilise electric power at particular periods of the day. This function is known as load management and is achieved by the remote switching in or out of loads. Load management may be under the control of the control centre or it may be an automatic feature such as when it is used for the control of street lighting.

3.1.5 *Teleprotection* (see Figure 6)

Where the occurrence of an incident on the power system requires protective action at another location teleprotection is used.

3.1.6 *Mobile radio* (see Figure 7)

In support of the operation of the power system, under the control of the control centre(s), there will be a maintenance organisation with one or more locations in the territory covered by the utility. These maintenance centres will have mobile crews who can be reached either in their vehicles or directly on a “walkie-talkie” basis. For this, mobile radio is used typically in the VHF (70–165 MHz) and UHF (400–470 MHz) bands.

3.1.7 *Computing traffic* (see Figure 8)

In modern utilities it is usual to have at least one main-frame computer with, in addition, smaller mini-computers located elsewhere connected to the main-frame.

The main-frame may be used by the control centre for off-line planning studies. It may also be used for administrative services such as wages and billing.

3.2 *Telecommunication services*

3.2.1 *Administrative telephony*

To satisfy the administrative needs of the utility (3.1.1) a private network is usually provided, which makes use of suitable communication media (see 5.1) together with private automatic exchanges and, if the network is large enough, with transit exchanges.

For connection to the public network, public exchange lines are usually provided to all locations requiring the service.

3.2.2 *Operational telephony*

To satisfy the operational telephony needs (3.1.2) a special purpose telephone system is usually provided with key calling of a limited repertoire of extensions and, where such a system is shared with the administrative private network (3.2.1), a priority feature which ensures that the control engineer always has access to the desired extension.

3.2.3 *Telecontrol*

Telecontrol systems (3.1.3) consist of equipment at the control centre(s), sometimes called master station(s), connected via suitable communication media to outstations located in the power stations (thermal and hydro) and substations. These outstations are interfaced to the relevant electrical parameters and receive commands and return information rapidly, accurately and continuously.

At the control centre(s) the equipment consists of mini-computers working with the out-stations and animating the mimic diagrams and VDU's.

3.2.4 *Load management*

Where load management is applied to domestic or industrial loads by remote tele-switching, requiring access to a large number of consumers, one way radio communication, may be quite sufficient, in which case there is one central radio transmitter and many radio receivers.

On the other hand where control of street lighting or control of domestic electric water heating is required, mains borne signalling may be used (also known as ripple control).

3.2.5 *Teleprotection*

Teleprotection systems provide a means of transmitting protection information or protection commands from one location to another via suitable communication media. Fast, reliable and error free operation is essential for such services.

3.2.6 *Mobile radio*

For mobile radio systems with a defined area to be covered there will typically be one or more base stations connected to the maintenance centre by suitable communication media. The vehicles will be equipped with a radio transmitter/receiver with access to one or more radio channels in the VHF or UHF band. Hand portables may also be used in this application and where the service distances are small, UHF is usually preferred. Where vehicles are used, some may be equipped with a text message capability.

3.2.7 *Computing traffic*

Computing traffic usually consists of large amounts of data transferred either to or from or both ways into the main-frame. There may also be a large amount of interactive traffic.

Such traffic requires error protection as well as high speed signalling, typically 2,4 kbits/s, 9,6 kbits/s, or 64 kbits/s and even higher. Suitable communication media are required for such traffic.

3.2.8 Other services

Telex, facsimile and electronic mail traffic usually consists of small amounts of data transferred between operational and administration centres. Signalling speeds range from 50 bits/s for telex to 2,4 kbits/s for facsimile and electronic mail. No error protection is usually provided for telex and facsimile error protection is provided however for electronic mail systems based on the CCITT Recommendation X.400. Suitable communication media are needed for all such traffic. Message switching facilities for telex and electronic mail bring extra benefits at reasonable cost.

3.2.9 Public address system (PA System)

Public address systems are widely used by electrical power utilities for administration, safety (fire, radiation, evacuation) and operational broadcasts. For internal power station operational requirements where only one way communication is necessary, a PA system provides a very convenient means of communicating to a group of people collectively.

3.2.10 Network management

It is usual for modern utilities to employ network management techniques for administering the telecommunications network. A centrally-located management centre collects traffic and transmission quality and failure data remotely and is capable of making software changes to accomplish the most reliable routing of traffic.

3.2.11 Power supplies

To support the aforementioned telecommunication services, power supplies are required which should be engineered to match the desired security and reliability. Thus all supplies should be backed by electrical storage, for example batteries, so that the supply continues to be available during power system failures.

3.3 Summary

An electrical utility may elect to provide its own entire telecommunication services or a portion of them for the following reasons:

- i) The essential service provided by an electrical utility requires integrity and availability of communication better than a PTT could normally offer.
- ii) A public telecommunications operator may not be prepared to provide all the facilities required in a cost effective way.

Regardless of whether or not the electrical utility or the PTT provides the service, isolation problems and general electro-magnetic compatibility (EMC) at substations and power stations should be taken care of in providing safe, secure and reliable service.

4 Service requirements

4.1 Telecommunication and operational services

4.1.1 Administrative telephony

In common with all industrial and commercial organizations an electrical public utility needs a suitable service of telephony. However, the requirements for such a service are more demanding than for many other organisations because the telephony facilities may strongly influence the image of the utility to the electricity supply users.

Administrative telephony should be able to service complaints from the public, demand for electrical supply from the public, as well as work organization, fuel provision and fuel movement within the organization.

4.1.2 Operational telephony

Due to the importance of the voice communication needs of staff in charge of generation, transmission and distribution of electrical power, there is a need for an operational telephony service.

In an electrical utility operational telephony is the most important working tool. Together with telecontrol, it is used for managing and supervising the power network but operational telephony has to be available even when the telecontrol system fails.

The traffic offered by the operators is not high; nevertheless operational telephony requires features that cannot be provided except by means of specially dedicated networks.

In addition to the very high reliability and availability required, an operational telephone network shall provide the following facilities:

- very rapid access;
- priority subscribers, with call intrusion and forcing down ("knock-down") facilities;
- conference facilities;
- alternative routing of calls;
- automatic re-routing of calls;
- hunting for free trunks in groups;
- non-blocking transit switching;
- closed numbering scheme;
- barring certain extensions from calling subscribers outside predetermined exchange areas.

It is also desirable to have indication of the origin of the incoming call.

In order to provide the above facilities, the operational telephone network should be based on special exchanges with a more sophisticated signalling system than usual.

A priority call, for example, has to be able to transfer the information about the priority throughout the network by means of a signalling system which enables the exchanges to perform in the manner required for this type of call, i.e. intrude on and/or disconnect a telephone conversation of lower status if free trunks or a subscriber cannot be found.

Similarly, features such as conference and re-routing of calls require the transfer of suitable information about the type and status of calls and of the trunk channels interconnecting the transit exchanges. Such features should be provided either for analogue or digital interconnection channels whether only a single channel is used or many channels.

As the calls in an operational network may be of an extremely urgent nature, the signalling system is required to be very fast and reliable, so that the time spent in setting up the call is kept to a minimum.

The attraction of a closed numbering scheme is that to reach a certain subscriber the same number is dialled irrespective of from which exchange within the network the call is placed.

To operate a network-wide closed numbering scheme and automatic alternative re-routing requires digital store and forward facilities and stored programme control (SPC) of the exchanges.

Operational staff at control centres should have the capability of maximum priority and intrusion ability to produce a grade of service of 100 % (i.e. availability of 100 %) with zero (or minimum) waiting time.

In order to ease the operation and speed up the calling procedures, such staff should be provided with equipment enabling calls to be set up to the required destination by simply pressing a key or button (one key or button) per destination.

The fulfilment of the above functional requirements can be easily accomplished by using dedicated meshed networks, which are the most suitable solution for medium and large size power networks. In such cases the operational telephone network can also be profitably used for internal administrative communications, at least as a back-up system.

For smaller networks with low traffic density or as a back-up facility to the dispatching and control operators, party line systems may be a suitable alternative.

It is clear from the foregoing that the transit exchanges and the other equipment used in the operational telephone networks of electrical utilities have to be quite special and different from those used in public networks.

4.1.3 Telecontrol

Telecontrol at its most basic concept means controlling a power station or substation remotely just as if the operator was actually at the station. One of the benefits is a noticeable saving in manpower since one operator can control several stations, thus reducing operating costs.

Telecontrol provides for data acquisition from the remote stations towards the control centre and in the reverse direction commands from the control centre to the remote stations.

Telecontrol does not however mean only telecommand for changing the state of circuit breakers and isolators (disconnectors), or setting some of the operational conditions of some of the equipment. It also means supervision of the overall state of the electrical network as a unique process to ensure its security, reliability, availability, and economy in electrical energy provision. To be effective, this requires the telecontrol system to carry out the functions of state estimation, detection of bad power system data, etc.

The power system functions that a telecontrol system has to satisfy are listed in the following Table 1. The consequent operational functions to achieve these are summarised in Table 2. The term energy management system (EMS) is frequently used to embrace all such aspects.

Except in very small electrical networks, the telecontrol functions are usually organised in an hierarchical structure, as shown in Figure 9.

At the highest level a telecontrol system can consist of a number of interconnected control centres serviced preferably by a common meshed telecommunication network. The telecontrol system may span more than one power administrative region at control centres and thus the authority over the telecontrol system itself does not necessarily coincide with any particular power system authority.

In most cases the main control centre (MCC) will not execute commands in real time via the telecontrol system but operates via the lower level centres by telephone instruction. Nevertheless, the main control centre will provide overall supervision of the total system and may well schedule the operation of the power stations.

At the level of Regional Control Centre (RCC) actual LFC operations as well as execution of commands may be performed. The RCC is also responsible for the next lower level of operation (District Control Centres), that execute commands after instruction by or agreement with their RCC.

The security, reliability and availability of the electrical power system requires that the telecontrol functions are fast even in updating the telemeasurements and should be of the highest security and reliability. Consistency of information between the measurements and status information is essential for satisfactory operation, especially in times of power system faults. Response times should be short particularly during power system faults when the amount of information to be returned will be very large.

Security is the probability that unwanted or incorrect commands do not occur, while reliability is the probability that a command is not missed and is correctly executed. Similarly the telemetering functions have to be highly reliable, secure and accurate.

All of the foregoing result in the following requirements:

- fast and predictable response times;
- use of suitable transmission protocols and coding for operational data transmission;
- high quality communication media;
- high reliability communication network;
- high availability communication networks both long term (equipment failure) and short term (noise, propagation, interferences).

The transmission capacity of the communication links should match the need to keep the overall response times small consistent with providing the right amount of error protection. Modern power system operation requires that the updating time of the information reaching the MCC is less than a few seconds. Taking into account the amount of information coming from the remote stations, the data throughput can be typically 200 bits/s to 2 400 bits/s between outstations and DCC, typically 2 400 bits/s to 9 600 bits/s between DCC and RCC, and typically 9 600 bits/s to 48 000 bits/s between RCC and MCC.

The data throughput figures are likely to increase with the introduction of the next generation of telecontrol systems which tend to require much shorter response times and higher throughputs in order to enhance the automatic computer-based system control functions and thus improve the security, reliability and availability of the service provided by the utility.

Significant developments in the use of expert systems at the different levels of telecontrol systems are currently underway. Among other things, these may lead to a potential reduction in the quantities of a real-time data transmitted as a result of local automatic alarm analysis in the event of a sudden increase in data.

The overall target availability for the telecommunication links of the primary network (RCC to MCC) should be better than 99,99 %, whereas lower values may be tolerated in the secondary networks where the availability should be better than 99,9 %.

Regarding the telecommunication network configuration, the required long-term availability imposes a need for redundant routing of signals on fully independent paths. This can readily be achieved by mesh configurations.

Redundant routing itself is not sufficient to ensure the required availability in the short term if there are any common mode failures that can affect both paths. Full redundancy means separate entries into a building from separate routes.

Notwithstanding such separation, each communication path should be of sufficiently high quality and high availability to achieve the required availability in the short term when one of the paths is out of service.

A further consideration is the need for flexibility should a DCC, RCC or even an MCC fail.

Table 1 — Power system functions (to be satisfied by telecontrol)

Network state determination	Topology determination and state estimation. Network equivalence.
Network analysis	Load flow calculations. Short-circuit calculations. Contingency evaluation. Security monitoring.
Thermal power production	Trend monitoring. Set value. Operation reports/production.
Hydro power production	Calculation of water flow. Supervision of legal obligations (levels, flows, etc.). Trend monitoring. Set value. Control signals to local regulating equipment. Operation reports/production.
Network and generation control	Load shedding. Load-frequency control and economic energy management. Load forecast. Unit commitment.
Specific telecontrol system functions	Non-current tagging of measurands. ^a Non-current tagging of monitored information. ^a
Post mortem analysis	Post mortem review. Reports of power system disturbances for immediate disturbance analysis. Reports of power system disturbances for subsequent disturbance analysis.
Statistical value processing	General. Statistical value generation. Storage of statistics. Checking of statistical data. Correction/complementing.
Preparation of statistical reports	General Operation reports, power grids. Load prediction (long term).
Training	Training simulator.
^a I.E. indication that measurands and/or monitored information are not being updated, and hence are “non-current”.	