

# **STRUCTURE OF TELECONTROL CENTRES AND OVERALL SYSTEMS**

**Working Group 01  
of  
Study Committee 35  
(Communication and Telecontrol)**

**1987**



# **STRUCTURE OF TELECONTROL CENTRES AND OVERALL SYSTEMS**

**Working Group 01  
of  
Study Committee 35 (Communication & Telecontrol)**

**1987**

**Copyright © 2005**

*"Ownership of a CIGRE publication, whether in paper form or on electronic support only infers right of use for personal purposes. Are prohibited, except if explicitly agreed by CIGRE, total or partial reproduction of the publication for use other than personal and transfer to a third party; hence circulation on any intranet or other company network is forbidden".*

**Disclaimer notice**

*"CIGRE gives no warranty or assurance about the contents of this publication, nor does it accept any responsibility, as to the accuracy or exhaustiveness of the information. All implied warranties and conditions are excluded to the maximum extent permitted by law".*

**STRUCTURE OF TELECONTROL  
CENTRES AND OVERALL SYSTEMS**

by

**Working Group 01  
of Study Committee 35  
(Communication and Telecontrol)**

**REPORT 1**

## CONTENTS

|         |                                                                                                           |    |
|---------|-----------------------------------------------------------------------------------------------------------|----|
| 1.      | <u>INTRODUCTION</u>                                                                                       | 3  |
| 2.      | <u>STATE OF THE ART</u>                                                                                   | 5  |
| 2.1     | <u>CONFIGURATION OF FUNCTIONS</u>                                                                         | 5  |
| 2.1.1   | <u>General</u>                                                                                            | 5  |
| 2.1.2   | <u>Control System Management Functions</u>                                                                | 7  |
| 2.1.2.1 | System Management Computer Programs                                                                       | 7  |
| 2.1.2.2 | Communication Networks                                                                                    | 9  |
| 2.1.2.3 | Functions at a Collecting Point (CP)                                                                      | 10 |
| 2.1.2.4 | Functions at Power Stations/Outstations                                                                   | 11 |
| 2.1.3   | <u>Application Functions</u>                                                                              | 11 |
| 2.1.3.1 | Functions of the National Control Centre (NCC)                                                            | 11 |
| 2.1.3.2 | Functions of the Area Control Centre (ACC)                                                                | 12 |
| 2.1.3.3 | Functions of the District Control Centre (DCC)                                                            | 13 |
| 2.1.3.4 | Application Functions at Power Stations/<br>Outstations                                                   | 14 |
| 2.2     | <u>CONFIGURATION OF TELECONTROL SYSTEM EQUIPMENT</u>                                                      | 14 |
| 2.2.1   | <u>General</u>                                                                                            | 14 |
| 2.2.2   | <u>Configurations Between a Control Centre/<br/>Collecting Point and Power Stations/Out-<br/>stations</u> | 16 |
| 2.2.3   | <u>Configuration Between Control Centres and<br/>Collecting Points</u>                                    | 18 |
| 2.2.4   | <u>Telecommunication Channels</u>                                                                         | 20 |
| 2.2.4.1 | Main/Standby Channels                                                                                     | 21 |
| 2.2.4.2 | Mesh Configuration                                                                                        | 21 |
| 2.2.5   | <u>Control Centre Structure in Telecontrol<br/>Systems</u>                                                | 21 |
| 2.2.5.1 | Hardware Function and Structure                                                                           | 22 |
| 2.2.5.2 | Software Function and Structure                                                                           | 24 |
| 2.3     | <u>MAN/MACHINE INTERFACE</u>                                                                              | 25 |
| 2.3.1   | <u>General</u>                                                                                            | 25 |
| 2.3.2   | <u>Functions</u>                                                                                          | 25 |
| 2.3.3   | <u>Equipment</u>                                                                                          | 27 |
| 2.3.4   | <u>Structure and Availability</u>                                                                         | 29 |
| 2.4     | <u>EMERGENCY SITUATIONS IN CONTROL SYSTEMS</u>                                                            | 30 |
| 2.4.1   | <u>General</u>                                                                                            | 30 |
| 2.4.2   | <u>Alarms</u>                                                                                             | 31 |
| 2.4.3   | <u>Fault Isolation</u>                                                                                    | 31 |
| 2.4.4   | <u>Fault Repair</u>                                                                                       | 32 |

CONTENTS

|      |                                         |    |
|------|-----------------------------------------|----|
| 3.   | FUTURE TRENDS                           | 32 |
| 3.1. | GENERAL                                 | 32 |
| 3.2. | CONFIGURATION OF TASKS                  | 32 |
| 3.3. | CONFIGURATION OF TELECONTROL SYSTEM     | 33 |
| 3.4. | MAN/MACHINE INTERFACE                   | 33 |
| 3.5. | EMERGENCY SITUATIONS IN CONTROL SYSTEMS | 33 |

List of Appendices

|            |                                                                                           |
|------------|-------------------------------------------------------------------------------------------|
| APPENDIX A | List of abbreviations<br>List of definitions                                              |
| APPENDIX B | Possible hierarchical software<br>Structure for power system load<br>Dispatch and control |
| APPENDIX C | Master computer system structure                                                          |
| APPENDIX D | Conceptual diagram of software<br>Structure for power system control                      |

## 1. INTRODUCTION

The methods for designing telecontrol systems vary very much in different countries due to different conditions. These conditions could be of a technical nature, e. g. power production and grid, as well as of an organisational nature. One is also dependent on the techniques and economics of the control system components, e.g. computers and communication equipment. The report discusses the most common methods for designing telecontrol systems, but many other methods could and will be applied in the future.

There are also many other factors affecting the telecontrol structure. In most countries remote control is applied to old as well as new generating and transformer stations. In addition, old remote control is often mixed with new remote control in the same centre. Putting in new control systems without disturbing the power system operation too much also causes problems.

A telecontrol system is an on-line real time system operating continuously and comprising both hardware and software. The following requirements affecting the structure must be considered:

### (1) Response Characteristics

Response characteristics are important in controlling a power system. It is especially important that response to a power system fault is actuated within the allowable time.

(2) Availability and security

Availability and security can be affected by the choice of the back-up philosophy.

(3) Operation characteristics

The system must be designed so that the operators can respond quickly and accurately.

(4) Expandability and maintainability

Expandability and maintainability aim at maintaining the system for a long time, and both hardware and software should fulfil these requirements in order to respond to alterations in the power system facilities and operation methods.

This report on the structure of telecontrol centres and overall systems should be considered together with a separate report on the functional requirements and a future report on the interfaces of telecontrol systems. The report is applicable to dispatch (decision) centres in the higher part of the hierarchy as well as to remote control centres.

The systems which are in use today (discussed in Chapter 2) have a structure governed by present-day techniques. New systems will, however, be greatly influenced by new components, techniques and methods. This is discussed in Chapter 3.

## 2. STATE OF THE ART

### 2.1 CONFIGURATION OF FUNCTIONS

#### 2.1.1 General

The structure of telecontrol centres and overall systems is largely determined by the operational philosophy established by the authorities for the management of the power system. The monitoring of the system is highly complex, since it must satisfy multiple operation requirements specific to each power station/outstation, taking into account the mutual interaction of conditions. At the same time it must comply with statutory laws, regulations and economic criteria for the proper functioning of the whole of each individual outstation. Furthermore, unforeseen events liable to affect the proper functioning of the whole power system must be predicted and kept to a minimum. From the foregoing it follows that operation must be split up into different levels of responsibility.

In countries with a national electricity authority, the power system might include some or all of the following levels:

National Control Centre  
Regional or Area Control Centres  
District Control Centres

In countries where electricity is generated, transmitted and distributed by a number of private companies or groups of companies there is usually an interconnected system comprising

Pool or Area Control Centres  
Major Utility Control Centres  
or  
Regional Control Centres  
Area (Zone) Centres

From the foregoing it is apparent that the same words, e.g. Area, may be used to define different responsibility levels within the power system and may give rise to some confusion. However, parallels can be drawn.

For example, the function and responsibilities of the 'Pool' Area Control Centres are similar to a National Control Centre, similarly a Major Utility (or group of Utilities) Control Centre corresponds to a Regional or Area Control Centre/District Control Centre.

It seems useful to divide the different functions on each level of hierarchy into application functions (such as load-frequency-control, state estimation, automatic switching) and control system management functions, which means internal functions to control and ensure correct operation of the telecontrol network (i.e. line protocol functions, routing functions, end-to-end dialogues, building of messages, etc.) and for further data processing in the whole installation.

It can be necessary to define

- control system management functions on each level
- application functions on each level
- demands of different application functions on telecontrol systems on each level

At NCC and ACC, sometimes also at outstations, main computer systems will perform application and control system management functions. Control system management functions can be handled by front-end-processors in multi-computer systems. Interfaces between application and system management functions should be defined. As microprocessors and minicomputers are introduced more and more into telecontrol systems, software is becoming an increasingly important element of the telecontrol equipment in both control centres and outstations.

In the data transmission network serving different centres, separation of "communication" and "processing" is a fundamental philosophy.

The structure of a telecontrol system affects several functional characteristics.

For example, if the structure of a distributed or hierarchical system is modular, then it has the following advantages:

- Structural suitability

The power system operation is divided hierarchically according to voltage hierarchy, which means that the operation has a modular conception. A similar modular conception of the overall control system design gives an easy way of updating the control system according to the power system operation development.

- Availability

Availability in the telecontrol system can be achieved by not excessively concentrating telecontrol systems. Local faults do not affect the whole system. A back-up between the different hierarchical levels is also possible.

- Extendability/flexibility

Internal modularity in the design of telecontrol systems can more easily adapt to extensions and alterations of the power system and power system control. It must be possible in telecontrol systems to update capacity and functions step by step.

- Specification and implementation are simplified.

- Maintenance is facilitated.

## 2.1.2 Control System Management Functions

### 2.1.2.1 System Management Computer Programs (Table 1)

This describes only on-line processing programs and does not cover off-line processing programs such as administration plans (demand and supply plans, work step plans, reliability forecasting and optimum system design plans, etc.).

On-line systems should be co-ordinated with off-line systems and data exchange should be possible. Data bases should be arranged for this purpose, which means that special care should be taken in the co-ordination of files and data bases in off-line and on-line systems (i.e. for power scheduling, for load calculations etc.)

| System Management Program |                                                                       | Explanation                                                                                                                                                                                             |
|---------------------------|-----------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| a                         | Data collection and distribution                                      | Collection of indications, measurements etc. sent from remote terminals, and distribution of control information                                                                                        |
| b                         | Data communication between centres                                    | Transmitting data on request or cyclically between adjacent centres or centres serving other voltage levels.                                                                                            |
| c                         | Console input/output function                                         | Processing of demands from the console, indications and alarms to the console                                                                                                                           |
| d                         | VDU input/output                                                      | Processing of data generation, input and output , etc. for VDU displaying data                                                                                                                          |
| e                         | Mimic board function                                                  | Output of indications, measurements etc. to the mimic board.                                                                                                                                            |
| f                         | System amendments                                                     | Processing of changes in constants, tables and data arising from power system development, without disturbing the use of the mimic board.                                                               |
| g                         | Extensions to the operating program                                   | Performing the processing required by application programs.                                                                                                                                             |
| h                         | Supervision of the availability of hardware (control system topology) | Supervising various parts in a telecontrol system, i.e. RTUs, telecommunication line computer interfaces, CPU, visual displays, printers etc. and giving an alarm indicating which part is unavailable. |

Table 1. System Management computer Programs

### 2.1.2.2 Communication Networks

The choice of the structure of the communication network should be made by starting with the primary operational requirements of information transfer, such as time-response, availability, transfer rate, etc. The network ought to have at least the following features in order to be effective:

(1) Transparency of information

Data link control protocols should be used, which enable one to combine bit oriented information (i.e. indications, measured values) and character oriented information (i.e. ASCII or BCD codes) without any restrictions.

(2) Standardization of exchange method

Transmission and exchange of all types of operational information, both monitored information and control information should be transmitted by means of standardized frame formats. Only a few significantly different frame format classes with appropriate rules for treating variable information field lengths should be defined.

3) Expandability

Modularity for both hardware and software should be employed to ensure high expandability.

(4) Reliability, availability and serviceability

The network should provide an appropriate standard of reliability, availability and serviceability. For example, a modification or confirmation of various tables could be made by operating a typewriter, a network diagnosis should be made by test programs and messages, detailed monitoring and alarming functions could also be contained. The concept for maintenance should be applicable to the specific conditions in the power company concerned.

(5) Full compatibility with existing facilities.

In many cases the network must interface with existing facilities such as telecontrol equipment using cyclic data transmission.

A functional and software configuration of a network is outlined in Appendix B.

The configuration of data links between a front-end-system and main-computer-systems should also be thought of in respect of the reliability of the hardware. Defining the interfaces between two systems, the advantages and disadvantages of configurations should be analyzed in respect of the reliability of the hardware and the software.

Data exchange between NCC and ACC and/or ACC and out-stations with telecontrol equipment of different manufacturers is often necessary. Therefore, it is desirable to define data formats, transmission procedures, error strategies and addressing methods in order to simplify or standardize the hardware and the software required to interpret telecontrol messages of different manufacturers and to limit the number of front-end-processors in control stations.

#### 2.1.2.3 Functions at a Collecting Point (CP)

Functions at a collecting point are largely dependent on the choice of the configuration of the network. They may include:

(1) Data assembly function

The data is checked, blocked and addressed according to the rules prescribed for the network.

This function must have interfaces with various existing transmission facilities.

(2) Data exchange function

Data blocks are transmitted at high speed between nodes. At a CP, these blocks are exchanged according to the description of headers attached to the blocks when they are assembled.

Transparency of information is important in the data link control procedure used in communication with CPS.

### (3) Data disassembly function

When the header indicates processing of data at the CP, the block is disassembled for processing at the centre.

According to need, disassembled data is transmitted to the appropriate point (e.g. RTU).

### (4) Other functions

Other major functions are data linkage for duplicated operating systems, monitoring and alarming for system operation purposes and automatic switching of duplicated equipment. A separate processor may be employed for these miscellaneous functions.

#### 2.1.2.4 Functions at Power Stations/Outstations

In the RTU at power stations/outstations the management functions at the lowest level are normally monitored and controlled from a higher level (NCC, ACC and DCC). In outstations a telecontrol outstation, i.e. remote terminal unit (RTU), is required to interface to the power plant and convert status indications, alarms and analogues etc. into coded telegrams for transmission to the control centre. In the reverse direction the RTU shall decode control or set point telegrams and output these signals to the plant according to conditions set by the local control equipment.

#### 2.1.3 Application Functions

The division of application functions among control centres of different levels tends to vary, to some extent, in various power companies and countries. The following represents some typical subdivisions.

##### 2.1.3.1 Functions of the National Control Centre (NCC)

The functions of the National Control Centre can include:

- (a) Co-ordination of the Area Control Centres.
- (b) Economical load dispatch. (Allocation of power production for best economy with a given degree of safety).
- (c) Monitoring and control of inter-area tie lines and national power exchanges with adjacent and other countries. Exchange of power with other adjacent electric utilities on a short term basis.
- (d) Responsibility for action to avoid interruption of generation and to improve power transmission system performance.
- (e) Collection in real time mode of all data of the power system for storing in a data bank which will be used for the authority's forward planning and statistical data.
- (f) Supervision of security within the network.
- (g) Co-ordination of recovery actions after a major black-out.
- (h) Load frequency control actions.

The telecontrol system required to fulfil the above functions is normally computer based and includes visual display units, event and data loggers, and an overall HV transmission system configuration diagram (mimic board).

The size of the computer system will be dependent on whether provision is made for an extended real time program (e.g. State Estimation, Security Assessment, Hydro Thermal Optimization etc.) or whether these tasks are carried out in an off-line mode on a separate computer installation.

#### 2.1.3.2 Functions of the Area Control Centre (ACC)

The functions of the Area Control Centre would include:

- (a) Carrying out all the NCC instructions including the scheduling of generating plants.
- (b) Dispatching of lower voltages networks.

- (c) Responsibility for authorizing the switching on of the HV transmission system.
- (d) Supervising inter-area MW and MVAR transfers.
- (e) Ensuring adequate transmission capacity and stability.
- (f) Supervising and controlling busbar voltages.
- (g) Remote control of outstations. (Depends on the size of the power network).
- (h) Dealing with unexpected incidents.
- (i) Monitoring of the security of the equipment and the staff.

#### 2.1.3.3 Functions of the District Control Centre (DCC)

If the size of the Area Control system is too large to be handled in one control room, it may well be necessary to introduce another lower level of responsibility, for example a District Control Centre responsible for the management of the distribution system and in very large systems the subtransmission system.

The functions of the District Control Centre would include:

- (a) Liaison with the Area Control Centre.
- (b) Switching of the distribution networks by remote control
- (c) Load shedding.
- (d) Supervising adequate system capacity.
- (e) Dealing with unexpected incidents.
- (f) Monitoring of the security of the equipment and the staff.

The telecontrol system required to fulfil the ACC and DCC functions could be a shared computer based master system, if the control rooms are in the same building. The system would be primarily a data acquisition and display system with remote control facilities. The display facilities would include VDUs and mimic diagrams and event and data loggers.

#### 2.1.3.4 Application Functions at Power Stations/Outstations

Application functions are not normally included in RTUs at power stations/outstations. However, there are stations where some of the allocated tasks such as remedial measures and water surface regulations, are automated. These are usually called local automation functions. With the new computer based equipment in centres and stations, finding the best allocation of functions can cause problems.

### 2.2 CONFIGURATION OF TELECONTROL SYSTEM EQUIPMENT

#### 2.2.1 General

A telecontrol system links the outstations, DCC, ACC and NCC. The system should have sufficient redundancy to ensure that no loss of equipment or telecommunication channels will cause loss of information from a major part of the HV network. Reliability must therefore be of such a level that a single failure can cause loss of information from isolated stations only. From the telecontrol point of view any grouping of outstations must take this constraint into consideration. To ensure higher reliability, the telecontrol equipment as well as the telecommunication channels may also exceptionally be duplicated.

Information for power system operations, i.e. data transmission, can be transmitted through various network configurations.

The organisation of the data network is probably the most important feature of any large telecontrol network and, as such, requires the appropriate amount of attention.

Data transmission network configurations can be broken down into a number of basic functional elements, which constitute the basis of all composite network configurations. These functional elements are described in sections 2.2.2 and 2.2.3.

A control centre consists of one telecontrol equipment and usually serves more than one outstation. The number of link terminals (data circuit terminating equipment) in a control centre may be more than one. The organisation of data transfer is different in the cases of one link terminal per outstation or one link terminal for all outstations together. This fact has to be taken into account while representing the functional elements by symbols.

The following symbols are used:



Main control centre

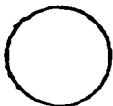


Control centre with one or more link terminals.

The small circles inserted into the symbols for control centres symbolize the number of link terminals per control centre.



Outstation, controlled station



Information collecting, concentrating and/or exchange points.



Data transmission channel



Standby data transmission channel (multirouting).

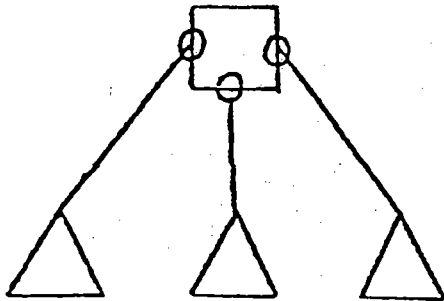
### 2.2.2 Configurations between a Control Centre/Collecting Point and Power Stations/Outstations

#### a) Point-to-point configuration



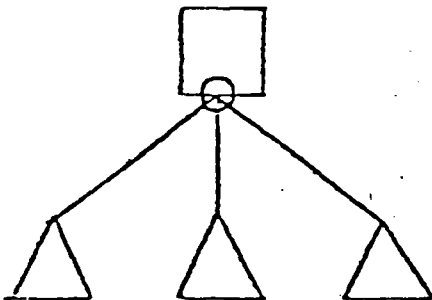
This configuration connects two telecontrol stations and is the simplest type possible.

#### b) Multiple point-to-point configuration

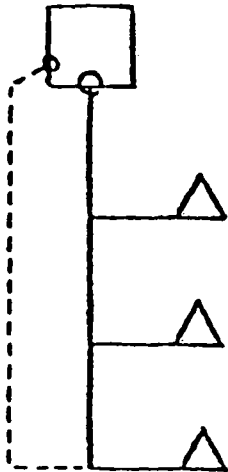


The control centre is connected to the outstations by one link terminal per outstation. At any time all outstations are allowed to transmit data to the control centre which in return may transmit messages to one or more outstations simultaneously.

#### c) Multipoint star configuration



The control centre is connected to more than one outstation by one common link terminal and by common or separate data link equipment. At any time only one outstation is allowed to transmit data to the control centre. The central telecontrol equipment may transmit data either to one or more selected outstations or global messages to all outstations simultaneously.

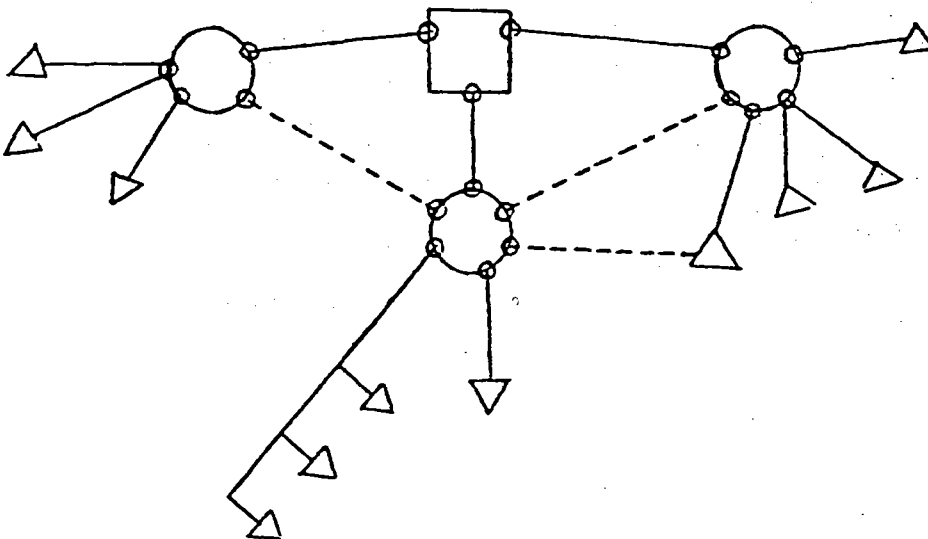


The control centre is connected to more than one outstation by a common path. The restrictions imposed on the exchange between the central and outstations is the same as in the multipoint-star-configuration (2.2.1 c).

The multipoint-partyline-configuration can be completed into a multipoint-ring-configuration by a standby data transmission channel. This is a preferred method to improve the availability of the communication path. If the path is interrupted in some location, full communication is maintained, since every station can be reached from two sides of the ring. Ring configurations are usually of the multipoint type.

#### e) Composite (hybrid) configuration

Configurations of the types 2.2.1 a)-d) can be combined in a great variety of composite configurations. The most important variety is the meshed network configuration in which communication among any stations is required.



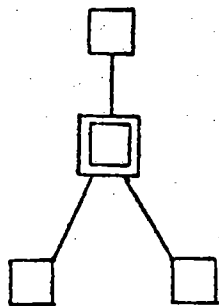
Information collecting, concentrating and exchange points have to be inserted.

Multirouting as shown in subclauses 2.2.1 d) and e) increases the reliability and availability of transmission.

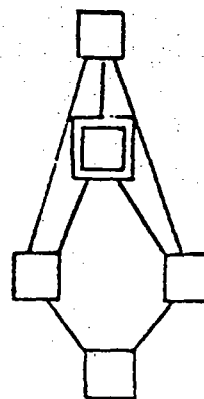
### 2.2.3 Configurations\_Between\_Control\_Centres\_and\_Collecting\_Points

The data transmission network between the control centres and collecting points can be divided mainly into two types, the star structure and the mesh structure.

Selection between the two types depends on the telecommunication network. Other factors affecting the selection are presented in table 2.



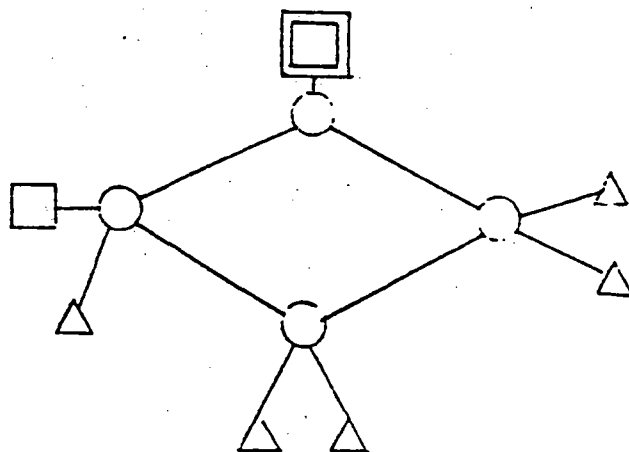
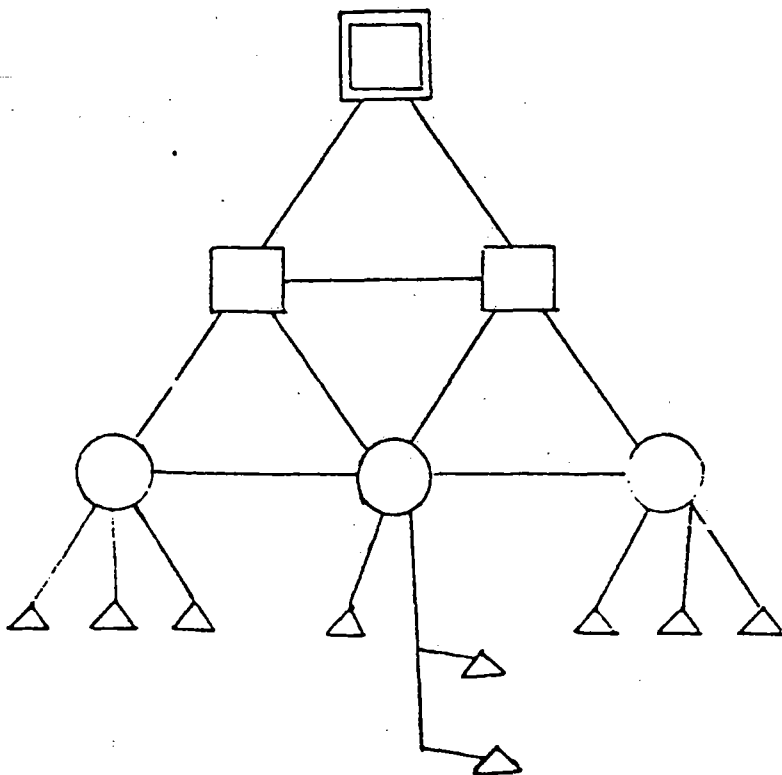
(a) Star structure



(b) Mesh structure

The mesh structure can in practice have a great many different applications. For example loop/ring may be seen as a special case of the mesh structure.

Examples of the mesh structure:



(b2) Loop/ring

| Fundamental configuration<br>Item                          | Star structure                                                                                                                                                              | Mesh structure                                                                   | Remarks |
|------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|---------|
| Security<br>Reliability<br>Availability<br>Maintainability | Since information required at the periphery is concentrated at the upper centre, a problem at that centre can have a considerable effect on the operation of other centres. | A fault in the centre does not effect information transfer around the periphery. |         |
|                                                            | Lines must be duplicated to prevent interruption of information flow.                                                                                                       | Line duplication is not necessary if routing is performed.                       |         |
| Time delay                                                 | Normally constant, because the route is fixed.                                                                                                                              | Normally small variations depending on the routing.                              |         |
| Expandability                                              | Increase of information and number of lower centres is restricted by upper centre capacity.                                                                                 | High expandability, as routing equalizes loads on communication links.           |         |

Table 2. Comparison of Star and Mesh Structure

#### 2.2.4 Telecommunication Channels

Factors which influence the arrangement of telecommunication channels between outstations, power stations and the control centres include the following:

- (a) Response time
- (b) Information transfer efficiency
- (c) Grouping of outstations
- (d) Speed of signalling
- (e) Available channel bandwidth
- (f) Alternative routing

An acceptable response time is achieved through a mutual dependence of factors b-f. For example, if the outstations are connected to the master system on an individual basis or in a point-to-point configuration, the signalling speed can be relatively low (e.g. 50/200 baud). Alternatively, if several outstations are grouped together in a multipoint-partyline-configuration, the signalling speed will have to be correspondingly faster to achieve the same response times (e.g. 600/2400 baud). The grouping of outstations with faster signalling channels tends to make better use of the bandwidth. The number of tandem hops (hops without the regeneration of bit information) on PLC and UHF radio is limited due to channel attenuation and distortion. Therefore, it is not possible to specify data channel bandwidths and the speed of signalling without knowledge of the HV network specifications, and the telecommunication system. In general, however, if multi-purpose PLC or UHF radio circuits are used as carrier channels, the speed of the signalling from the outstations to the District and Area Control Centres will be 50/600 baud, whereas the channels connecting the ACC with the NCC would be 1200/9600 baud.

These matters are treated in greater detail by CIGRE working groups WG35-03 Teletransmission and WG35-04 Transmission Systems.

#### 2.2.4.1 Main/Standby Channels

A channel between the centre and a single outstation is normally not duplicated. The channels between a group of outstations and the centre will generally be duplicated as 'Main' and 'Standby' Channels. Where it is possible, the standby channel should be routed differently from the main channel to avoid simultaneous loss of both channels due to the same fault. Similarly the channels between the ACC and the NCC will be duplicated as 'main' and 'standby' and, if possible, routed over different communication circuits.

#### 2.2.4.2 Mesh Structure

An alternative method to the main/standby channel system is to provide a message switching system in which the data from outstations and centres are collected at various concentration or collecting points which are connected together in a mesh structure allowing at least two alternative routes to and between the Control Centres.

#### 2.2.5 Control Centre Structure in Telecontrol Systems

The control centre structure in telecontrol systems naturally varies depending on the operational organisation, the extent of control, the number of desired functions, and so on.

The computer based master systems at the National Control Centre and Area Control Centres must be fully redundant from the hardware point of view and carefully configured, so that no single fault can put the system out of action. This applies particularly to power supplies.

The structure of the master system (see Appendix C) has been based on a medium or large HV network, which makes it highly desirable to have a front-end computer system to handle the data acquisition. The duplicated main

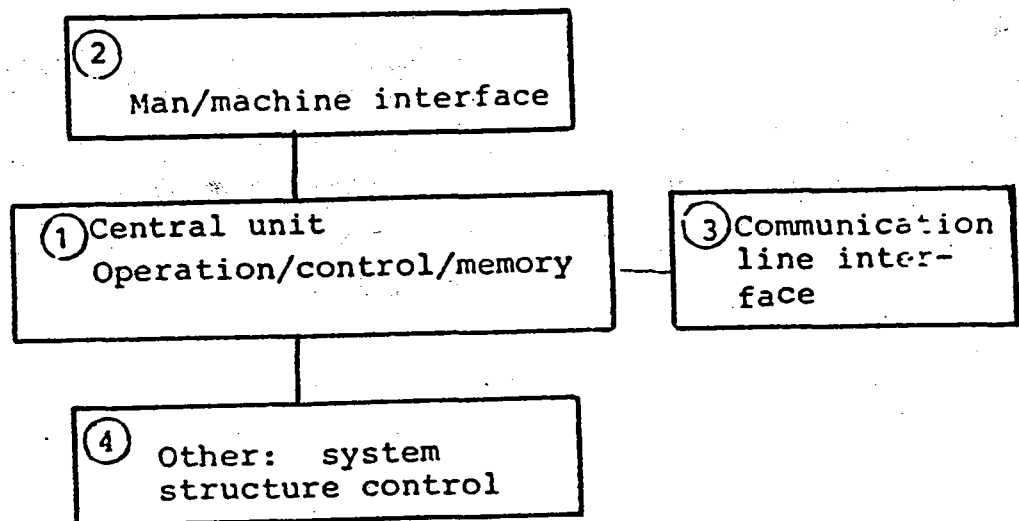
computers are then relieved of this task which otherwise might require too large a percentage of their load and have a serious effect on the VDU display response times and capacity for real time program execution.

Of two duplicated main computers in operation, one (on-line computer) is working whereas the other is meant for back-up purposes (hot stand-by). Both are updated continuously from the front-end system. Various changes in constants and parameters (Operational Data Amendment, ODA) can be carried out on the back-up computer and transferred automatically to the on-line computer via an inter-computer data link between the main computers.

System Amendment (SAM) is also carried out on the back-up computer.

#### 2.2.5.1 Hardware Function and Structure

The hardware function modules can be divided into four main parts as follows:



The modules are explained in detail in Table 3.

|   | Hardware function module        | Purpose                                              | Equipment                                                                                                                         |
|---|---------------------------------|------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|
| 1 | Central unit                    | Heart of business processing,<br>(See table 4)       | <ul style="list-style-type: none"> <li>o Central processor</li> <li>o Internal memory</li> <li>o External memory</li> </ul>       |
|   | Man machine interface           | Interface for operation and maintenance personnel    | <ul style="list-style-type: none"> <li>o See table 5</li> </ul>                                                                   |
| 3 | Communication line interface    | For communication between each station of the system | Front end processor or network node<br>Communication control adapter                                                              |
| 4 | Other: system structure control | Control of tele-control system structure             | <ul style="list-style-type: none"> <li>o Switching equipment of duplicated systems</li> <li>o Line switching equipment</li> </ul> |

Table 3. Hardware functions

### 2.2.5.2 Software Function and Structure

The complexity of the Control Centre software does not allow it to be described in detail. The main part of the operation programs controlling the system is called the operating system.

The operating system of the telecontrol system is developed by each manufacturer and tailored to the computer itself. It can differ in each case in the following four aspects:

(a) Basic design of the operating system

Operating systems can either be designed as a series of different complete systems, from which the user selects the most appropriate one, or as a group of program packages from which the user selects the programs he needs and assembles them to form a complete system. (For one example see Appendix D.)

(b) The limitation of the operating system

The operating system may or may not be considered to include language compiling, various facilities such as system editing, various diagnostic programs, simulators and data generators, etc., in addition to the monitor.

(c) The level of the operating system support for applications

The operating system may control peripherals either directly or through the application programs.

(d) Terminology

"Task", "program", "job" and "background job", for example, all have different meanings in different systems.

The main functions of the operating system are:

- (a) - task control
- (b) - input/output control
- (c) - system operation control
- (d) - file management
- (e) - job management

They are explained in detail in Table 4.

## 2.3 MAN/MACHINE INTERFACE

### 2.3.1 General

The basic requirements of the man/machine interface are to provide:

- operational personnel with adequate and reliable real-time information on the actual status of the power system and operating possibilities to control the power system in both normal and emergency situations,
- maintenance and supporting personnel with adequate information and facilities to maintain and update the system,
- protection against human errors,
- guidance for the operator in emergency situations, simulation studies.

### 2.3.2 Functions

The functions of the man/machine interface can be divided into six main groups which can be described as:

- Indications,  
to monitor the actual power circuit arrangements and all kinds of alarms.
- Measurements,  
to supervise the loading situations, voltages, production and consumption of electric energy.
- Commands,  
to carry out the different kinds of commands in order to initiate a change of state in the operational power equipment.

|   | Classification           | Operating system function                    | Explanation                                                                                                |
|---|--------------------------|----------------------------------------------|------------------------------------------------------------------------------------------------------------|
| a | Task control             | Main memory control                          | Manages the efficient allocation of work areas to tasks                                                    |
|   |                          | Task priority and parallel processing        | Controls event and wait statuses and schedules task execution according to task priority level.            |
|   |                          | Interrupt processing                         | Analyses interrupts generated by internal and external events and executes the appropriate routine.        |
|   |                          | Timer control                                | Controls internal date and time and performs task start, delay, repeated start, indicated time start, etc. |
| b | Input/output control     | Auxiliary memory input/output control        | Input/output processing for the auxiliary memory devices such as drums, discs and magnetic tapes.          |
|   |                          | Process input/output processing              | Input/output control of digital input/output, analog input/output, etc.                                    |
|   |                          | Peripheral equipment input/output processing | Input/output processing for typewriters, CRTs, line printers, etc.                                         |
|   |                          | Communication input/output processing        | Input/output processing relating to information transmission with other centres or remote terminals        |
|   |                          | Connection processing between computers      | Input/output processing relating to information transfer between computers                                 |
| c | System operation control | Error processing                             | Supervises the operating state of system devices and processes alarms, aborts and change-overs, etc.       |
|   |                          | Multisystem control                          | Supervision of multisystem, data transfer, device transfer.                                                |
|   |                          | Control between hierarchical levels          | Controls data transmission, back up transfer, starting/restarting, etc. between hierarchical levels.       |
| d | File management          | File management                              | Access protection, control of reading and writing on main storage, extended storage and auxiliary storage  |
| e | Job management           | Operation utilities                          | Tasks necessary for system operation and maintenance. Used on line or off line.                            |
|   |                          | Language processing                          | Compiling, assembling, and linking of source programs and conversion to executable programs                |
|   |                          | Program development utilities                | Editing, copying, checking, test runs, etc.                                                                |

Table 4. Main Functions of the Operating System

- Data base interactions.
- System amendment and maintenance,  
to update the telecontrol system due to extensions  
and changes in the power system and to monitor the tele-  
control system itself.
- Control and supervision of the data acquisition system.

### 2.3.3 Equipment

The functions mentioned above can be carried out by the following main items of hardware (Table 5):

#### - Mimic diagram

It is used to represent the topology and sometimes measurements of the power network. Active and/or passive elements on the mimic diagram may be used to display the state or to initiate commands to the power system equipment.

Table 5 includes details of the functions which can be accommodated on a mimic diagram. In practice, however, the actual number and type of functions included depend on the operation philosophy. The modern trend, particularly in the case of dispatching centres, is to reduce the functions included on the mimic, but in other cases mimic diagrams may offer advantages which justify their use for many of the functions listed.

In some cases slide projectors are used for static diagrams of the objects, e.g. for complementary purposes in a back-up mode.

#### - Control console

The main purpose of the control console is to provide command facilities for an operator. In addition to that it also provides some monitoring facilities which complement the mimic diagram.

#### - Visual display unit (VDU)

In addition to the equipment mentioned above, some kind of VDU-system (CRT-display at the moment) is selected to display more detailed diagrams of the power system and all additional information collected.

| Object                                                            | Power system                                                                                                                   |                                                                                        |                                                                                      | Telecontrol system                                                                                  |
|-------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| Function<br>Equipment                                             | Indication                                                                                                                     | Measurement                                                                            | Command                                                                              | System amendment & Maintenance                                                                      |
| Mimic diagram                                                     | Annunciator<br>Multi-aspect indicator<br>Semaphore<br>Discrepancy switch<br>Indication lamp<br>one/multi colour                | Analog panel meter<br>Numeric display<br>Segment display<br>e.g. quartiles<br>Recorder | Control discrepancy switch<br>Push-button                                            | Lamps<br>Push-buttons                                                                               |
| Control console                                                   | Push-button lamp<br>Indication lamp<br>one/multi colour<br>Discrepancy switch<br>Control console<br>Control discrepancy switch | Analog panel meter<br>Numeric display<br>Segment display<br>Recorder                   | Push-button<br>Control discrepancy switch<br>Keyboard                                | (Push-buttons<br>(to control stand-by devices))                                                     |
| Video-display (CRT)<br>Alphanumeric<br>Semigraphic<br>Fullgraphic | Symbol<br>Alphanumeric sign                                                                                                    | Numeric value<br>Curve<br>Bar diagram<br>Thermometric scales                           | Keys and switches<br>Cursor (track ball, joy stick, key)<br>Light pen<br>Poke points | Alphanumeric value<br>Symbols<br>Keys (for up dating)<br>(for traffic volume, line quality etc.)    |
| Other peripheral equipment                                        | CRT -hard copy<br>Typewriter<br>Lineprinter                                                                                    | CRT -hard copy<br>Typewriter<br>Lineprinter                                            | Logging typewriter                                                                   | Typewriter (logging)<br>Lineprinter (statistics)                                                    |
| Maintenance<br>Control console                                    | _____                                                                                                                          | _____                                                                                  | _____                                                                                | Indication lamps (for system and transmission alarms)<br>Push-buttons (to control stand-by devices) |

Table 5. Man/Machine Interface

Control console and visual display units are usually combined.

- Other peripheral equipment

The VDU system is often equipped with a separate hard-copy device which will make it possible to copy the emergency situations on the power system for later studies.

The other peripheral equipment connected to a computer system and used in the man/machine interfaces are different kinds of printers on which reports, lists and tables are printed.

- Maintenance panel

This is used for monitoring the operations of the telecontrol system itself and for the switching of the standby devices.

In modern systems it is possible, on a limited basis, to use a control console and to have special VDUs for maintenance purposes.

#### 2.3.4 Structure and Availability

For the proper operation of the telecontrol system it is important that the structure of the control centre is carefully investigated. In the case of the computer configuration the way the man/machine equipment is connected can have considerable influence on the availability of the whole system.

Because of high availability requirements on the man/machine interface it is not advisable to connect all the equipment to the same computer - not even in the case of hot standby.

The structure of larger systems is shown in Appendix C, Fig. 1a. In that structure the mimic diagram and the control console are connected to the front-end computers and the VDUs and other peripherals are connected to the main computer. The VDU systems are often under the control of two or more drivers (see Appendix C).

Nearly the same availability can be achieved by replacing the usual standby system with three computers instead of four (Appendix C, Fig. 1b) and dividing the functions in normal situations among the three computers. In case of failure the two remaining computers can take the whole load, but with an adverse effect on the response time.

To achieve the higher availability offered by multiple computer systems it is essential that special attention should be given to the design of the change-over and the switching arrangements between computers.

## 2.4 EMERGENCY SITUATION IN CONTROL SYSTEMS

### 2.4.1 General

An emergency situation in the control system can be defined as a situation where a fault has already occurred.

The emergency situation can be dealt with in different ways from the operational point of view due to system failure consequences.

In the most serious cases of a failure situation it should be possible to supervise and control the power system from a sublevel, or the tasks of the control centre should be transferred to an adjacent centre. This centre then collects the information required according to a pre-determined scheme. In an extreme emergency, control can be exercised from local control rooms and for this reason the advantages of retaining such control rooms should be borne in mind even when comprehensive centralized control is implemented. A further important matter is to ensure that a minimum staff is available to man local control rooms in such an extreme situation. The local control rooms, of course, also offer important advantages in relation to station maintenance operations.

As a last action, when no local control rooms are available, the equipment can be operated directly, but the dangers inherent in such a method of operation should be borne in mind, and this is a further reason for retaining the local control rooms.

The recovery from an emergency situation can be divided into different steps:

- alarming of the fault
- fault isolation
- repair of the fault

#### 2.4.2     Alarms

The ability for alarming of a fault depends on how extensive is the supervision over the faulty equipment or function. It is very important that both working and standby equipments are supervised to ensure high availability. Fault alarms must also be indicated where there is someone able to understand and interpret them and to initiate maintenance and repair action. Alarms must also be analyzed to see how they affect the ability to supervise and control power stations and the power network. A failure which for example occurs in an interface in the control centre or collecting point (concentrator) can be of varying seriousness to the dispatcher the consequences depend mainly on the structure of the control system.

#### 2.4.3     Fault Isolation

To facilitate fault isolation in the equipment or a function, the system structure is divided into a number of independent units such as line equipment, RTUs, CPU, interface and modems. The division of alarms (fault isolation) is very important for the initiation of repair action and for choosing the correct measuring equipment, spare parts and personnel for the repair action.

The supervisory requirements of the system itself and the distribution of information in an emergency situation are dependent on the system structure, maintenance organisation, personnel skill and availability requirements.

#### 2.4.4 Fault Repair

For making an effective repair action it is very important to have high maintainability and rapid access to maintenance resources, e.g. skilled personnel, spare parts, instruments etc.

### 3. FUTURE TRENDS

#### 3.1 GENERAL

In order to be able to say something about the future one has to define the word "future". It is also necessary to define whether the description applies to a few experimental systems or to the great majority of the systems. Here we assume the tendency for the majority of new installations during the next ten years. The rapidly advancing technology in the field of electronics and computer programming makes it impossible to look far ahead.

It should also be pointed out that the requirements of the "user" will to a very great extent be the guiding factor for the development of new systems. This means that SC32, SC23 and others should define what is their view of the future requirements.

Assuming the growth of the electric power systems as well as the rapid increase in the electronics and new technologies for the use of computers, it should be possible to draw some conclusions. Factors which will have influence could be the use of microcomputers, better communication with fibre optics and developments in computer programming techniques.

#### 3.2 CONFIGURATION OF TASKS

The number of new tasks in the field of telecontrol will increase in the near future. A new advanced technology will enable more exact and versatile performances of the tasks than at present (for example time tagging with

centralized standard time, Snap shot, local data processing and storing).

Increasing intelligence in the form of micro/minicomputers will enable data compression by using several types of group commands, initiation of longer automatic operation sequences and data transmission of pre-processed data.

### 3.3 CONFIGURATION OF TELECONTROL SYSTEM

The most significant trend in the development of the tele-control hardware will be an increase in intelligence in each section of the hardware. It will enable the use of local automation in combination with remote control in a systematic way.

Using microprocessors as a component, most devices will be interfaced to each other, at least in larger systems, by some kind of internal bus design (e.g. the IEC-bus). In this kind of solution it is possible to distribute the intelligence and, as a consequence, to increase the availability of the functions in the system.

What is mentioned above is valid both in control centre installations and in the configuration of the data transmission networks. The programs for the mesh structure type of data exchange networks will become more general.

### 3.4 MAN/MACHINE INTERFACE

The most significant trend in the development of man/machine interfaces will be an increase in interaction. This will be possible because of the rapid development in the area of computer technology and the decrease in the price of computer memories. As a result, it will be economically feasible to develop the VDU systems in particular.

The VDU systems will take over functions from other types of interfaces. The CRT systems will be developed towards full graphic and may include a moving map type feature. New VDU types other than CRTs may also be developed.

A combination of the mimic diagram and the control console will also be developed and could prove to be more useful and versatile by using microprocessors.

### 3.5 EMERGENCY SITUATIONS IN CONTROL SYSTEMS

Emergency situations in control systems can be caused by many types of equipment failures and be of varying seriousness. It would not be practical to list all the possible failures in a control system and then evaluate whether they could lead to an emergency situation or not. Therefore, in the future it seems better to define different emergency situations and specify requirements on the control system behaviour in these cases, which for example could be:

1. Total system breakdown from the operator point-of-view caused by e.g. the unavailability of the whole communication network or the whole man/machine system, a power feed breakdown.etc.
2. Unavailability of a group of stations caused by e.g. a node failure.
3. Unavailability of a single station caused by e.g. RTU failure, a local communication line failure,etc
4. Overloaded control system caused by e.g. a major power system breakdown, the addition of new functions or new stations, etc.

In situations 1-3 alarms should not only be presented plainly but their impact on the dispatcher's ability to supervise and operate the power system should also be interpreted automatically. The correct maintenance and repair actions can also be pointed out automatically. In the future, control systems will probably become more and more intelligent and precise in the following:-

- fault isolation
- automatic interpretation of alarms given to dispatchers and maintenance personnel
- storing of fault finding routines
- ability of remote restarting of degraded systems
- self-healing according to schemes prepared in advance
- guidance of repair action

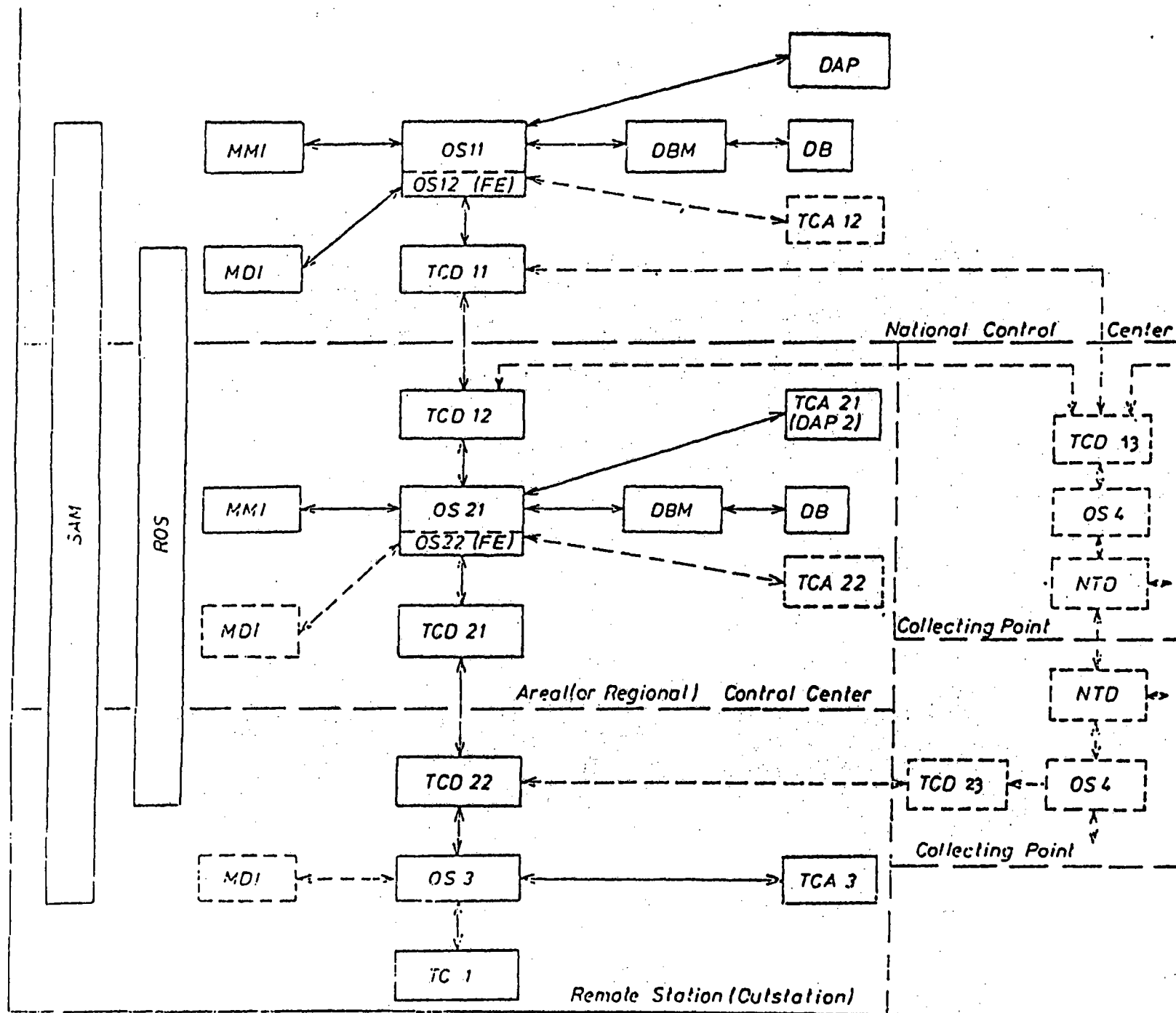
LIST OF ABBREVIATIONS

|      |                                                                                                                                    |
|------|------------------------------------------------------------------------------------------------------------------------------------|
| ACK  | An acknowledgement signal sent between the RTU and the CC to indicate that a control function has been successful                  |
| ADC  | Analog to Digital Converter - A device for converting analog signals to an equivalent digital form.                                |
| BCD  | Binary Coded Decimal - signals encoded in such a way that they can easily be represented as a decimal number.                      |
| CC   | Control Centre - where information for dispatching or remote control is used.                                                      |
| CP   | Collecting Point - a point in the system where information transfer between RTUs and the CC is marshalled for onward transmission. |
| CPU  | Central Processing Unit - the main arithmetical and logical part of a computer.                                                    |
| CRT  | Cathode Ray Tube - see VDU.                                                                                                        |
| DAC  | Digital to Analog Converter - a device for converting digital signals to an equivalent analog form.                                |
| DCC  | District Control Centre                                                                                                            |
| NACK | An acknowledgement signal sent between the RTU and the CC to indicate that a control function has been unsuccessful.               |
| RTU  | Remote Terminal Unit - the outstation of the remote control system.                                                                |
| VDU  | Visual Display Unit - a device used to give tabular and/or graphical information regarding the state of the network.               |

## APPENDIX A2

### LIST OF DEFINITIONS

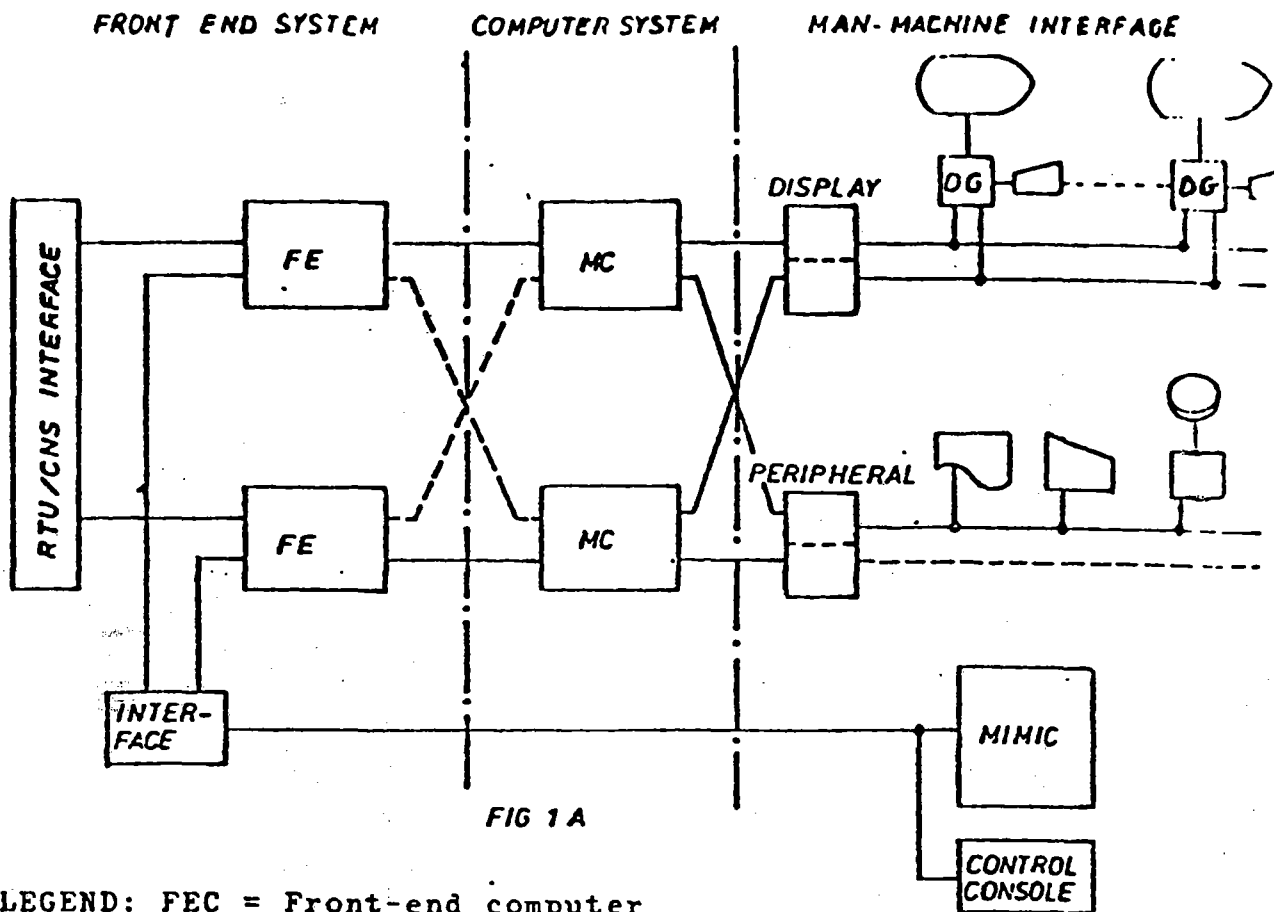
|                            |                                                                                                                                                                                                                                      |
|----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CHECKBACK                  | Method of increasing the security of coding for control functions by re-transmitting the code received at the RTU back to the CC in order to check its validity.                                                                     |
| CHECK FORWARD              | Method of increasing the security of coding for control functions either by transmitting the code twice (either sequentially or by using two paths) or by using an error correcting code.                                            |
| DISPATCHING CENTRE         | A CC from where the generation and loading of the electrical network is controlled.                                                                                                                                                  |
| GRAY CODE                  | A coding method in which each successive step gives only a one bit change in the code (very useful for make before break situations such as tap position inds).                                                                      |
| PULSE LENGTH CHECK         | A method of checking that all pulses are within a specified length (it is similar to signal quality detection but checks the digital pulses).                                                                                        |
| PULSE NUMBER CHECK         | A method of checking where the number of pulses to be received is known and can be checked.                                                                                                                                          |
| REMOTE CONTROL CENTRE      | A CC from where remotely controlled stations and plant are actually controlled.                                                                                                                                                      |
| SHANNON'S SAMPLING THEOREM | This states that a function must be sampled at a rate no less than twice the highest frequency contained in the function if no information is to be lost (this is a theoretical figure, in practice five times is usually required). |
| SIGNAL QUALITY DETECTION   | A method of checking in the modem the quality of the received signal.                                                                                                                                                                |
| TELECONTROL CENTRE         | The general term for Remote Control Centres and Dispatching Centres.                                                                                                                                                                 |



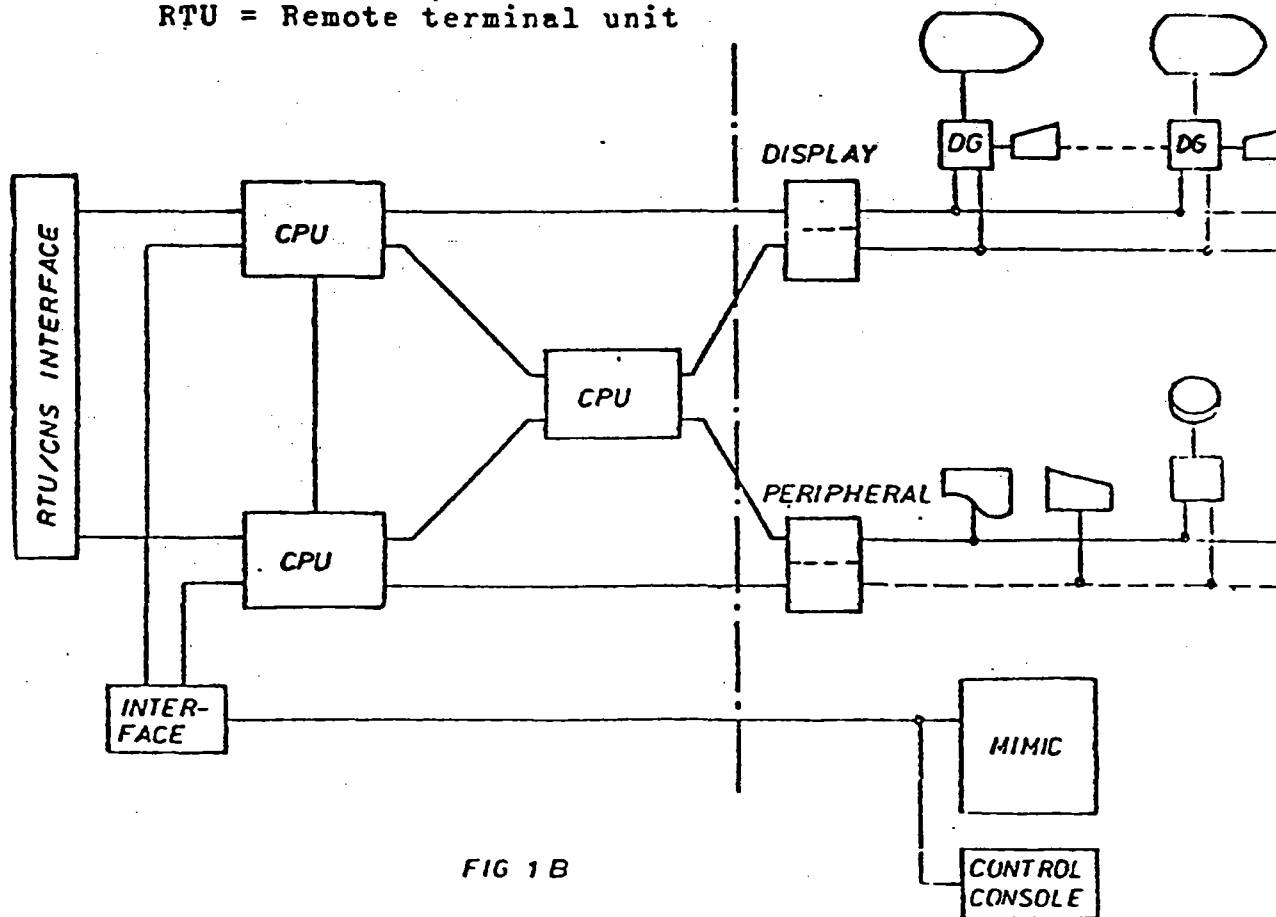
- DAP DISPATCH APPLICATION PROGRAM  
 OS OPERATING SYSTEM  
 TCD COMMUNICATION DRIVER  
 TCA TELECONTROL APPLICATION PROGRAM  
 MMI MAN MACHINE INTERFACE (HIGH QUALITY)  
 MDI MIMIC DIAGRAM INTERFACE (LOWER QUALITY)  
 DBM DATA BASE MANAGEMENT  
 DB DATA BASE  
 FE FRONT END  
 TCI TELECONTROL INTERFACE  
 ROS ROUTE OPERATING SYSTEM  
 SAM SYSTEM AMENDMENT  
 NTD NETWORK TRAFFIC DATA

POSSIBLE HIERARCHICAL DATA  
 STRUCTURE FOR  
 POWER SYSTEM DISPATCH AND  
 CONTROL

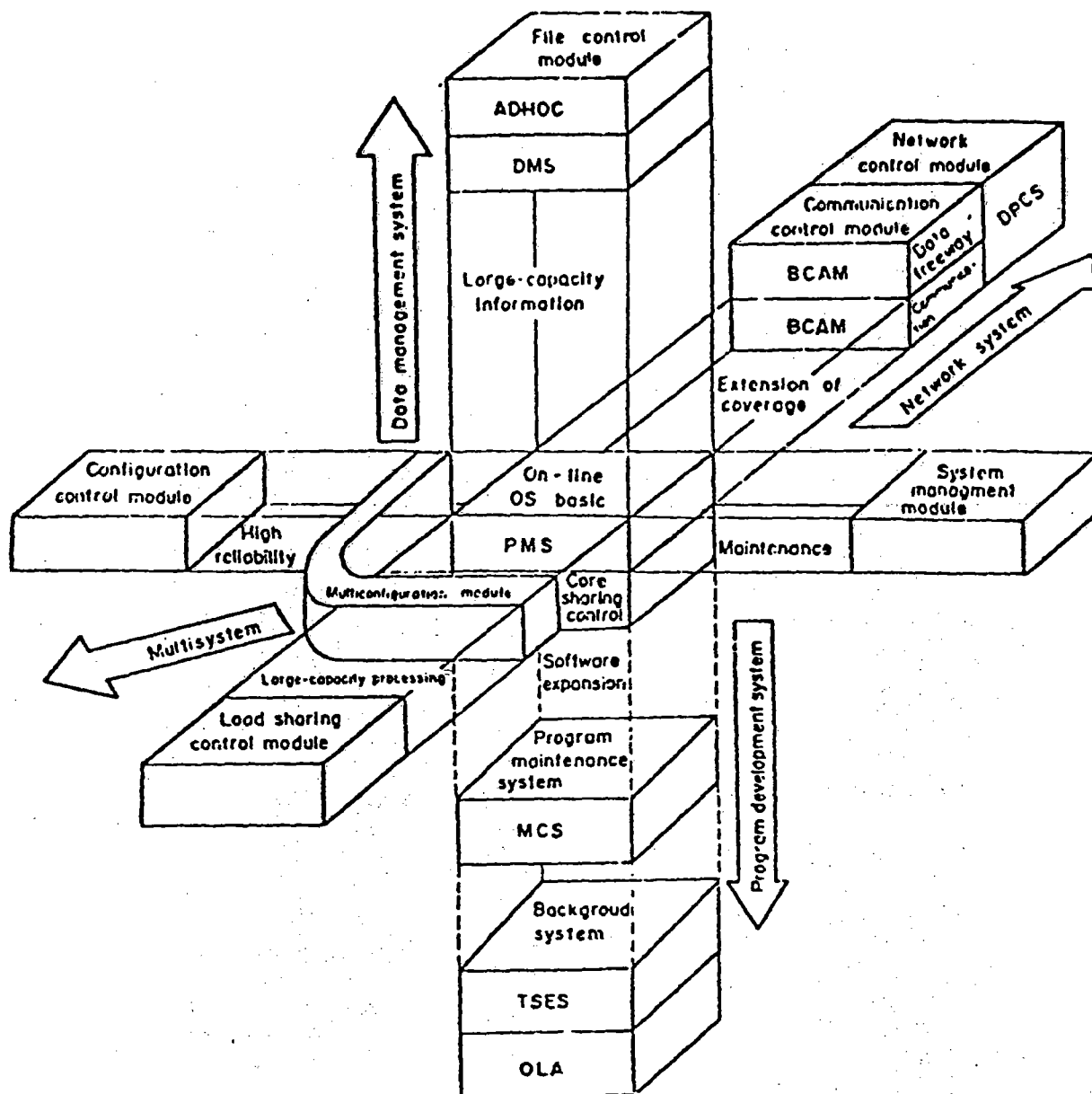
# APPENDIX C



LEGEND: FEC = Front-end computer  
 MC = Main computer  
 DG = Display generator  
 CNS = Communication network system  
 RTU = Remote terminal unit



Master Computer System Structure



Note : PMS = Process monitor system  
 BCAM = Basic communication access module  
 DMS = Data management system  
 ADHOC = Advanced data handler for on-line use  
 MCS = Man-machine communication system  
 TSES = Time-sharing executive system  
 OLA = On-line assembler  
 DPCS = Data processing control system

CONCEPTUAL DIAGRAM OF  
 SOFTWARE STRUCTURE FOR  
 POWER SYSTEM CONTROL

**REPORT 2**

**PART 1**

**OPERATIONAL AND FUNCTIONAL  
REQUIREMENTS FOR TELECONTROL  
SYSTEMS**

**CHAPTERS 1, 2, 3  
REMOTE TERMINAL UNIT**

| CONTENTS                                                       | Page |
|----------------------------------------------------------------|------|
| 1 FOREWORD                                                     | 3    |
| 1.1 General                                                    | 3    |
| 1.2 Analysis of the Operational and Functional requirements    | 3    |
| 1.3 Topics not covered                                         | 4    |
| 2 GENERAL TELECONTROL FUNCTIONS                                | 5    |
| 2.1 Basic Functions for Dispatching and Remote Control Centres | 5    |
| 2.2 Telecontrol Functions                                      | 6    |
| 2.2.1 Data Transmission for Dispatching Purposes               | 6    |
| 2.2.2 Data Transmission for Remote Control Purposes            | 7    |
| 3 REMOTE TERMINAL UNITS                                        | 8    |
| 3.1 Introduction                                               | 8    |
| 3.2 Teleswitching                                              | 9    |
| 3.2.1 Classification                                           | 9    |
| 3.2.2 Output Signal                                            | 10   |
| 3.2.3 Processing                                               | 11   |
| 3.2.4 Transmission Requirements                                | 13   |
| 3.2.5 Test Command (Dummy Command)                             | 15   |
| 3.3 Teleindication                                             | 15   |
| 3.3.1 Input Form                                               | 15   |
| 3.3.1.1 According to Presentation Format                       | 15   |
| 3.3.1.2 According to Presentation Time                         | 16   |
| 3.3.1.3 According to RTU Processing                            | 17   |
| 3.3.2 Input Circuit                                            | 17   |
| 3.3.3 Processing                                               | 17   |
| 3.3.4 Transmission Requirements                                | 19   |
| 3.3.5 Reliability of the Input Circuits                        | 22   |
| 3.3.6 Check Information                                        | 22   |

|                                                      | Page |
|------------------------------------------------------|------|
| 3.4        Telemetering and Telecounting             | 22   |
| 3.4.1     General                                    | 22   |
| 3.4.2     Types of Input Signals                     | 23   |
| 3.4.2.1   Analog Measurand                           | 23   |
| 3.4.2.2   Pulse Information                          | 25   |
| 3.4.2.3   Parallel Coded information                 | 26   |
| 3.4.2.4   Isolation                                  | 26   |
| 3.4.3     Processing                                 | 26   |
| 3.4.3.1   On Demand Transmission                     | 26   |
| 3.4.3.2   Cyclic Transmission                        | 27   |
| 3.4.3.3   Special Procedures-examples                | 27   |
| 3.4.3.4   Snapshot and Filtering Techniques          | 28   |
| 3.4.4     Accuracy                                   | 28   |
| 3.4.5     Transmission Requirements                  | 29   |
| 3.4.6     Input Reliability                          | 30   |
| 3.5        Set Point Commands                        | 30   |
| 3.5.1     General                                    | 30   |
| 3.5.2     Processing in the RTU                      | 31   |
| 3.5.3     Output                                     | 31   |
| 3.5.4     Transmission Requirements                  | 32   |
| 3.5.5     Instruction Commands                       | 32   |
| 3.6        Synchronizing Signal                      | 33   |
| 3.6.1     General                                    | 33   |
| 3.6.2     Interface                                  | 33   |
| 3.6.3     Processing                                 | 34   |
| 3.6.4     Transmission Requirements                  | 34   |
| 3.7        Power Supplies                            | 35   |
| 3.8        Maintenance                               | 35   |
| 4           REMOTE CONTROL CENTRES (to be developed) |      |
| 5           DISPATCHING CENTRES (to be developed)    |      |
| 6           DATA TRANSMISSION (to be developed)      |      |

## APPENDICES

## 1            FOREWORD

### 1.1          GENERAL

This report covers the operational and functional requirements of electric power system telecontrol systems. User requirements are presented to cover an area not yet treated by Cigre and to provide the necessary elements for the telecontrol equipment standards activities of the IEC Technical Committee n. 57.

Functions described are:

- a)    the remote control of unmanned stations
- b)    the monitoring and supervision of power systems  
      (dispatching systems)

These remote control and dispatching functions are used both in integrated telecontrol systems and where two different telecontrol systems are used.

This approach is intended to clarify the various concepts of power system operation and control. In very large power systems, the remote control and dispatching systems may be two different sub-systems, control centers may be different - as well as telecontrol requirements - even though they belong to the same hierarchical control system. The operational and functional requirements of the two above mentioned sub-systems must be known and coordinated in order to have an integrated control system.

### 1.2          ANALYSIS OF THE OPERATIONAL AND FUNCTIONAL REQUIREMENTS

The analysis of the operational and functional requirements in telecontrol systems deals with:

- 1.    The general telecontrol functions
- 2.    Remote Terminal Units (RTUs)
- 3.    Remote Control Centres
- 4.    Dispatching Centres
- 5.    Data transmission

The above five items are the titles of the following five chapters of this report.

Chapter 2 is an overview of the basic functions of telecontrol systems with specific reference to dispatching and remote control systems.

Chapter 3 deals with RTUs and the data transmission between RTUs and Control Centres (CCs) and between RTUs and Collecting Points (CPs) when a CP network is interposed between RTUs and CCs. Emphasis is placed on the functional requirements and the fundamental characteristics even though examples of both good and poor solutions are illustrated. For the data transmission protocols reference is made to Report No 3 of CIGRE SC35 WG01.

Chapter 4 describes the operational and functional requirements of Remote Control Centres.

Chapter 5 deals with the operational and functional requirements of Dispatching Centres.

The functions to be performed are identified and characterized by the corresponding requirements.

Chapter 6 summarizes the functional requirements of data transmission.

Appendices are attached to the report when they are needed.

### 1.3 TOPICS NOT COVERED

The following fields are not covered in this report:

- a) local fault recording for keeping track of pre- and postfault information,
- b) recording of the most significant electrical variables in pre- and postfault conditions,
- c) local recording of sequence of events at the remote station,
- d) power plant automation which is independent of the telecontrol functions,
- e) communication channels between remote stations and centres,
- f) control functions at the dispatching centres which are outside the data transmission and supervisory functions, (e.g. economic dispatch, security, and other automatic functions) which normally require large computer systems. This applies to the control centres of large power systems that use front-end computer (s) for communication functions and main computer (s) for power system computations.

The functions a, b, c, d, may be performed by the same equipment that performs the telecontrol functions in the remote station.

## 2 GENERAL TELECONTROL FUNCTIONS

### 2.1 BASIC FUNCTIONS FOR DISPATCHING AND REMOTE CONTROL CENTRES

The first objective of control systems for system dispatching is to achieve operating security - i.e. continuity of operation - of the power system.

The second objective is to improve the economics of power system operation. It is important to note that it is the global power system that must be controlled not just single stations. Therefore the telecontrol systems for system dispatching and security analysis may consist of several hierarchical levels with different functions to be performed by each level.

Complex multi-computer control centres are needed to handle large amounts of data and support advanced application programs.

It is usual that the dispatching Centres for very large power systems supervise the network, but are not involved in switching operations which are performed by personnel at manned stations and remote control centres.

The basic functions performed by remote control centres are the monitoring of both manned and unmanned stations in order to check their integrity and the execution of switching operations.

The latter operations are carried out on the basis of instructions given by the dispatching operators or computers, or in autonomous mode, for example, in the case of disturbance on lines or in case of danger to people or power plant equipment. The remote control centres also collect significant data from the stations in order to inform the maintenance personnel on the nature of the failures and the need for repairs. In some systems, and most smaller systems, the dispatching and remote control functions are combined in one physical location or centre. This integration is favoured by the availability of modern powerful computer systems.

Modern remote control systems are characterized by a strong concentration of stations which are controlled by the same centre. It is necessary to use complex computer systems to manage all of the control functions. The operational constraints - limited number of operations concurrently performed by the operators - and the security objectives are such that automation of stations remains necessary.

It is important that the functions of the automatic devices at the remote stations are coordinated with the control functions carried out at different levels of centres.

## 2.2 TELECONTROL FUNCTIONS

### 2.2.1 Data Transmission for Dispatching Purposes

The data transmission between remote stations and the dispatching centre (\*) is based upon the criterion that the station is considered as a node of the entire power system. With this consideration it is necessary to transmit the following data:

- a) status information of circuit-breakers and isolators in order to know the actual arrangement of lines transformers, generating units, etc;
- b) measurements of real and reactive power flows (on lines, transformers and generating units) bus-bar voltages, frequency (in a limited of nodes) and hydraulic levels (e.g. basins and reservoirs) in order to know the operating conditions of the stations within the power system;
- c) meter readings of real and reactive energy at tie-line points in order to evaluate energy interchanges and balances;
- d) readings of sequence of event recordings with high time resolution in order to know the behavior of the station as a component of the transmission system and of its devices during system disturbances;
- e) other data relevant to the station (such as transformer tap-change information) and the telecontrol equipment (power supply, alarms, etc).

A certain number of remote control signals are sent from dispatching centres to the remote stations. They may be classified into:

- a) regulation signals sent to the generating units for load frequency control;
- b) instruction commands for the attendants in the control room of the manned stations or remote control centres;
- c) a limited number of telecommands for load-shedding, insertion of generating units, etc.

---

(\*) In this case the dispatching centre is the first level of a hierarchy of centres (e.g. Regional Control Centre)



Despite the trend of station automation which considers the automatic devices as an integral part of the station - for instance the automatic device can perform emergency recovery or protection back-up schemes - this Report does not cover this aspect, even though there are cases where the automatic functions are carried out by the RTU itself.

### 3 REMOTE TERMINAL UNITS

#### 3.1 INTRODUCTION

In a telecontrol system, the equipment located at the remote controlled station is often called Remote Terminal Unit (RTU). The RTU would either be hard wired or would have one or more CPUs, with local data input and output devices, memory and data transmission equipment.

The user must specify the precise details of the input, output, processing, and data transmission requirements (including reliability requirements).

The following paragraphs are guidelines for specifications for each type of information i.e.:

- teleswitching
- teleindication
- telemetering and telecounting
- set point commands
- synchronizing signal

The specification of the requirements have to be concentrated on the functions which are necessary for supervising and influencing the physical process in the remote station on a real time basis. This requires detailed descriptions of the intended reactions during and after typical events, disturbances or worst case situations. Temporary conditions as well as accuracy and reliability conditions of data acquisition and reacting functions have to be specified for these circumstances. These requirements have to be described in a way which is not based on specific hardware solutions, so that developing technology may be adopted gradually.

The requirements for the input and output devices are similar for a wide variety of RTU types ranging from the very simple hardwired RTUs to sophisticated processors.

The data transmission between RTU's and the CC (Control Centre) or CP (Collecting Point) is similar in both a self-contained telecontrol system and the first level of a multi-level telecontrol system.

This data transmission is strongly influenced by the RTU characteristics and available telecommunication channels and represents the typical data transmission in the telecontrol field. On the other hand, the data transmission among CC's or CP's has normally little relationship with the RTU data transmission system and is more similar to the general purpose data transmission between computers.

The main points that define the data transmission between RTU's and CC's (or CP's) are:

- telecontrol system configurations;
- data transmission requirements;
- efficiency of the data transmission path
- data transmission procedures.

In certain cases, consideration may have to be given to the available data transmission facilities in the design of the telecontrol system.

In the following paragraphs of this chapter only data transmission requirements are described.

These requirements, strongly characterize the data transmission and consequently the RTU and the handling at the CP as well.

The main requirements are:

- a) very reliable information transmission;
- b) high accuracy;
- c) low information transfer times;
- d) short response times.

### 3.2 TELESWITCHING

#### 3.2.1 Classification

Teleswitching commands may be classified according to several points of view:

- according to the commanded device (one or two state devices)
  - o single command
  - o double command

- according to the associated status information of the commanded device
  - o single-point information
  - o double-point information
  - o without any associated information
- according to the duration of the output signal
  - o pulse command
  - o maintained command
  - o persistent command

(The use of that last category of command should be replaced by set-point whenever possible)

- according to the response time of the commanded device, i.e. the time needed by a two-state device to reach a new steady state upon reception of the beginning of the command.
  - o fast moving devices (typically 200 ms)
  - o slow moving devices (typically 200 ms to 1 sec)
  - o very slow moving devices (typically 1 sec to 30 sec)
- according to the facilities which can be offered by some telecontrol equipment
  - o selection command
  - o group command
  - o broadcast command
  - o instruction command
  - o function command

(in that last category, the automatic device may be in or outside the RTU)

### 3.2.2 Output Signal

Except for the instruction command (for which the output interface has to be defined by the user according to display facilities and audible signalling devices), the output command signal given by the RTU is the same for any commanded device. It is generally in the form of a single pulse of predetermined duration (independent of the duration of the initiation

signal at the CC). Considerable thought has to be given to the security of the output signal. Where the security of the coding requires "double command" mode then it is also reasonable to expect that failure of any one output signal will not hazard the system under control. To this end all commands should depend upon the switching of two independent output signals, one of which may be common to a number of command functions.

Sometimes the output signal is maintained until the change of state is executed or until the end of a predetermined delay longer than the response of the slowest device.

In any case the output signal is given through a barrier device to an interposing relay. The characteristics of the output signal (closed loop to be energized externally, or polarity: duration, level and impedance to be determined), the barrier device and the interposing relay must be matched. Precautions must be taken against the breaking current of the coil of the interposing relay, at the level of the coil and at the level of the barrier device.

If the telecontrol equipment and the interposing relays are not provided by the same contractor in charge of the whole installation, the user must define completely the existing or future interposing relays (worst case). The manufacturer of the telecontrol equipment must take the necessary disposition in order to match the connection and take precautions against electrical interferences even if the device which reduces the breaking current of the coil is out of service.

The output circuit must be protected against grounding (short-circuit).

Another way is to specify the output signal (duration, level, impedance) the output circuit (breaking capability) and possible parasitic signals (shape, level, impedance of the generator, mode of application) in the worst case.

### 3.2.3 Processing

The RTU must interface with at least three kinds of commanded devices

- fast moving device (i.e. reaching a new steady state in less than about 200 milliseconds)

The telecontrol system must be prepared to transmit the related change of state that has to occur in 200 ms and this transmission must be given the highest priority. If there is no change of state, the telecontrol system must proceed with the transmission of other data such as measurands.

The "closed" position of a circuit breaker must always be transmitted even if, after about 20 ms it is re-opened by a protective relay.

- slow and very slow moving device (i.e. moving in some seconds to several minutes).

There is no specific time priority requirement for these devices. The telecontrol system can go on with other functions. The change of state will be transmitted as other information which do not follow the command. The intermediate state that the commanded device may have during the switching operation, may (or may not) be transmitted according to the information processing at the CC.

- device without any associated information

There is no specific time priority requirement for these devices and the telecontrol system can proceed with other functions.

The operator must be able to supervise the performance of an initiated command within the telecontrol equipment and in the peripheral equipment for immediate localisation of errors in case of malfunctions or failures.

- Acceptance and correct transfer of the command message by the telecontrol equipment.
- The execution of the initiated action in the peripheral equipment

This is usually performed by individual return informations or by measurands.

In the case of slow or very slow moving devices the operator must be able to watch the intermediate state information (e.g. the transit state of a slow-moving isolator).

Generally, some acknowledgment information (positive: ACK, or negative: NACK) must be given in order to indicate the good or faulty transmission of the command (in some cases, no answer may be considered as a NACK).

The ACK may be the final new steady state, a feedback measurand or a special message (or special bits in a message corresponding to another function).

Sometimes, it is required that the output of the command is suppressed if the state of the commanded device is indeterminate or in accordance with the command. That precaution, generally taken at the CC (discrepancy switch or equivalent) is sometimes required also at the remote station in the RTU. Facilities should be included to override this constraint especially for test purposes.

If necessary the user may specify that the NACK has two different meanings, e.g:

- NACK 1 for telecontrol equipment failure
- NACK 2 for failure outside telecontrol equipment (delayed for slow moving device)

According to choice of display at the CC (mimic diagram, CRT, printers, etc) ACKs and NACKs will be displayed properly (display includes audible alarms). Generally it is required that the changes of states following a command are displayed distinctively: the RTU or the CC must keep in mind that a command has been given for a device up to the final steady state of the NACK (sometimes there exists two different delays for NACK 2: slow and very slow moving devices). ACK is transmitted from RTU to CC, NACK may be transmitted from RTU or extrapolated at the CC.

### 3.2.4 Transmission Requirements

#### - Reliability

Commands must be transmitted with the highest reliability\*. The probability of wrong commands due to undetected errors should not be more than  $10^{-12}$ , even with the worst signal-to-noise ratio. This value is consistent with the probability of unwanted commands due to failures of the RTU and may be reached due to an error-detecting system of high performance using:

- o signal quality detection
- o coding system
- o pulse length check
- o pulse number check
- o multiple message transmission or check forward technique
- o echo principle or check-back technique
- o select before operate principle
- o a combination of these techniques

The consequence of such a low probability of wrong commands due to undetected errors is that a higher probability of loss of commands due to detected errors, should be accepted: for instance  $\leq 10^{-10}$  when the bit error rate, due to data transmission line is  $\leq 10^{-4}$  - is a probability that may be reached:

---

\* Precautions against human errors, which can be achieved to some extent by local and/or remote lockout techniques or plausibility tests, are outside the scope of this paper as well as programs of aid for the decision.

- due to a data transmission procedure with repetitions either systematic or in the case of NACK no answer.
- by using two or more transmission lines with automatic switching to cope with transmission line failures.

A consequence of these repetitions and the switching is that the transmission delay may increase. An important point is that, generally, on the data transmission lines, the bit error rate reaches high values during limited periods of time (bursts): the repetitions allow these periods to be shaken off. This point should also be taken into account in the automatic data transmission line switching criteria (delayed switching).

For commands, the reliability measures (generally against erroneous output and, only in special cases, against loss) must be taken all the way from initiation at the CC up to output by the RTU in hardware and software aspects, (human error being outside the scope of this report).

The RTU has to ensure that only one output circuit is selected (the one corresponding to the address transmitted in the message sent by the CC) before outputting the command signal. This may be done by decoding, selection of an output, recoding and comparison. The comparison may be done locally (RTU) or better at the CC after retransmission (check back principle).

Precautions in the wiring, wrapping and soldering should be taken to avoid problems with opposite polarities or with the same polarities seen through different impedances appearing on adjacent pins of connectors or connecting strips or in the same cable.

The user has to define the greatest probability of unwanted commands he will accept (e.g.  $10^{-12}$ ) whatever the telecontrol equipment failures (power supply, components, environmental conditions, short circuits, parasitic signals, earthing, breaking of fuses, etc.).

#### - Transmission delay

The second objective to be achieved is a short transmission delay in the range of a few seconds or less (according to the specific application) when the bit error rate is not too high.

### 3.2.5 Test Command (dummy command)

It is usual to include a test command for the purpose of ensuring that the command function is operating correctly in the telecontrol equipment. At the CC, the check command may be one of the operational commands; the RTU must have a device to simulate a switched two state device and its double point information. This check may be performed automatically and in the case of failure an alarm should be given at the CC.

### 3.3 TELEINDICATION

Teleindication is monitored binary information describing the state or the change in state of

- operational equipment in the network
- alarms
- automatic devices

#### 3.3.1 Input form

Information may be classified according to several criteria.

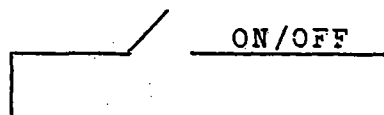
##### 3.3.1.1 According to Presentation Format

According to the presentation format at the remote station

- o single point information

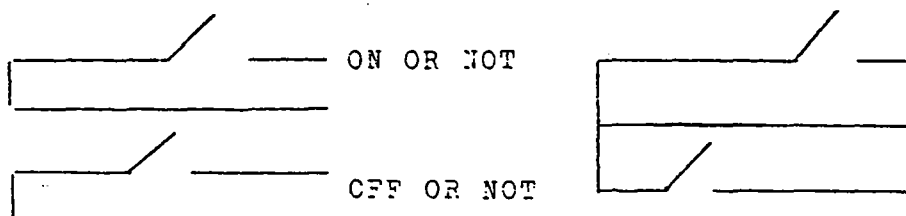
This information is generally given by one contact setting up an open or closed loop.

The significant state is normally the closed loop and exceptionally the open loop.



- o double point information

This information is generally given by two contacts setting up two normally complementary loops (4 wires or 3 wires with common return wire).



This information may take 4 possible states:

1. determined state ON ("ON and not OFF")
2. determined state OFF ("OFF" and not "ON")
3. indeterminate state OFF (Neither ON nor OFF)
4. indeterminate state ON ("ON and OFF")

The first two determined states are prevailing under normal operating conditions.

In some cases (supply failure, break of wiring, short circuit, transit from one state to another state) the states of contacts and loops can be identical i.e. not complementary. This indeterminate state should be transmitted if it lasts longer than a specified time.

The specified time may be chosen short (about 100 ms covering only the response time of the relays that represent the state of a fast moving device) or long (10s or more, covering e.g. the intermediate state of a slow-moving isolator, while in transit).

Generally, because there is only one delay time in the RTU, only the first case is chosen. The intermediate states of slow moving devices may be transmitted and transformed in faulty states at the CC if they last longer than another specified time, (e.g. delayed audible alarm).

### 3.3.1.2 According to Presentation Time

According to the length of time of presentation at the remote station

- o Some simple or old telecontrol equipment defined "persistent information" as having a long duration in each state, for which therefore it was not necessary to store the changes of state in the RTU.
- o In the telecontrol equipment where each change of state (appearance and disappearance) is stored, it is not necessary to distinguish the "persistent information". The duration of each information may be in any proportion, but greater than about 10 ms below which any change of state is considered as noise or relay bounces and therefore rejected. For some input signals, only the transition from OFF to ON is relevant information, while the ON/OFF-transition (disappearance of the state ON) has no physical significance. Typically this is the case with short pulse shaped information where the "ON-state" lasts between 5ms and 5s. It is sometimes specified that the ON/OFF transition of such information is not transmitted in order to accelerate the transmission of significant changes of state: such information is called "incremental information".

ON



### 3.3.1.3 According to RTU Processing

See Sect. 3.3.3

### 3.3.2 Input circuit

Whatever the category of information, the input circuit consists of a barrier device whose characteristics are matched with the input signal. The user must define the electrical interferences which can be superimposed, on the input signal while the manufacturer takes the necessary precautions.

If the input circuit consists of a relay, the breaking current of the coil has to be extinguished. If it is an optocoupler other precautions against the susception of noise, such as repetitive sampling of the input signal with majority evaluation have to be taken.

The filtration of the contact bounces as well as indeterminate states may be done by either hardware or software.

### 3.3.3 Processing

Information may be transmitted

- cyclically
  - on demand
    - o interrogation command
    - o station interrogation command
    - o general interrogation command
  - spontaneously (after a change of state)
    - o in an order of priority
    - o chronologically
- (see also separating capability  
absolute chronology  
time resolution  
centralized absolute chronology)

Note: often several kinds of transmission are used in the same telecontrol equipment with different levels of priority e.g.:

- o spontaneously and on demand
- o spontaneously and cyclically
- o in an order of priority with high priority and chronologically with low priority

- Special case of chronology

o Memory in the RTU

The changes of state should be kept in a RTU memory in the order of occurrence up to the correct transmission to the CC.

That memory contains the address code, the new state of the monitored device and the time, if the absolute chronology is requested.

The size of such a memory must be large enough to contain the nearly worst case of possible changes of state in a given period of time (taking into account the number of changes of states which can be transmitted during that time).

o Overflowing of the memory

When the memory overflows (too many changes of state in the given period), all information without correct chronology has to be marked at the output.

\* For example:

- o a message "end of chronology" is transmitted to the CC just after the last correctly stored change of state
- o a message "recovery of chronology" is transmitted to the CC just before the transmission of the first correctly stored change of state
- o all the changes of state transmitted between "end" and "recovery" of chronology (for which the chronology is uncertain) are transmitted with special bit(s) which indicate that uncertainty

Each information which changes its state between "end" and "recovery" of chronology, but for which the new state is ready beyond "recovery of chronology", is not lost: the new state will be transmitted, only the chronology of occurrence will be lost.

If, on the other hand, the new state is not maintained beyond "recovery of chronology", the change of state is lost. Multiple changes of state of information during this period between "end" and "recovery" of chronology are also lost. Practically, the information losses should be very exceptional because of the memory size.

- \* An alternative mode of operation may be specified when a memory overflow occurs: New events are stored and replace the oldest events that have not been yet transmitted. In this way more importance is given to the most recent events because they might be more useful to understand what actually has been occurring. Old events are not lost since they are logged at the remote station.

- o Time tagging

In order to limit the number of time bits in transmission, the time is not generally coded on 24 hours but only on several minutes (e.g. 8, 10 or 16).

A special message is elaborated and transmitted by the RTU to indicate the change of time module.

An alternative solution is to transmit the elapsed time since the last event; a special message is transmitted if there is no event during the time coding capability.

### 3.3.4 Transmission Requirements

- Reliability

The transmission reliability is defined by the probabilities of erroneous information and of undetected loss of information. These probabilities depend on the transmission code and the data transmission line quality.

The requirements may be different for the two above-mentioned probabilities:

- o wrong information may have a higher probability for cyclic telecontrol systems because the erroneous information is corrected during the following cycles; wrong information is very dangerous in systems where it trips an automatic process.
- o loss of information is most critical for quiescent telecontrol systems.

These probabilities should be fixed by the user, by choosing convenient

- o transmission code with high redundancy,
- o data transmission procedure ensuring correct accepting of an event at the CC before it is reset in the RTU,

by using, as for commands (see sect. 3.2.4)

- o an error-detecting system of high performance
- o automatic retransmission after error detection and automatic switching of transmission lines in case of line failures.

by adding an interrogation of all states periodically or on a long cycle basis and when the CC does not understand what the RTU has tried to transmit.

The probability of wrong information or undetected lost information<sub>1</sub> at a bit error rate of  $10^{-4}$  should be less than  $10^{-10}$  except for fleeting information for which the above mentioned interrogation is useless. A consequence of these low probability figures is that generally the transmission delay increases.

It must be kept in mind that the input circuits at the RTU must be in accordance with the above reliability requirements.

#### Transmission delay

The information may be classified in at least two categories:

- o high priority information such as circuit breaker state information and main alarms
- o low priority information such as isolator state information and minor alarms

The transmission delay for the first category of information should be limited whereas it may be greater for the second category.

It is difficult to give figures for the transmission delays because these delays depend not only on the performance of the telecontrol equipment (procedures of transmission, message lengths, modulation speed, etc) but also

- o on the possible number of changes of state in a short period of time
- o on the use which is made of the received information at the CC
- o on the disturbances on the transmission channels (repetitions, switching of channels).

When there is only one change of state at the out-station, and if the transmission channel is not disturbed at that moment, the transmission delay of this change of state may be specified: less than some seconds (1 to 5 for example), the transmission speed has to be chosen accordingly. When there are many changes of state in a short period of time, there are two possibilities:

- o if the transmission delay is the most critical parameter, the transmission speed must be high
- o if the transmission speed is limited (because of available transmission channel bandwidth), the transmission delays will be determined by the transmission procedures.

If the transmission channels are too noisy, the repetitions and switchings of channels will increase the transmission delays - in any case, the user has to specify the worst case at the CC for instance

- o the possible number of changes of state in one second
- o the possible number of changes of state in 30 seconds
- o and
  - . either the maximum transmission delay for the last change of state
  - . or the highest transmission speed (in this latter case the manufacturer will determine the transmission delay for the last change of state: according to the transmission procedure and the message lengths, without repetition and switching of channels; one telecontrol equipment may have a better performance than another).

Another method is to ask the amount of information that it is possible to transmit (without too noisy transmission conditions) in a period of time e.g. 10 seconds.

The upper limit of good transmission conditions may be fixed at a bit error rate better than or equal to  $10^{-4}$  for example.

When there is a combination of high priority change of state transmission and chronological messages used for logging or for post fault analysis, the chronological messages have the lowest priority and their transmission delays may reach some minutes.

### 3.3.5 Reliability of the Input Circuits

No special precaution can be taken for the input of teleindication except:

- o care of wiring, wrapping or soldering
- o twisted pairs with grounded screen to reduce parasitic signals
- o use of double point information for the most important information in order to detect the failure of an input
- o use of resistors put in parallel with the contact in order to detect the opening of wires between the contacts and the RTU input circuit

### 3.3.6 Check Information

It is usual to require check information for the purpose of ensuring that the telecontrol system is operating correctly.

The RTU initiates a change of state every ten or fifteen minutes. At the CC, these changes of states are monitored in order to give an alarm if there is a failure.

## 3.4 TELEMETERING AND TELECOUNTING

### 3.4.1 General

These information items are supplied at the remote station

- either on a proportional form: analog current or voltage, pulses to be counted over a given period.
- or on an absolute value form according to a code

They represent the value at a given time (instantaneous measurand) or during a given time (integrated measurand counted measurand) of:

- electrical quantities: current, voltage, real or reactive power, frequency
- hydraulic quantities: water flow, level of water, etc
- meteorological quantities: temperature, humidity, sun, rain, wind (speed and direction)
- pollution quantities
- etc

They are transmitted either periodically according to a given cycle or on demand from the CC (by the operator or automatically at a given time).

### 3.4.2 Types of Input Signals

#### 3.4.2.1 Analog Measurand

- In most cases, the information is given in the form of an analog current supplied by the output of an analog transducer.

Sometimes, but it is not recommended, the information is given in the form of an analog voltage.

For the output characteristics of analog transducers see IEC 13 B standards.

The choice of the input range must be easy for each input in the RTU

- The input circuit of the RTU must have:
  - o either a low and precise impedance in d.c. (e.g. not greater than 1000 ohms) for current inputs. This impedance must not vary more than half of the accuracy of the ADC (in %) with variable factors such as temperature, etc
  - o or a very high impedance in d.c. for voltages
- The user may specify that the input circuit is to be designed so that a galvanic isolation is provided from mechanical earth and electrical earth. The check isolation voltage must be specified by the user selecting one of the available standards (e.g. 500 V, 50 Hz, 1 minute)
- The user has also to specify
  - o the differential voltages which can appear between the two input wires
    - o without any perturbation of the measurand
    - o without damage of the input circuit
  - o whether current loops have to be protected against interruptions

Note: in case of exceeding overvoltage only the input circuit may be damaged

- o the residual ripple which can be superimposed on the analog information without any perturbation of the measurand

- The scanning of each input should not introduce a significant error on the analog information
- For each input, a checking device must allow, without disturbing the other inputs
  - o to isolate the input from the Analog to Digital Converter (ADC) and to close the analog circuit if necessary (for currents) on an impedance equal to that of the input circuit
  - o to connect, on ADC side, a test set for maintenance or adjustments
  - o to measure the analog input value
- The analog information is converted to a digital value by an ADC which is generally common for all inputs. The accuracy of the ADC must be defined by the user consistently with the accuracy of the analog information: e.g. better than 1 or 0.5 or 0.2 %).

That accuracy is so defined for all the influence values. If necessary, the user may specify the digital code (binary, BCD or other) and the number of bits he needs (with or without a special bit for the sign).

Note: generally it is not the digital code and the number of bits initiated by the ADC and transmitted by the RTU to the CC that are important (if the accuracy is respected), but the user must impose a specification for outputs (display, connection to a computer, etc). Therefore the manufacturer has the possibility to transcode before outputting.

- The input circuits and the ADC must be capable of tolerating a permanent overload of at least 20 % without damage
- In case of input overload the output message may be:
  - o either the exact value corresponding to the input information
  - o or the maximum value it is possible to code (with the correct sign)
- To cope with the specific condition of the data acquisition system at the remote station, the user may specify that the input circuits and the ADC are to be designed so that a galvanic isolation is provided between the transducer and the ADC at the time the conversion of measurands occurs.

The isolation voltage must be specified by the user. If no galvanic isolation is required, the input circuits and the ADC can be designed without any other constraint than those above specified.

#### 3.4.2.2 Pulse Information

These pulses are normally generated by the contacts of relays (or other equivalent barrier devices) setting up closed or open (or complementary) loops, polarized or to be energized by the input circuit of the RTU.

The user has to define precisely the shape of such pulses (level, length, impedance of the generating circuits, maximum and minimum rates, complementary or not) and the processing to be applied e.g.:

- check (for validation) of the pulse lengths (or duration of complementarity), check (for invalidation) of the pulses rate or duration of non-complementarity, overload of the encoding capacity, etc.
- counting process
  - o automatic at given periods of time
  - o by local or remote command
  - o or without reset
- encoding
  - o code
  - o number of bits
- display device
- setting device (to a predetermined value)
- in the case of integration of pulses on a short period of time (e.g. 10 seconds) the user may specify that the transmitted value is not too old (e.g. 10 seconds during the 10 to 12 seconds before transmission).
- counting (or counting and decounting) on a given period of time. The accuracy of the period of time must be precise (consistent with the accuracy of the sensor).

In case of counting/decounting, the user must indicate if it can occur at the same time (i.e. a pulse to be counted and another to be decounted)

### 3.4.2.3 Parallel Coded Information

The values are supplied in parallel, on decimal or binary coded form. For hydraulic measurements the Gray code is frequently used as well. The highest figure to be transmitted corresponds to a decimal number of six digits. Each digit may be supplied on binary or BCD form or in 1 out of 10 form.

The data reliability may be increased by redundant source encoding: each bit may be supplied on complementary form (direct and complement wise), the duration of non-complementarity is to be checked in order to detect a failure and to give an alarm (abnormal duration to be fixed by the user).

To inspect the data integrity, the acquisition must be done so that the changes of the value should not lead to the transmission of an erroneous value. Sometimes a special signal may be supplied which brackets the change of value (or complementary duration) of that signal which must be checked in order to detect a failure and give an alarm (durations to be defined by the user).

Generally, the information is supplied by contacts of relays setting up closed or open loops to be energized by the RTU, but sometimes the information is supplied by a low level electronic interface (5 V, 12 V) to be defined by the user.

### 3.4.2.4 Isolation

As for analog information specific conditions may exist for requesting galvanic isolation between the telecontrol equipment and the transducer (or other device) which supplies the input values (pulse form or coded form).

## 3.4.3 Processing

### 3.4.3.1 On Demand Transmission

The demand is done at the CC, manually or automatically at a given time. The RTU transmits the demanded value (s) once according to priorities.

For telemetering, the demand may concern one, several or all the measurands.

For telecounting, the demand generally concerns all the readings of an area. The demand must be transmitted to each remote station in less than a given time (to be fixed by the user) on the basis of the accuracy required by the data handling process at the CC.

In each remote station the readings must be stored immediately without loss of information and without disturbance on the interface, then transmitted according to priorities (generally the transmission of integrated values has a low priority).

Nevertheless all the readings of an area must be transmitted to the CC in a given time (to be fixed by the user). Sometimes, the order to store and transmit a reading is given by the clock at the remote station. (See Sect 3.6)

### 3.4.3.2 Cyclic Transmission

The information is included in a cycle and transmitted periodically. The duration of the cycle may be chosen between some seconds and some minutes. Inside a cycle, some information may be transmitted several times, i.e. repeated with a multiple cadence.

Case of telecontrol equipment using a combination of cyclic\_and\_spontaneous\_transmission - - - - -

The cyclic information transmission does not take up all the cycle: time slots are reserved for transmission of spontaneous information (commands, indications, set points).

As a general rule, all the measurands are transmitted in the duration  $D$  of a cycle. In the case of bursts of priority information the cycle is allowed to reach the value  $2 D$ , i.e. all the measurands are transmitted at least once in a period of time  $2 D$ .

Commands and spontaneous set points are generally transmitted with higher priority than measurands but, as they are less frequent, they can be neglected in the cycles. The indications also have a higher priority than measurands and can delay the transmission of cyclic information. The number of indications which can be sequentially transmitted must be limited in order to allow the transmission of measurands in the period of time  $2 D$ .

### 3.4.3.3 Special Procedures - examples

- Some measurands, normally included in a cycle, may be accelerated on demand, i.e. repeated several times in the cycle up to a contrary command.
- Some measurands, normally not transmitted in the cycle, may be included in the cycle (using blank spaces) and therefore periodically transmitted up to a contrary command.

- In order not to burden the cycle with measurands which do not change in value, it may be convenient to specify that a measurand is transmitted only if its value is out of given thresholds (mini/maxi) or changes of more than x% (to be specified) with respect to the previous cycle: data reduction.

In the data reduction technique, a large threshold reduces the amount of data to be transmitted in steady conditions and permits a decrease of the transmission speed but affects the accuracy of the measurands proportionally.

Besides, if the telecontrol system is sized on the basis of the worst conditions - since a fault in the station may cause a change in all the measurands - there is no significant advantage in sizing the bandwidth of the communication channel connecting the RTU with the CC. On the contrary, this technique may be conveniently used in the data transmission among CC's in a multi-level telecontrol system, because of the small probability that all the measurands collected by the first-level CC and retransmitted to the second-level CC will change in value at the same time.

#### 3.4.3.4 Snapshot and Filtering Techniques

The snapshot technique may allow updating times longer than those of pure cyclic systems, as measurands are frozen. But the real advantage of this technique is not only the longer updating times, but also the better accuracy of data handling at the CC since the programs use homogeneous data.

The snapshot technique, which requires more complex RTU's, can be quite useless when the measurands are filtered at the RTU in order to transmit averaged values (on a 5-10 sec basic) rather than instantaneous values. This filtering action, which is also necessary in order to meet Shannon's sampling law, ensures very small errors in the processing of measurands sampled at different times even if no snapshot is adopted.

#### 3.4.4 Accuracy

The accuracy should be better than 0,5 % of the nominal range of the main measurands when processing is involved whereas it may be less than 1 % for the other measurands and less than 2 % when they are only presented to the operator. The former accuracy is typical of dispatching systems and the latter is suitable for remote control systems where monitoring is the main function.

The data transmission procedures should not degrade the intrinsic accuracy of measurands.

### 3.4.5 Transmission requirements

#### - Reliability of cyclically updated measurands

A reasonable objective for transmission reliability is a probability of undetected errors less than or equal to  $10^{-6}$  when the bit error rate of the data transmission line is  $10^{-4}$ . The loss of updating is generally limited to not more than a few cycles if the noise occurs in the form of bursts.

The global reliability increases if other actions are provided for by the CC, e.g:

- a) threshold alarms activated after a certain number of times that the measurand is not in the normal range;
- b) programs operating on the average of the received values.
- c) state estimation

#### - Reliability of on demand or spontaneous measurands

If there is generally no need for protection against loss of information for the cyclically transmitted measurands, for the on demand or spontaneous measurands transmission procedures with protection against loss of information should be used in order to achieve a probability figure less than  $10^{-10}$ .

A similar figure is to be ensured for the probability of erroneous information.

#### - Updating time

The updating time is a characteristic of the specific application.

For dispatching systems, the updating time is normally in the range of seconds. For remote-control systems telemetering generally consists of:

- a) cyclic transmission, for threshold checking purposes and/or logging;
- b) on demand transmission for monitoring during a limited period of time.

The corresponding updating times may be respectively:

- a) very long, in the range of minutes
- b) short, in the range of a few seconds

### - Meter readings

They are normally transmitted after a freeze command has been sent to the RTU to ensure simultaneous reading of the meters. The data transmission reliability should be high, (i.e. the loss of information or erroneous information should be less or equal to  $10^{-10}$  when the bit error rate of the data transmission line is  $\leq 10^{-4}$ ) as meter readings are one shot data.

A further improvement can be obtained by means of checks performed by the CC on a received value and the previous one.

For this reason, as well as for other requirements (manual updating, statistical or tariff reasons) the full meter reading should be transmitted rather than the increment or the decrement.

The number of decimal figures for each meter reading depends on the maximum foreseeable time interval between two readings.

The transmission delay is not a severe requirement since the meter readings are frozen and are used for computing balances rather than for real time control.

### 3.4.6 Input Reliability

The following precautions may be taken

- o care of wiring, wrapping or soldering
- o use of twisted pairs with grounded screen to reduce parasitic signals
- o use of complementary input information
- o check of the conversion accuracy of the ADC (periodically, e.g. at each cycle)
- o filtering

## 3.5 SET POINT COMMANDS

### 3.5.1 General

Two kinds of set point commands may be distinguished:

- these, called "spontaneous set point command" for which input, transmission and output should be performed with the same reliability as commands
- these for which the same transmission reliability as for measurands in the reverse direction is enough. These set point commands may be transmitted much more often (generally cyclically) than those of the first type.

### 3.5.2 Processing in the RTU

The received value is transferred to a memory corresponding to the address for the set point. That memory controls the output of the value either in analog form (through a Digital to Analog Converter DAC) or in digital form according to a code (binary, GRAY, BCD, 1 out of 10 etc). The output form may be different from the input form and/or the transmission form: a conversion has to be made either at the CC or in the RTU. The stored value is kept until the correct reception of a new value occurs:

- in case of cyclic transmission it may be specified that the stored value is kept during a given number of cycles before giving an alarm.
- in case of arhythmic transmission, the correct storage of a new value may initiate an ACK signal to the CC.

The transfer between the memory and the DAC or digital output interface should be monitored in order that any failure gives an alarm at RTU and CC sites. If there is a power supply failure, the same alarm should be given. If a wrong transmission is detected, the last stored value is kept in memory for arhythmically transmitted values and an alarm is given at the CC, if automatic retransmission remains unsuccessful.

### 3.5.3 Output

#### Analog output

The DAC supplies the value in the form of direct current. The normally used output ranges are the same as for the input of measurands.

The output circuits are normally completely isolated from the grounded frame and electrical earth.

The user has to specify the test isolating voltage within the available standards.

Any of the output wires can be earthed by the user without disturbance on the output signal. The output of the ADC is a generator supplying a d.c. current that is independent of the load. The output d.c. current may be supplied in algebraic form ( $\pm$ ).

The user must specify:

- o the maximum value of the load impedance (normally 3000 ohms)
- the response time (normally shorter than 300 ms)
- the error introduced by the DAC under the worst conditions (e.g. 1 or 0.5 % of the range)
- the residual ripple on the output current (e.g. less than 0.5 % of the full range).

- Digital output (parallel code)

Digital outputs are generally supplied by relays (or other barrier devices) whose contacts set up closed or open loops (or polarized wires). The breaking capability of contacts (V, A, VA) must be specified by the user (or level of voltage, impedance, etc).

The user has also to define if he needs complementary information, and/or a special signal which brackets the changes of state, and/or to specify the greatest time of no-significance (when there is a change of state) which he accepts.

For cyclic set point commands output by relays, it is recommended that relays which are guaranteed for more than  $10^4$  operations are used. According to the input specifications of the commanded device, mercury wetted relays can be specified.

#### 3.5.4 Transmission Requirements

The spontaneous set point commands should be regarded as analog commands with the same reliability and transfer time as the commands even though an undetected error might be tolerated in some cases provided the operator detected the error, halted the set point, and sent another set point.

Cyclic set point commands should be regarded as measurements transmitted by the CC to the RTU's.

This means that:

- a) the reliability can be the same because an undetected error is quickly compensated by another transmitted value.
- b) the updating time can be related to the time response of the controlled devices, that is, normally a few seconds.

#### 3.5.5 Instruction Commands

The instruction commands transmitted to the control room operator in a manned station may be considered as set point commands. They should be as reliable as spontaneous set point commands when they could lead the operator to take important actions. An acknowledgment signal is recommended. The transmission delay should not exceed a few seconds.

### 3.6 SYNCHRONIZING SIGNAL

#### 3.6.1 General

When only the relative chronology of occurrence is required, there is no need for synchronizing signal (s).

When the absolute chronology is required, it is better that all equipment at the remote station which is in charge of tagging the change of state information or of indicating the time (clocks, pulses of recorders, etc.) is synchronized.

When centralised absolute chronology is required, a synchronizing signal is absolutely necessary.

The synchronizing signals may be

- transmitted
  - o either from the CC by the telecontrol equipment itself
  - o or by another equipment
- elaborated at the remote station

The corresponding equipment, which may vary from mechanical or electronic clocks to radio-synchronized devices, are outwith the scope of this paper.

#### 3.6.2 Interface

The interface may be an output interface when the synchronization is transmitted from the CC and when the RTU distributes synchronizing signals to the other equipment at the remote station.

The interface is an input interface when the synchronizing signals are elaborated by another equipment located at the remote station.

These input and output interfaces may be done at low (electronic ) level or by relays (when the speed is not too high), in parallel or serial (pulses) form (or a combination of these two forms), with or without complementarity and with or without a special signal bracketing the changes of state.

If there is a device in the remote station to supply synchronizing signals to the RTU, the user has to specify the input interface in the RTU.

If not, the manufacturer must describe precisely the input interface. If the synchronization is transmitted from the CC, the user has to specify the output interface of the synchronizing signals to the other equipment of the remote station.

Because the input and output synchronization signals can go from a pulse each ms to a pulse each 24 hour from coded information indicating the time at a ms, in parallel and complementary form, to 5 wires indicating the hours (0 to 23) coded in binary, by means of serial codes or any combination of the above possibilities, it is not possible to define these interfaces more precisely in this paragraph.

The only thing which can be said is that the following general rule applies. The input and output interfaces should be made so that the RTU is isolated from the connected equipments.

### 3.6.3 Processing

Nothing very precise can be said about processing for the same reasons as interface (multiple forms of presentation). The input signal should be monitored and in case of failure, the RTU should run with its own clock: this degraded functioning should be indicated at the CC. If it continues for a long time (depending on the accuracy of the clock of the RTU), another alarm should be given (especially in the case of centralised absolute chronology).

If the synchronization is transmitted from the CC, the user must specify the time accuracy of the output signals with regard to the reference time at the CC.

In the case of input/output parallel codes, a good precaution is to use complementary bits and care should be taken with the reading at the moment of a change of state.

### 3.6.4 Transmission Requirements

To synchronize the RTU clocks, which provide for the absolute time of event recording, two techniques can be applied:

- a) a master clock at the CC can be used to transmit synchronizing signals to the RTU s:
- b) external broadcasting signals can be utilized

This second technique is outside the scope of this document. The former has to satisfy two fundamental requirements:

- a) the transmission reliability should be good, at least equal to that of telemetering; however, the RTU has to cope with the loss of synchronizing signals and to perform checks comparing the incoming signal and the previously received signal;

- b) the transmission delay should be consistent with the accuracy of absolute time and should be well-known in order to take it into account.

### 3.7 POWER SUPPLIES

As the RTU is unmanned it is important that the Power Supplies are secure and reliable. All the equipment should have the same standard of power supply. The main source of supply should be a common battery with duplicate chargers. The RTU equipment is supplied from this battery both direct and via dc-dc convertor power supplies. The battery capacity will depend on the conditions in the station. Considerations which have to be taken into account are whether a diesel is supplied, number of ac infeeds available, location of the station, access difficulties under adverse weather conditions etc. A reasonable battery capacity is six hours where a standby diesel is provided or where the location and access are such that attendance would always be possible within three hours. In other cases 12 hours or 24 hours capacity may have to be provided or a diesel installed.

### 3.8 MAINTENANCE

With modern solid state equipment any preventive maintenance is normally minimal. Apart from checking power supply voltages, modem distortion and ADC calibration there is little good that can be achieved by touching the RTU equipment.

The RTU equipment should have in-built self checking routines and action only taken when these routines or other tests show that a fault exists in the equipment. Alarms, Indications and Analogs can best be checked during routine maintenance of the primary station plant.

## APPENDIX 1 to Chapter 3

## DATA TRANSMISSION LINE QUALITY

This quality may be expressed by the bit error rate, but:

- the bit error rate is an average value over a long period and it can reach high values during limited periods of time
- this criterion is not easily usable in the necessary checks to verify the corresponding undetected and detected errors, and loss of information or commands.

Another way is to express the data transmission line quality by signal to noise ratio but that requires very precise definitions of the check conditions which are outside of the CIGRE scope. (See IEC publications or CCITT recommendations).

REPORT 2

PART 2

OPERATIONAL AND FUNCTIONAL  
REQUIREMENTS FOR TELECONTROL  
SYSTEMS

CHAPTER 4

REMOTE CONTROL CENTRES

## 4 REMOTE CONTROL CENTRES

### 4.1 Introduction

### 4.2 Remote Control Centre Functions

#### 4.2.1 General

#### 4.2.2 Data Acquisition

##### 4.2.2.1 General

##### 4.2.2.2 Teleswitching

##### 4.2.2.3 Teleindication

##### 4.2.2.4 Telemetry and Telecounting

##### 4.2.2.5 Set Point Commands

#### 4.2.3 Data Base Structure

##### 4.2.3.1 Data Base Organisation

##### 4.2.3.2 Data Identification

##### 4.2.3.3 Data Base Allocation

##### 4.2.3.4 Data Base Access

#### 4.2.4 Data Management Software

#### 4.2.5 Man-Machine Interface

##### 4.2.5.1 General

##### 4.2.5.2 Visual Display Unit (VDU)

###### 4.2.5.2.1 Tabular Displays

###### 4.2.5.2.2 Graphical Displays

##### 4.2.5.3 Keyboard

##### 4.2.5.4 Printer

##### 4.2.5.5 Mimic Diagram

#### 4.2.6 Archiving

### 4.3 System Performance Criteria

#### 4.3.1 General

#### 4.3.2 Response Times

#### 4.3.3 Availability and Degradation

### 4.4 Hardware Configuration

#### 4.4.1 General

#### 4.4.2 Computer Systems

#### 4.4.3 Disk Memory

#### 4.4.4 VDUs

#### 4.4.5 Printers

#### 4.4.6 Mimic Diagram

#### 4.4.7 Line Buffer Units

### 4.5 Software Configuration

#### 4.5.1 General

#### 4.5.2 Basic Software

#### 4.5.3 System Software

#### 4.5.2 Application Software

#### 4.6 Testing

##### 4.6.1 General

##### 4.6.2 Module and Integration Tests

##### 4.6.3 Factory Acceptance Tests (FAT)

##### 4.6.4 Field Installation and Acceptance Tests (FIAT)

##### 4.6.5 Availability Demonstration Tests (ADT)

#### 4.7 Installation

#### 4.8 Commissioning

#### 4.9 Maintenance

#### 4.10 Facilities

##### 4.10.1 General

##### 4.10.2 Power Supplies

##### 4.10.3 Air Conditioning

##### 4.10.4 Fire Protection

##### 4.10.5 Security

#### APPENDIX 1 Response Times

#### APPENDIX 2 Hardware Configuration

#### APPENDIX 3 Worst Case Conditions

## 4.1 Introduction

The basic functions performed by Remote Control Centres (RCC) are real time functions such as information collection, information display and remote control of plant. It is essentially a switching centre which acts on instruction from the Dispatching Centre.

However in Emergency conditions it may have to take autonomous decisions with regard to the part of the interconnected network for which it is responsible. These decisions will comply with general instructions laid down by the Dispatching Centre covering the particular emergency situation that exists at the time.

The Equipment at the RCC generally consists of two Computer Systems each having one or more CPUs, Memory (Internal and External) and Input and Output Devices, VDUs (monochrome or colour or both), Keyboards, Printers and a Mimic Diagram.

The RCC Functions are specified in Chapter 4.2. The approach in this report deals with the requirements for the Data Acquisition, Data Base Structure, Data Base Management, Man-Machine Interface and Archiving Functions separately.

Chapter 4.3 deals with System Performance Criteria (ie Response Times and Availability and Degradation).

The work of the RCC covers both planned and unplanned situations the latter being less than 10% of the total work load. Therefore the RCC should be so designed as to give Response Times which facilitate the normal planned work. It is however important that during unplanned situations the Response Times are such that the Emergency can be adequately dealt with. The Response Times are covered in Section 4.3.2.

In order to deal with all circumstances the availability of the RCC equipment must be of a very high order. Not only must the RCC be able to deal with both planned and unplanned situations but it must also be able to deal with these situations when all the RCC equipment is not functioning correctly (eg on a failure of one Computer System). These situations are dealt with in Section 4.3.3.

The Configuration of the Hardware and Software is specified in Chapters 4.4 and 4.5 respectively.

A dual Computer System incorporating separate Front End Computers (FE) to undertake the Data Acquisition function is specified. It is extremely important that either machine can take over all the tasks with the minimum of Operator inconvenience.

The Software Configuration is based on a Modular structure and describes the three main blocks into which the Software can be divided. These are Basic Software, System Software and Application Software.

Chapter 4.6 deals with Testing which due to the highly sophisticated and complex nature of an RCC Computer System is an extremely important subject. This Chapter gives a user specification for the Test Procedures and lists the various types of test, both in the Factory and in the Field which have to be carried out. It also lists the availability figures which are required for the various tests.

Installation, Commissioning and Maintenance are covered in Chapters 4.7, 4.8 and 4.9.

The Section on Installation details the tasks to be carried out and the liaison required with the Manufacturer.

The Chapter on Commissioning lists the final test and Acceptance procedures and is a follow on to Chapter 4.6 Testing.

With the use of high reliability solid state equipment preventive maintenance has been drastically reduced and maintenance consists basically of fault finding and repairing.

Chapter 4.10 deals with the other Facilities required in the Remote Control Centre. Although these facilities do not directly form a part of the RCC Computer and Display equipment they are vital to the correct functioning of the RCC.

## 4.2 Remote Control Centre Functions

### 4.2.1 General

The Remote Control Centre Functions are dealt with in the following sections from the point of view of the User.

The Approach in this report deals with the Remote Control Centre Functions in the following five different sections:-

- Data Acquisition
- Data Base Structure
- Data Management Software
- Man-Machine Interface
- Archiving

The Data Acquisition, as its name implies, acquires the data from the RTUs in the Power Stations, Switching Stations etc. It also passes instructions (eg Control Commands) to the RTUs.

The Data that is collected by the Data Acquisition and the Instructions to be sent are stored in the Data Base. Also stored in the Data Base is Data that has been computed from the Raw Data and fixed Data describing the Power System network. Each item of Data in the Data Base has a unique identifier.

The Data Management Software allows the Manufacturer to erect the Data Base and the User to operate on the Data Base to alter and update it.

To the User (ie Operator) the Man-Machine Interface is the most important part of the RCC Equipment. It forms the link between the Operator and the Power System which he is monitoring and controlling and thus requires very precise specification.

As the RCC is dealing basically with Real-Time Control the Archiving Function is of lesser importance and has consequently been given less emphasis.

Although all these sections are inter-related and inter-connected they can from the functions point of view be dealt with separately and this is done in detail in the following sections.

## 4.2.2 Data Acquisition

### 4.2.2.1 General

The Data Acquisition (DA) has two main functions. One is the collection of data from the Remote Terminal Units (RTU) and the transmission of Control Commands to the RTUs. The second is the transfer of information from and to the other levels in the Control hierarchy particularly the Dispatching Centre. This second function will be dealt with in another document.

The Data Acquisition function should be carried out by separate Front End Computers (FE) within each Computer System and Line Buffer Units (LBU). The Outputs from and the Inputs to the FEs should be transferred via the LBUs to the RTUs.

The operation of the DA is determined not only by the configuration of the Telecontrol System but also by the Telecommunication Network. The number and type of channels play a major role in deciding how the Data Acquisition should be structured. In general the greater the Telecommunications facilities available the simpler the Data Acquisition.

Each message sent from the RCC to the RTUs is generated in the DA. It may be as a result of a decision by the Data Acquisition or an operator entry or on instruction from some of the Application Programs. The Data Acquisition should generate the particular station address code information address code and the appropriate start stop and check bits required. On start-up the Data Acquisition must do a complete scan of all the RTUs in order to initialise the system with the correct live data.

The Data Acquisition function should strip all the incoming information of its start stop and check bits and verify that it is valid data. All information should also contain codes which identify uniquely the following information:-

- Station
- Information type
- Actual variable or variables

Using this information the DA should decide the action to be taken.

The various types of information should be dealt with as follows:-

#### 4.2.2.2 Teleswitching

Teleswitching covers the transmission of Commands from the CC to the RTUs. The commands must be transmitted with the highest reliability. The probability of wrong commands due to undetected errors should not be greater than  $10^{-4}$  even with the worst signal to noise ratio (see part 1 section 3.2.4).

The Commands should be transmitted with the highest priority and should take precedence over all other Data Acquisition functions being carried out at the time.

The Commands may be classified from several points of view:-

According to the Command method.

- 1 Single Stage Operation - where the operator has only one action to perform.
- 2 Two Stage Operation - where the operator has to perform two separate operations.

According to the Associated Status Information of the Commanded device.

- 1 Single or Double Point Information
- 2 No Associated Information

According to the type of output signal.

- 1 Pulse Command - where the Command is sent only once.
- 2 Persistent Command - where the Command is transmitted until the required action has been completed. This type of Command is generally being replaced by 'set point' commands.

According to the destination of the Command signal.

- 1 Selective Command - A single specific command to one station
- 2 Group Command - A specific command to a group of stations
- 3 Broadcast Command - A specific command to all stations

6

- 4 Function Command - A command sent to a single station which initiates a pre-determined sequence.
- 5 Group Function Command - One of a number of commands sent to more than one station to carry out a pre-determined sequence.

#### 4.2.2.3 Teleindication

Teleindications are monitored binary information describing the state of the following:-

- Automatic Devices
- Alarms
- Operational Equipment (eg Circuit Breakers, Isolators etc)

The information can be classified according to a number of different criteria:-

According to the Format of Presentation

- 1 Single Point Information - In this type of information only one bit is used to indicate the state of the plant. A '1' is normally used to indicate true and an '0' to indicate false and as both are correct no further verification should be made.
- 2 Double Point Information - This type of information uses two bits to indicate the plant state and gives four possible conditions as follows:-
  - 10 - Determined State On
  - 01 - Determined State Off
  - 00 - Indeterminate State Off
  - 11 - Indeterminate State On

The first two states occur under normal conditions.

The two indeterminate states occur due to a fault condition or on transit from one state to the other. Normally the RTU will not transmit this condition if it arises due to the transit of a slow moving device (eg an Isolator). In the event of an indeterminate state occurring the DA should check its validity before displaying it to the Operator.

According to the Acquisition Method

Information may be received by the DA in a number of different ways as follows:-

- 1 Cyclically - where the information is interrogated as part of a pre-determined interrogation cycle. This acts as a confirmation that no changes of state have taken place.

- 2 Spontaneously - information that is transmitted automatically from the RTU (eg a change of state as the result of a command).
- 3 On Demand - information that is acquired as the result of a specific request by the DA (eg where no change of state has been received after a command has been given).

In certain cases combinations of the above will be used. For example the Spontaneous information received may be in an abbreviated form requiring a request from the DA to obtain the precise details.

#### According to the DA Processing

The information received by the Data Acquisition should be dealt with in various ways depending on the type of information.

All the information should contain bits which indicate the station from which the information comes the type of data and the actual data.

The DA should deal with this information in the following ways:-

- 1 Information passed directly to the Data Base - this type of information does not require any processing by the DA and is only used when a particular display is called for by the Operator.
- 2 Information giving an event printout - this type of information should be passed to the appropriate section of the Data Base and should activate the event printing and archiving routines. It might also require time information which would be expanded from the incoming data or where none was present added.

Information giving an alarm condition - this type of information should be transferred to the Data Base and should call the appropriate event printing archiving and alarm display routines.

#### 4.2.2.4 Telemetering and Telecounting

This includes instantaneous and integrated quantities. Both are treated in a similar manner by the DA.

They can be classified from various points of view as follows:-

According to the coding method

- 1 Pure Binary
- 2 Binary coded Decimal
- 3 Gray Code  
etc

According to the Coding Format

- 1 Standard Zero
- 2 Centre Zero
- 3 Suppressed Zero
- 4 Quadratic conversion to Linear

The DA should be capable of interpreting which coding method and format is being presented and should be capable of transferring it to the Data Base in a standard form.

According to the Acquisition Method

Information may be acquired by the DA in the following ways:-

- 1 Cyclically - the DA should interrogate all the Telemetering and Telecounting information on a cyclic basis. The cycle time depending on the type and importance of the information. Some of the faster changing variables should have a cycle time of a few seconds while slower changing quantities could have cycle times up to 30 minutes. This cyclic scan should be a flexible arrangement with facilities to vary the updating times when required.
- 2 Spontaneously - some of the Telemetering may be transmitted spontaneously by the RTU and should be dealt with by the DA with high priority. Included in this type of information are Telemetering quantities out of limits (where the limit checks are done by the RTU) and Telecounting information in which a variable has reached a pre-set level.

- 3 On Demand - the DA should be able to override the normal acquisition of Telemetry and Tele-counting information in order to get an immediate update of a particular variable or variables. Once the required information has been obtained the DA should return to its normal scan. The DA should also be able to give a Freeze Command before taking a reading or series of readings. The DA should also be able to collect readings automatically at the end of a counting period (eg every hour, every day etc.).

#### According to the DA processing

- 1 Information that is checked for overlimit conditions - this can be sub-divided into information that only has upper limit constraints and information that has both upper and lower limits to be checked. If an overlimit condition is detected then the appropriate event printing archiving and alarm routines have to be activated. Otherwise the new value of the particular variable should be passed to the appropriate area of the Data Base. The Overlimit check could be a two stage function with the main check only taking place when there was a significant change from the previous reading (ie data reduction in the RCC).
- 2 Information that requires no overlimit checks should be passed directly to the appropriate Data Base allocation.

In both cases 1 and 2 above before passing the cyclically acquired information to the appropriate computations (ie translation into engineering units, database updating, limit checking etc) it is useful to check if the difference of the acquired data in two consecutive cycles is greater than a threshold  $\Delta x$  which takes into account the metering errors. This avoids meaningless computations.

#### According to the Encoding Method

- 1 Information transmitted singly - this information should consist of a single variable with a unique address identifying it.
- 2 Information transmitted in Groups - in this case a number of variables are transmitted in sequence with a single address identifying the 'group' of information.

#### 4.2.2.5 Set Point Commands

Two types of Set Point Commands are generally used as follows:-

- 1 Single Shot Set Point Commands - these are transmitted once only and with the same reliability as 'Commands' (ie using checkback before execute where this is employed for commands).
- 2 Cyclically Transmitted Set Point Commands - these are transmitted as part of the general interrogation cycle and generally require a much lower degree of security.

The user must specify the number of bits and the coding method (eg pure binary, BCD etc) to be used. The coding method should be determined by the type of output required at the RTU.

In the case of Cyclically transmitted Set Point Commands the user has also to specify the updating time. This is determined by the device that is being controlled.

#### 4.2.3 Data Base Structure

This section explains the operational and functional requirements of the Data Base structure and also describes how these can be applied in one particular type of Data Base. This is only one method of implementing the Data Base Structure and is not necessarily the best solution for all situations.

##### 4.2.3.1 Data Base Organisation

The Data Base contains the data upon which the processing is to be performed and in some cases the data that has been processed.

The Data Base should consist of three Major segments:-

- Data Acquisition Data (DAD). This segment should contain the data that is acquired from the power system, essentially measurements and statuses. It should also include outbound data such as the telecommands.
- Computed Quantities Data (CQD). Several types of data can be created by computing information based on the raw data. The CQD segment of the Data Base should be the repository for these computed quantities. Included in the CQD should be such items as channel flow rates, energies, volumes, etc.
- Fixed Network Characteristics. This section of the Data Base is fixed and consists of Substation Layouts, Power System Topology etc.

From the logical point of view data belonging to the DAD and CQD should be organised by station, that is every point should be associated with one and only one station.

Data that cannot be assigned to a station which is part of the system should be assigned to a 'Ghost' station which logically replaces a nonexisting station. It should apply to data such as computed totals or states. More than one 'Ghost' station could be created and a name should be assigned to each of them.

No particular constraints should apply to the ordering of the data within the table-section relevant to a given station.

#### 4.2.3.2 Data Identification

Each data point in the Data Base should be identified and referred to by the application programs by means of the 'identifier' (a symbolic name).

The identifier should be the abbreviated name of a data point. It should be alphanumeric and from 1 to 8 characters in length.

Unique identification of data acquisition data and computed quantities data should require a two part identifier. The reason for this is that these data points are unique only within a station. For example, at Station A there might be a telesignal TS1 and a telemeasurement TM1. At Station B there might also be a telesignal TS1 and a telemeasurement TM1. Therefore unique identifiers for the above data are A.TS1, A.TM1, B.TS1 and B.TM1. No data point should require more than a two part identifier for unique identification.

Appropriate programs should be designed to allow access to the data base by the operator by means of a mnemonic procedure to address a data point through an 'external name'. The 'external name' may consist of:-

- station name
- kV level
- point name
- data type

#### 4.2.3.3 Data Base Allocation

The various components of the data base (tables) should be predetermined to reside at a given level of the internal memory hierarchy. This determination should be made by an analytical evaluation involving primarily frequency of access and size. Based on the outcome of this analysis the initial sizings of the core-resident data base, the RAD-resident data base and the disk-resident data base are obtained. The above allocation should be tunable and changeable (within physical limitations) based on actual timing and throughput characteristics.

For the most part the previous analysis also lends insight into the number and size of the files to be allocated on the mass memory devices. It should be normal that a small number of large contiguous files are allocated on the disks. This should be done in order to avoid the overhead that is normally involved with file operations, namely opening and closing.

#### 4.2.3.4 Data Base Access

The process/data relationship should be established at design level in order to eliminate the need for the processes (programs) to search and sort the data on-line with negative consequences for the response times.

The above interrelationships could be solved by means of multiple chains which link the data together in various ways, but a more efficient solution is to remove these interrelational links from the context of the data base and put them in the context of the processes. A close analysis of what really occurs in an RCC shows that there is typically only a relatively small amount of 'raw data' in the system and numerous processes and visualisations which are applied against that raw data.

The raw data is represented by the data acquired from the stations (ie TM's, TS's, etc).

At design level each process and visualisation should be mapped to the raw data that it requires. This mapping method provides the single most efficient and flexible arrangement of the system data base elements and simultaneously allows processing to occur at real-time rates.

Centralised I/O Service In addition to the off-line facilities described above certain on-line facilities should be provided for access to the data base by the various application programs. These features should include the following ones:-

I/O Service (IOS). A central service should be provided for access to any table. This service makes it easy for a program to do data base I/O as all of the details are managed by the service.

Data Base Services (DBS). Three primitive services (Find, Get and Put) should be provided for user program access to the data base. These services make it easier to access elements in the data base.

Data Base Contention. Because there are a number of programs running at a number of priorities in the system task mix, it is possible in an ill-designed data base to have write contention occurrences. The following strategies should be employed to alleviate these situations:-

Sector Bounding. Because no two tables can co-exist in the same sector, the possibility of two programs writing into the same sector is precluded.

Static/Dynamic Data Isolation. Wherever possible the static parameters of a certain process should be segregated from the dynamic parameters of the process.

Single Source Update. Another design goal that should be employed is to design the system such that each table has one and only one module that is responsible for its update. This precludes contention problems.

Interprogram Interlocks. As a final resort, contention should be resolved by using interlocks between the contending modules.

Automated Data Base Initialisation. Another function which should be provided is the data base initialisation at start-up time.

Three modes of start-up are normally used (cold start, warm start and hot start).

An initialisation program should be provided to initialise appropriately the data base depending on the type of restart.

#### 4.2.4 Data Management Software (DMS)

The data base already described contains both fixed and variable items of data. The fixed data includes the description of plant parameters, display formats and local and remote equipment configurations whereas the variable data contains dynamic information which is collected from outstations, input locally by engineers or derived internally by the software itself.

DMS is a package which provides assistance to the manufacturer in constructing the data base or better the fixed data items to be held in the data base. It also provides assistance to the user in the maintenance of the data base as changes occur. The amendments should be made in a secure and efficient manner.

An interactive DMS is preferred mainly for the construction of displays as the user can more easily visualise the layout of the display. The source data preparation and interactive editing should occur via VDU and Keyboard with data presented in a user oriented format.

The DMS package should operate in the environment of the reserve computer system. It should not interfere with the primary computer functions with the exception of the time when the new data base is actually being produced on the reserve system.

At this point a failover process is necessary to incorporate and test the new data base.

The equipment which should be involved with the DMS operations is the following:-

- Computer Console. The computer should be used to invoke any function of the DMS initially. It should be used to start a run, specify certain options, designate input devices and stop a run.
- RAD/Disk. The rotating memory devices should be used for storage of the map and definition files, for temporary work space files and of course as the destination of the data base itself.
- Line Printer. The system line printer should be used for all hard copy DMS reports, for reporting error conditions and for any other listing type operations.

- System Console. A dedicated system console should be used as the control and input device for the interactive input stream. For the interactive input stream two VDU's would be required, one being the control VDU and the other being the data VDU. The data VDU should be used only when producing display backgrounds, as all other input functions should be handled via the control VDU.

The DMS package should perform the following basic functions:-

- to construct and maintain the data definition file and the map, that is the data base architecture and allocation.
- to process the input data necessary to generate the data base tables.
- to verify that certain known relationships exist in the newly generated data base.
- to provide the guidance and coordination of the process of switching to the new data base that is to guide the operator in the necessary steps to follow and to inform the system software that the restart is due to the installation of a new data base.
- to provide a formatted report of the data base contents (both the map and the data definition file and the formatted tables.

#### 4.2.5 Man-Machine Interface

##### 4.2.5.1 General

The Man-Machine Interface (MMI) provides in the Control Centre the interface between the Transmission and Generation System and plant and the Operational Staff. To enable the Power System to be monitored and assessed continuously so that effective decisions for operating the system economically safely and securely the actual and evolving operating conditions have to be presented in a manner that enhances comprehension. The facilities provided must be suitable for all phases of operation (eg normal emergency etc.). The information must be provided to the Operational Staff by the MMI on the basis of the following functional requirements:-

- in sufficient quality and quantity
- in adequate time
- in a logical order

This should be done to enable the Operator to take decisions in the most appropriate manner.

The information that is required is of different types as follows:-

- Real Time Information (Status Alarm and Load Flow Information)
- Historical Information (for later Analysis)
- Predictive Information
- Support Information (fixed information)

The MMI consists of a number of different items as follows:-

- VDUs
- Keyboards
- Printers
- Mimic Diagram

The VDUs and Keyboards are normally incorporated in a Work Station which also includes other items such as voice communication equipment (ie telephones etc). These other items are not dealt with in this report.

The particular functions of the four items of the MMI (listed above) in a specific RCC depend on the size, importance and status (eg existing or new) of the RCC.

In a relatively small existing RCC the Mimic Diagram should retain a very important operational role with Control functions being carried out from it and most of the indications and some of the alarms and analog readings being displayed on it. In this case the VDU and Printer should be responsible for Data Logging and Event Recording facilities only.

In a large RCC the most important functional item (from the user point of view) is the VDU and all the Controls, Data Logging and Event Recording should be carried out from it. The Mimic Diagram has a role to play simply displaying an overview of the System.

The various types of Telecontrol data have differing requirements for the MMI and these can be specified as follows:-

- 1 Teleswitching - Teleswitching commands are of several different types but the methods of operation should be similar. Suitable displays to enable the teleswitching commands to be carried out should be provided together with the required Keyboards. The operation of each command should be recorded on a Printer.
- 2 Teleindication - Teleindications consist of three distinct types of information which describe the state of the following:-
  - (a) Automatic Devices (eg Protection In/Out, Auto-Switching In/Out etc)
  - (b) Alarms
  - (c) Operational Equipment (eg Circuit Breakers, Isolators etc)

The position of the Automatic Devices should be indicated on the appropriate VDU display and by a printed message. Alarms should also be dealt with in this manner but in addition they should give an audible warning and an immediate message on one or more VDU. Circuit Breakers and Isolators usually change their state as the result of a Teleswitching Command and under these circumstances they should be treated in a similar manner to the Automatic Devices. When they change their position automatically they should be treated as alarms.

- 3 Telemetry and Telecounting - All telemetry and telecounting information should be displayed on the appropriate VDU page together with facilities for showing and altering overlimit settings. In the event of an overlimit occurring it should be treated as an alarm.

- 4 Set Point Commands - Displays to enable these commands to be carried out together with a printed message detailing the Commands actually operated should be provided. Both 'One-shot Set Point Commands' and 'Cyclically Transmitted Commands' should be transparent, in operation, to the Operator.

#### 4.2.5.2 Visual Display Unit (VDU)

The VDU displays information relating to the Remotely Controlled Plant. The information is displayed in such a way that it is readily and easily accessible by the Operator.

Three different functions should be performed by the VDU and should normally occupy separate sections of the display.

Firstly it should display information on all or part of the system as requested by the Operator (eg tabular displays could be arranged in a series of 'pages').

Secondly it should display alarm messages as they are received. This is done irrespective of which Page is being displayed by the Operator.

Thirdly it should give a response to the Operator's commands (eg by directly echoing characters typed in from a standard alpha-numeric Keyboard).

The VDUs can be either monochrome or colour and can display information in one of two ways:-

- Tabular
- Graphical

These two types of displays are dealt with in the following chapters.

#### 4.2.5.2.1 Tabular Displays

All Remote Control Centres should be equipped with at least two VDUs.

The two VDUs should be identical and should incorporate the same functions. Each should be able to display any page of information either separately or simultaneously.

The VDUs should provide the following displays:-

- 1 On request from the Operator the VDU should display the following functions:-
  - (a) Telemetering and Telecounting Information
    - (1) by station or group of stations
    - (2) by function (eg voltages, load flows by area, hydraulic readings etc.)
  - (b) Teleindications
    - (1) by station or station voltage or circuit.
    - (2) by function in some cases.
  - (c) Combinations of the above two functions by station or item of plant.
  - (d) Operator controlled variables (eg limit settings, both maximum and minimum, inhibits etc.)
- 2 The following should be displayed automatically on the VDUs :-
  - (a) Change of state of alarms and indications.
  - (b) Failures of the Telecontrol Equipment.
  - (c) Analog values out of limits.
- 3 On response to the Operator's Commands the VDU should display the following:-
  - (a) Echo his control operations.
  - (b) Acknowledge his Commands (eg 'Message Accepted').
  - (c) Respond to requests (eg limit settings not available elsewhere).

The Information Pages that can be requested by the Operator should have a standard format. They should incorporate at the top a title and time and date information which is automatically updated by the Computer.

Each page should then consist of a number of lines of information. The number of lines available for this is dependent on the size of the VDU screen and the space on the screen that is reserved for the other functions, but at least 15 lines should be available.

The information on the page should be arranged in a logical manner with each variable clearly identified by the displayed text (which in most cases will have to be abbreviated). In the case of a Circuit Breaker the station name, circuit name and circuit identification (numeric or alpha-numeric) would be required to positively identify it. This should be followed by the Circuit Breaker position which should be capable of showing all combinations of the input information including the '00' and '11' conditions. These latter two should show clearly that the incoming information is false.

Under certain conditions (eg when a item of plant is under test or an indication is faulty) it is necessary to inhibit one or more variables. This should be achieved by a simple two-stage procedure (eg first select the variable by Cursor Control, Light Pen etc and then give an inhibit command). An indication should then be given on the VDU screen next to the variable that the inhibit condition has been applied. The inhibit condition should be able to be applied to all variables (ie alarms, indications and analogs).

When a variable has been inhibited any changes of state that occur should not be recorded.

When the Operator is carrying out Control Functions which are normally performed using an appropriate graphical display a two stage procedure should generally be used with a 'select and confirmation' stage preceding the actual 'execute' stage. On completion of the 'select and confirmation' stage it is essential that the displayed information page (which could be abbreviated) should show clearly and unambiguously the precise details of the circuit and device that has been selected together with any abnormal conditions (such as alarms concerning the circuit that is being controlled) that are present. This display could also give the Operator guidance as to the next stage of the operation.

The Information that is displayed automatically will occupy an area of the screen specifically reserved for that purpose. It should display all changes of state of alarms and indications, Telecontrol Equipment failures and Analog Values out of limits. The display format will either consist of enough information to completely specify the particular alarm condition or information to direct the Operator to the appropriate information page.

The appearance of a 'change of state' should be indicated on the appropriate area of all VDU screens by the required indication. This indication will be displayed in such a way that it is immediately obvious (eg reverse video or a flashing signal) to the Operator.

The 'change of state' should also be accompanied by an audible alarm which should immediately warn the Operator of the 'alarm condition'. In certain situations a two-stage audible alarm system should be used with a loud initial warning being replaced by a quieter intermittent device.

The alarm message on the VDU screen should be able to be acknowledged from the Keyboard associated with either of the VDUs.

When more than one alarm message is present the Operator should be able to display quickly and easily all the outstanding messages on one or more VDU pages. He should be able to acknowledge them singly or collectively. He should also be able to display the acknowledged messages.

The messages should be queued in chronological order and the number waiting to be dealt with should be indicated.

Messages relevant to alarms of different priority should be displayed by using different colours.

Once the alarms and 'changes of state' have been acknowledged by the Operator they should be automatically stored in chronological order on one or more information pages. When the page or pages set aside for this purpose have been completely filled, the first page can be deleted either automatically or manually with a copy of the page kept by the Printer or on Disk or both.

Responses to the Operator's Commands should occupy one line of the VDU display. This line would normally be at the bottom of the screen.

The first stage of the Control Function by the operator is the 'select and confirmation' stage. It should consist of the 'selection' by the operator of the desired command string from predefined strings displayed automatically by the system on the appropriate graphical display. The 'confirmation' should consist in the colour change of the selected field.

The second stage of the Control Function is the 'execute' stage. It should consist in the depression by the operator of a specific pushbutton on the keyboard. For safety reasons this pushbutton should have a protective cap.

#### 4.2.5.2.2 Graphical Displays

The ability of the VDU to display graphical formats is the most powerful aid that the Operator has in the Man-Machine Interface.

In all except for the smallest RCCs some of the information will be displayed in graphical display formats. Normally the graphical displays would be presented on colour VDUs with each Work Station having two or three Colour monitors.

The following Graphical Display Formats should be provided:-

- System Overview - With the present limitation of display size this has to be provided in an abbreviated or fragmented form with the Mimic Diagram still providing the main representation.
- Sub-System Displays - These consist mainly of displays of sections of the Electrical Power Network being controlled but they could also include Generation Displays showing the overall prevailing Hydraulic conditions.
- Substation Displays - These are complex displays of the substations under the control of the RCC. They show the substation topology and help to assist the Operator in deciding the correct switching strategies to be employed.
- Hydraulic Displays - Displays of the Hydraulic systems associated with the Hydro Generation plant.
- Analog Displays (eg Graphs, Histograms etc).

The System overview should be used to give the Operator an immediate indication of the overall state of the network. Use should be made of the available colours and symbols to represent the different voltage levels and the particular network configuration. In this type of format there is a tendency to display too much information making it difficult for the Operator to understand. This should be avoided.

The Sub-System Displays should give more detailed information on discrete parts of the electrical network. They should show Circuit Breaker Positions and the main Power Flows (both Real and Reactive). Hydraulic conditions should be shown in Diagrammatic form giving information on Levels, Flows and Actual Storages.

The Substation Displays should be the most detailed. They should show all the relevant information from each Substation. Circuit Breakers and Isolators should be Identified by different Symbols and should use different Symbols and/or Colours to indicate their positions (ie Open or Closed).

Graphical displays give the greatest scope for the advantages of Colour Monitors to be utilised. Colours can be used for the various voltage levels, for different Circuit Breaker positions, to show that alarm conditions are present and for numerous other functions.

As the main responsibility of the RCC is the station rather than the system most of the graphical displays will be displays of the stations. For this reason character-oriented rather than full graphical VDUs are sufficient for this application.

The graphical VDUs will also be used to display the 'changes of state' and other messages on a message area and have a 'command' line for echoing typed input commands etc.

The various types of messages can be displayed in different colours in order to distinguish them with a similar system being used for the 'commands'.

#### 4.2.5.3 Keyboard

The keyboard provides the means by which the Operator can communicate with the Computer. The 'keyboard' should consist of some or all of the following items:-

(a) Standard Alpha-numeric Keyboard. This can be used for calling up pages, entering missing information, altering limit settings on analog readings, carrying out control functions and inputting messages that may require to be transmitted. In any one system it may be used for any or all of these functions.

Normally any instructions typed in on a standard keyboard should be echoed on the 'Command' Line and de-limited by using a particular key (eg the 'RETURN' key or the 'SPACE' bar) Once an instruction has been terminated in this way the Computer outputs a response on the 'Command' line to indicate whether or not the instruction has been accepted as a valid one.

Specific responses such as ('message accepted', 'command unknown', etc) considerably assist the Operator in the operation of the system and should be used.

To implement commands from a standard Keyboard the Operator should use a series of mnemonics. These should take the form of Alpha-numeric codes and should be simple and straight forward to understand and use. Abbreviations of the actions that the Operator is taking is one way to achieve this. All commands should be terminated by a de-limiter.

(b) Special Function Keyboard. This should consist of a set of keys the number being determined by the particular system requirements. These requirements should also determine the function of each key.

These keys can be used for calling up pages altering alarm settings and carrying out control functions. They can be used in conjunction with a standard alpha-numeric Keyboard.

The Special Function Keyboard may be a soft Keyboard where the function of each key is determined by the particular VDU display and is identified on the VDU screen.

Use of a Special Function Key should either cause a particular display on the VDU or should give a response on the message line.

(c)Cursor Controls. These are keys used to control the position on the VDU screen of the 'Cursor'. They enable the Operator to position the cursor on or adjacent to a variable that has to be altered or controlled. The Cursor is normally controlled either by five keys on the Alpha-Numeric Keyboard or by a Joystick type Controller or by a Tracker Ball.

(d)Light Pens. The light pen is a fast and reliable method of selecting a particular item (eg for selecting a Circuit Breaker that is going to be operated). It has the disadvantage that the Operator must be positioned very close to the VDU screen and must have a steady hand.

(e)Touch Sensitive VDUs. This is a very new method which has not so far been widely used. They have the advantages of the Light Pen (ie fast and reliable) without some of the disadvantages.

With the present very sophisticated hardware and software it is important that whatever type of 'Keyboard' is used the Commands should be as far as possible unambiguous both to the Operator and the Computer. It is invariably easier to select displays either by using a multi-stage dialogue or a series of straightforward mnemonics than it is to use a numeric code which has to be committed to memory or extracted from an index.

#### 4.2.5.4 Printer

The Printer keeps a hard copy of the information dealt with at the RCC. This information consists of three basic types:-

(a)Event Recording. This should be a record of all the events that have taken place (eg 'changes of state' of alarms and indications, control functions etc). It should be a continuous record containing information to specify the location the item of plant and the event together with the time and date.

Each event that is printed should occupy a separate line on the print-out and should be printed in a specific format. The print-out should give the following information:-

- station name
- circuit identification (eg line name)
- device identification (eg alarm name)
- new state of variable
- time and date

Some of the above information may have to be abbreviated.

The 'Event' printing should only use every alternate line. This gives a text that is clear and easy to read and positively identifies the 'events' from the 'request' printing.

(b)Cyclic Printing. This should be carried out at pre-determined specified intervals (eg every half hour, every day etc).

(c)Request Printing. This type of printing should be carried out on receipt of a request from the Operator. The information requested and the format of the printout should be one of a number of types (eg a printout of a display or of the values of all the readings of one type of variable).

In the case of display printouts all the information such as title and time and date information should be given. Usually with 'request' printing it is only necessary to give the time information once at the beginning of the print-out.

All 'request' printing should be printed in a way that identifies it from the 'event' printing (eg by using every line or indentation). It should also preferably start on a new page.

Although all the printing may be carried out on a single printer it is better to split the tasks and use two printers. One Printer should carry out the event printing and the other should handle the Cyclic Printing and Request Printing. This not only ensures that the continuous event log is undisturbed but also gives an immediate standby in the event of a printer failure.

All the information that is printed should at the same time be filed on disk or tape in order to simplify any future automatic processing that is required.

Print Formats should use a Foreground and Background structure similar to the VDU displays this gives a flexible format which is more easily changed and updated.

#### 4.2.5.5 Mimic Board

All Remote Control Centres should have a Mimic Board which is at present the best method of giving an overview of the network but has the disadvantage that it is difficult to update. In nearly all cases the Mimic Board is an integral part of the Man-Machine Interface. In some cases it will also provide a first or second stage of back-up to the main control point from which the Network is operated. In other cases it will only form part of a first or second stage of back-up to the Computer System. In this latter case it should be driven directly from the incoming data by the Line Buffer Units or by the Front End Computers.

In the former case where the Mimic Board is not used as a Control Point it can be driven directly from the Computer System. This would normally be done using an interface either hard wired or microprocessor based.

Where a number of stations are controlled from one RCC the electrical interconnections between the stations should be included on the diagram. This would apply for all types of Mimic Board.

The facilities which should be displayed on the Mimic Board vary with the size, importance and layout of the system. Examples of the displayed facilities for two systems are given below:-

(a) A Mimic Board required only for Operational purposes and providing no back-up to the Control Point should display the following information:-

- Circuit Breaker Positions
- Controlled Isolator Positions
- A General Alarm for each Station

These indications could be displayed by a method giving a clear unambiguous maintenance free indication (eg Semaphore indicators or LEDs). The type of indication used depending on the type of Display System.

The Mimic Diagram can be used to give an added safeguard that the Operator has selected the correct circuit breaker. This is psychologically important where the Operators have been used to operating from a Mimic Diagram.

If this indication is required on the Mimic Diagram then the type of indication used must be capable of providing this function.

(b) A Mimic Board providing a Control Point for the Network and acting as a back-up for the Computer functions. This type of Mimic Diagram should display the following information:-

- Circuit Breaker Indications
- Controlled and Auto Isolator Indications
- Some other Isolator Indications
- All other Controls with their associated Indications
- A skeleton Alarm System
- A single switchable Analog Meter

The Indications and Controls for the Circuit Breakers should make use of devices that give both indication and control facilities (eg Discrepancy Switches or LEDs with a separate control key).

The other controls and indications could either use Keys with integral indications (eg lamps or LEDs) or control Keys and separate indications.

Tap Position Indications for transformers with manual tap changing should be displayed on seven-segment digital displays and the Alarms could use similar display techniques to those used for the indications associated with the controls.

The analog meter incorporated in the Mimic Board should be scaled in relative rather than actual units. It should only be used to give the Operator the relative value of the load flows rather than the actual values.

Where the RCC is also controlling Hydro-Electric Power Stations the Mimic Board should also display other functions. The most important of these are the Hydraulic Readings which are required for Water Management. It is usual for a number of reasons to display these in a diagrammatic form using Analog meters for the Hydraulic Readings (eg Reservoir Levels, River Flows etc) and LEDs for any Hydraulic Alarms and Indications (eg Head Loss, Dam Spilling etc).

#### 4.2.6 Archiving

Archiving is the long term storage of Data. The amount of data to be stored for long term analysis in an RCC is relatively small. Most data is only required for short term storage (eg post fault analysis etc).

The data that has to be archived should be stored in a form that makes retrieval and processing a relatively straightforward operation.

This data should be stored on Disk or Magnetic Tape or Cassette and if high security is required the data can be written simultaneously to two disks. With large capacity inexpensive disks available this is an option that can easily be justified.

Although Disks are more expensive more bulky to store and require more careful handling than Mag Tape, they have the great advantage that different types of data can be stored in separate files. This is not possible with Mag Tape.

The Main Types of Data that has to be archived is:-

- (1) Events
  - Alarms
  - Status Changes
- (2) Cyclical Information
  - Analogs (eg Periodic Load Surveys)
  - Integrated Quantities
- (3) Outgoing Instructions initiated by Operator
  - Control Commands
  - Set Point Commands
- (4) Sequence of Events
  - Data transmitted with Time information for Post Fault Analysis
- (5) Pre and Post Fault Data
  - Information indicating the state of the Network should be kept on Disk and continually updated. When a Fault occurs this Data should be written to the archiving media thus giving Pre and Post Fault Conditions.

### 4.3 System Performance Criteria

#### 4.3.1 General

The Remote Control Centre Equipment should be designed in such a way that it is secure in operation but fast in speed of response. Although speeds of response are important they are only one factor that has to be taken into account. Like most factors in the design of the RCC speeds of response are a compromise between what is required and what is practicable. The requirements that are set should be such that they can be met by a solution that is cost effective.

Response times for a number of different functions have to be considered under this heading and can be categorised as follows:-

- Response times for information from and to the RTU
- VDU Responses to the Operator's Instructions

An RCC has to monitor and control continuously that part of the network for which it is responsible. Ideally, therefore, the Equipment of the RCC should have 100% total availability. Unfortunately this figure is not attainable and the design of the system must take account of this fact and the requirement for the system to operate in a degraded form when some of the equipment is unavailable.

#### 4.3.2 Response Times

Response Times for a number of different functions have to be considered under this heading and can be categorised as follows:-

##### Response Times for information from and to the RTU

These will vary with the type and importance of the information to be updated. Times for information from the RTU range from not greater than four seconds for circuit breaker indications to not greater than 30 minutes for water levels from large reservoirs. A list of suggested maximum response times is given in Appendix 1.

An important factor which has to be considered is the modification of these Response Times when the required information has altered in response to a Command by the Operator (eg where a Circuit Breaker has changed its position due to a Command by the Operator the indication should be updated in the range of one second).

The maximum response time for data transmitted to the RTU should be not greater than one second.

##### VDU Responses to the Operator's Instructions

(1)Echoing his typed input. This time has to be specified such that the Operator does not have to pause during the input of instructions. Whether use is made of an alpha-numeric Keyboard with each character being echoed individually or a special function Keyboard with Keys requiring a large number of characters to be echoed the response time to meet the criteria mentioned above is less than 100 ms.

(2)Acting on the Operator's Instructions. Each Instruction string used by the Operator will be ended by some delimiter (eg the 'RETURN' key) which causes the Instruction to be implemented. Within 500 ms a response to the Command should be given. This will take the form 'Message Accepted' etc if the Instruction is correct and has been accepted by the Computer. If the Instruction is incorrect then the response would be of the form 'Invalid Input.

For tabular Alpha-numeric displays the page should be completely written within two seconds. For more complicated graphical displays a figure of four seconds should be achieved.

These figures assume that none of the pages displayed at the RCC require any complex calculations to be carried out before the complete display can be presented to the Operator.

#### 4.3.3 Availability and Degradation

The Requirements for simultaneous action and the taking over of functions is of importance in the dimensioning of the system and assigning the functions. Also important are the varied specified priorities for simultaneous operation and the ability, in some cases, to wait a certain time until a function becomes available.

It is desirable that some reduced operation capability should be available even in the presence of faults in the information system (ie so called 'graceful degradation', see fig. 1).

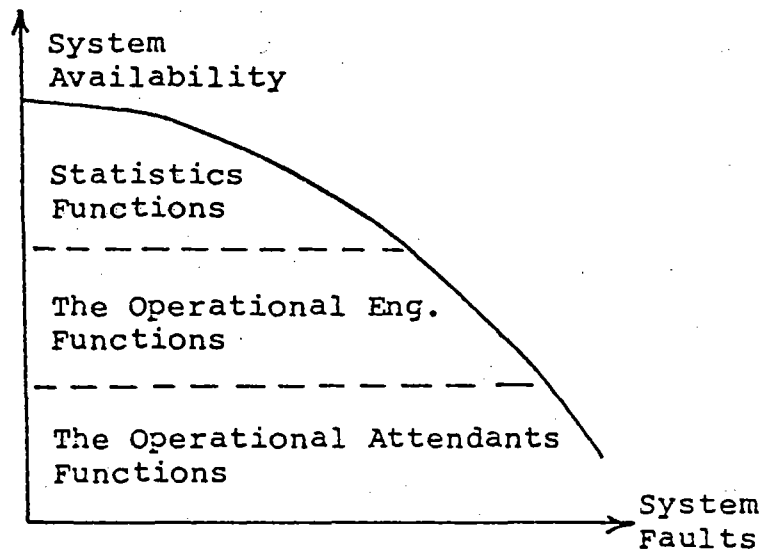


Fig. 1 Graceful Degradation

The functions in the figure are described below.

##### The Operational Attendant

Where a hierarchical structure of control is used the Operator in the lower layers should be able to take over specific functions from the upper layer in the event of an equipment malfunction or communications failure.

It is desirable that the system be so designed that operation even in a degraded state (poorer performance, more cumbersome procedures, priority equipment only etc.) can be carried out even with faults in the information system.

### Operational Engineer (operations management)

The Operational Engineers in the RCCs are the executive organ for operations management and represent the operations offices. Both are also in charge of planning functions for their respective networks.

They should in their duties and through their operating positions have access to the same functions as the operators.

During faults in the information system when capacity limitations apply these functions may be suppressed so that the operator's functions are given priority.

### Processing of Statistics and Analysis of Faults

Statistics functions should be able to be performed simultaneously with other information system functions and be available at the various control centres for their respective networks. Faults which involve temporary limitations of capacity should cause these functions to be assigned lower priority than the operational functions.

### Availability Requirements

When dimensioning a system configured as above the following availability requirements could be used (T is the total time per year when the function is not available; F is the number of faults per year).

Any non-vital function lost but the main control functions still available:

T = 100 hours/year                      F = 20 faults/year

All vital functions in a control centre unavailable:

T = 10 hours/year                      F = 2 faults/year

## 4.4 Hardware Configuration

### 4.4.1 General

The actual Hardware required for any particular Remote Control Centre will largely depend on the size of the RCC (ie the amount of information that has to be processed and the variety and complexity of this processing).

The recommended system is shown in Appendix 2.

### 4.4.2 Computer Systems

It consists of Dual Computer Systems one acting as the Primary Computer with the other, Secondary Computer, on 'Hot' Standby having a Database containing exactly the same Data as the Primary machine. The two systems can be either loosely or tightly coupled. In a loosely coupled system data is transferred by means of a data link or input/output devices. In a tightly coupled system data is transferred via shared memory. Apart from the largest systems loose coupling is preferable.

Each Computer System should consist of a Main Computer for Data Processing and Display tasks and a Front End Computer (FE) for Data Acquisition. The Data transfers between the two computers should be arranged so that in the event of a failure of one FE and the other Main Computer it would be possible to cross connect the operational FE and Main Computer. Each Main Computer should have a Console (either a VDU or a Printer). The Printer is preferable as it can keep a hard copy record of the start-up dialogue.

The Main Memory of each Computer should be semiconductor RAM although with the high performance of modern micro computers some PROM may also be included. As the semiconductor RAM memory is volatile it should be equipped with a no-break supply. Battery Back-up should be provided even where the Computer system has its own UPS.

Initially in a predefined worst case condition (see Appendix 3) the Computer Processing Utilisation Factor should not exceed 50%. Similarly the amount of Computer memory used should not exceed 50% of the Maximum capacity.

#### 4.4.3 Disk Memory

All systems require some form of Disk Memory. In small systems a 'Memory Based' arrangement could be used with the disks being used for program loading long term storage of data and any 'off-line' functions which are undertaken. As the Disks are liable to be the single least reliable part of the Computer System, a 'Memory Based' system would improve System reliability. In this type of system relatively slow access small capacity disks (eg floppy disks) would be suitable.

All larger systems should use disk based operating systems requiring large capacity disks with fast access times possibly even some fixed head disk (RAD) capacity.

The Minimum Requirements for the Disk Memory are as follows:-

(1) For a 'Memory-Based' system

Twin Disks each with at least 150 KB of storage, a mean access time less than 100 ms and an information transfer rate of 30000 Bytes per second.

(2) For a 'Disk-Based' system

Twin Disks each with 10 MB of storage, a mean access time less than 10 ms and an information transfer rate of greater than 100000 Bytes per second.

In all cases where an FE is employed it will make use of a 'Memory Based' Operating System.

#### 4.4.4 VDUs

The RCC will require a number of VDUs, the number and type depending on the size of system used.

The System shown in Appendix 2 proposes two VDUs each with its associated Keyboard per operating position.

Where Monochrome VDUs are used they should normally be of the alphanumeric type with standard keyboards. The VDUs can be driven by either a Serial or Parallel Interface. Serial Interfaces are simpler and should be satisfactory for most applications. Using seven bit ASCII codes a complete display (80 characters by 24 lines) would be written in one second at 19200 bits per second.

Colour VDUs should be of the semi-graphical seven colour type being able to display all the alphanumeric characters as well as a number of graphical symbols. A typical Colour Display might have 36 lines each of 72 characters with each character using an 8 \* 6 dot matrix. The VDUs should be driven by conventional RGB or RGBS signals. Where Colour Monitors are used the Computer Console should be a separate Monochrome VDU and should interface to the Computer via a Serial line. The Colour Monitors should preferably be used in pairs with one Keyboard per pair.

With the present advances in displays true Graphical VDUs and large projection VDUs may well become standard bits of hardware in the near future.

#### 4.4.5 Printers

Two Printers should be used each one capable of printing 132 characters per line at a speed of not less than 30 characters per second. They should be of the Matrix type capable of printing all the Alpha-Numeric characters (lower case letters are not necessary). Each Printer should be driven from the Computer by means of a Serial Interface using standard seven bit ASCII codes.

#### 4.4.6 Mimic Board

The Mimic Board should be a wall panel of a size and in a position such that it can be viewed from any Control Position.

All Circuit Breakers and Isolators should be displayed using discrepancy or semaphore indicators or Red and Green LEDs. All three methods give an unambiguous indication with equipment that is largely maintenance free.

Alarms can be indicated by signal lights or LEDs.

Analog Indications such as line load flows should either use Moving Coil Analog Meters driven from the Computer via a DAC or Quartiles. Where Analog Meters are used they should be scaled in percentage. Digital Meters are not recommended for this type of indication.

The only functions for which digital indications are recommended are frequency and the control centre clock. Digital readings and or Recorders may also be used for Total Generation (both Thermal and Hydro) and inter-region and international power transfers.

The Mimic Board should be fed from the Front End Computers by means of a Serial Multiplexor.

#### 4.4.7 Line Buffer Units

The Line Buffer Units (LBU) convert parallel signals from the FE to a serial code for transmission to the RTUs and conversely convert serial signals from the RTUs to parallel signals for the FE.

The LBU should be microprocessor based and should communicate with the RTUs utilising the appropriate protocols.

## 4.5 Software Configuration

### 4.5.1 General

The RCC software configuration should present the following features:-

- have a high reliability, a safe operation and good response times;
- allow the software updatings and/or upgradings (eg integration of a new function, modification of parameters etc) to be carried out simply;
- have an efficient diagnostic system.

The above features require a particularly effective real-time operating system, modular application programs and on-line diagnostic programs.

The system design development testing and integration of programs should be accomplished by means of a Top Down Development approach.

The software integration should utilise the Skeleton System technique that provides an interface verification process in the earliest possible stage of the software development.

The Skeleton System should comprise the Operating System services and small pieces of code which are called 'stubs'. A stub is very simple code which is used to simulate a program not yet developed. The Skeleton System will be used to verify the static interfaces defined for the relevant real programs whose implementation will come later. As a result of this activity any potential logical design errors which are encountered may be removed from the design specification.

The 'stubs' will be subsequently replaced with more complete and real versions and therefore tested in an environment more and more close to the final one.

As far as the programming language is concerned Structured Programming should be adopted by utilising high-level languages as much as possible.

In the software configuration it is possible to identify three main areas:-

- Basic Software
- System Software
- Application Software

The interconnection of these three main software blocks in building the complete software system is shown in simplified form in Fig 2

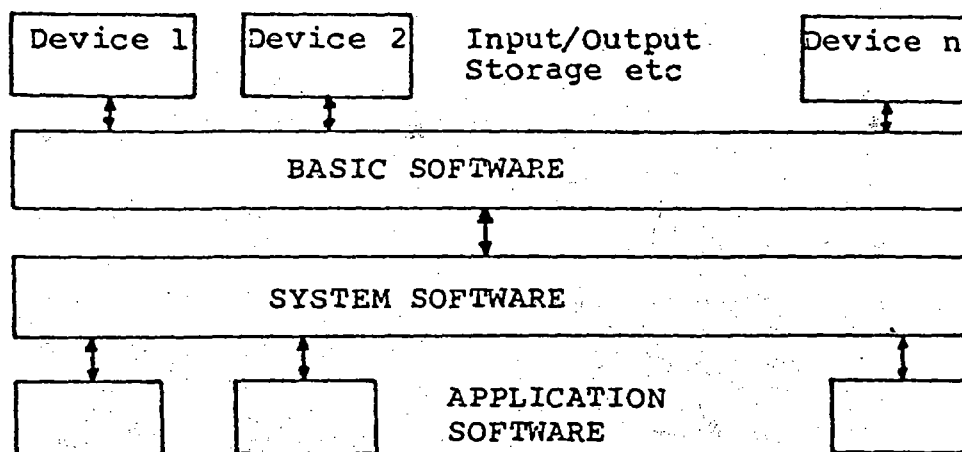


Fig 2 The Main Software Blocks

A good structured software system will ensure that changing the Computer System will only require the Basic software to be changed.

#### 4.5.2 Basic Software

The Basic Software performs the main function of supervision and organisation of the data and programs distributed on the basis of priority response times and hardware and software configuration.

The Basic Software consists of four main blocks:-

- Operating system
- Compilers
- Utility programs
- Maintenance programs

As far as the operating system, which is the base of the Computer Software, is concerned it should be a real-time multiprogramming user-oriented operating system. It should provide memory management and protection intertask communication and data management services. It should allow fully protected foreground and background tasks operating concurrently while still maintaining timely responses to real-time demands. Some of the significant features of the operating system and its extensions should be:-

- Multiprogramming
- Multitasking
- Assignment and management of the processing software priorities
- Foreground/background processing
- Multilevel access to I/O devices
- Comprehensive error recovery
- Programs and data protection
- Recovery of the processing state and auto-restart after a power failure.

The operating system and its extensions should also take into account the adopted hardware configuration (dual computer, dual-port disks etc) and should allow the CPU utilisation to be determined. It should also check that there is no program preventing the execution of lower-priority programs.

Compilers are needed for translation of programs written in high-level languages.

Utility programs consist for example of routines for data input/output, debugging, file opening on random access memories and similar functions. Sometimes these programs are part of the operating system.

Maintenance programs are needed for hardware and software checks and should include an efficient on-line debugging system which can be utilised during the system generation and testing as well as during the development of new programs.

#### 4.5.3 System Software

The system software development should be based on the use of modular programs.

The programs should have a standard structure organised on two hierarchical levels:-

- the main module having the function of co-ordination

- a set of specific sub-modules oriented to particular problems.

These sub-modules should be easily changeable and replaceable.

Each sub-module should be able to communicate data and parameters to several sub-modules at the same time either through direct calls or through the corresponding main modules relevant to the calling and receiving sub-modules.

The system software of an RCC should be organised through the following main program groups:-

- Data acquisition and transmission from and to the RTUs and the Dispatching Centre
- Processing of binary information
- Processing of telemetering information
- Command software
- Topology programs
- Man-machine dialogue
- Simulation software for training
- Data base and display pages management
- Archiving management
- Logging management
- Data modification system

#### 4.5.4 Application Software

The criteria of modularity described for the System Software should also apply to the Application Software.

The Application Programs are typical of a given RCC. They will be used to solve special programs.

This application will generally use modules and sub-routines of the System Software.

## 4.6 Testing

### 4.6.1 General

A comprehensive test programme has to be provided for the RCC that assures the system meets the operational requirements and the system performance specified in the User specifications. Testing should start early in the development phase and continue throughout the RCC project. The test programme should include module, integration, acceptance and availability demonstration tests.

The User should be responsible for factory and field acceptance tests with assistance from the manufacturer who will take care of the detailed test procedures. Testing will be accomplished by the manufacturer with the User's supervision.

The test procedures are a collection of tests where each test contains the following:-

- A Description of the item to be tested referencing the appropriate section of the User specification.
- B Description of the test configuration, i.e., basic HW and SW required with any additional test SW and/ or HW required which will be supplied by the manufacturer.
- C Description of general procedure to be followed coupled with the expected results of the tests. This can be accomplished in many cases with single statements and/or tables.

The purpose of the test procedures are to provide a structured environment so that all personnel associated with tests have a basis for agreement on the test results.

### 4.6.2 Module and Integration Tests

Each HW and SW module will be subjected to a set of tests by the manufacturer prior to the acceptance test. Emphasis should be given to the following tests:-

- A HW/HW integration tests: they demonstrate that the interface between two HW modules is fully operational. Testing is typically conducted with diagnostic or test SW that should be included in the RCC supply.

- B SW/HW integration tests: they demonstrate that the SW can operate the HW properly.
- C SW integration tests: detailed SW testing must be conducted on all new SW that is to be developed. This testing should begin with the verification of the basic function to be performed by each module and progress through a logical sequence as all required functions are completed and integrated into the system. A top-down approach is strongly recommended to manage SW development and testing.

The test procedures should be made available for the User who may witness these tests at his discretion.

#### 4.6.3 Factory Acceptance Tests (FAT)

The RCC system should be subjected to a FAT to demonstrate the system functions, performance and system reconfiguration capabilities. Two or more RTUs should be integrated with the system. Meanwhile simulations will be made to verify the communications load with the remaining RTUs and the ACC.

#### 4.6.4 Field Installation and Acceptance Tests (FIAT)

Installation of the RCC will be initiated following the successful completion of the FAT provided that all the equipment has been run continuously for at least 200 hours at the factory.

During the FIAT the available RTUs will be used in actual operation to verify that data can be acquired from the stations and control commands can be issued to the station devices.

A subset of the FAT procedures will be repeated during FIAT and in addition tests will be carried out to check the proper installation of the RCC equipment (eg on and off switching to verify no mutual influence of different equipment, transients on the UPS within the allotted ranges etc.).

#### 4.6.5 Availability Demonstration Tests (ADT)

The RCC computer system should be subjected to a continuous 2000 hour availability demonstration test to verify that the RCC will meet an availability of 0.999 for vital functions and 0.99 for non-vital functions. The test is deemed unsuccessful if during the 2000 hour availability period any of the vital functions are unavailable for a total time of two hours or any of the non-vital functions are unavailable for a total of 20 hours. A function will be considered available only if it is fully operating without any performance degradation.

During the ADT every instance of failure shall be diagnosed and repaired and the component restored to service. If the failure is in a HW element the total time for diagnosis, repair and restoration to service shall be counted as unavailable time.

If the failure is due to SW which does not repeat itself after a re-try, then the diagnosis, repair and restoration time shall not be counted as unavailable time. However, before the re-try all the necessary tests and dumps of main and auxiliary memory for diagnosis shall always be done first. The time necessary for these tests and dumps shall be considered as unavailable time if the standby computer is unavailable for failover. However if the standby computer is unable to perform the primary function after failover the necessary dumps will also be performed on this computer and the required time will be computed as down time.

The time it takes for automatic failover in a redundant configuration shall be counted as unavailable time. If the configuration is non-redundant, such as during preventive maintenance, then the time it takes for manual restart shall be counted as unavailable time.

In order to have a correct recording of unavailable time an appropriate log shall be kept.

#### 4.7 Installation

Installation covers planning co-ordination and other activities applicable to the installation of Control Centre equipment.

The installation phase includes all activities necessary to get the equipment which has been verified in the Factory Acceptance Test (FAT) working correctly in the predefined operational environment.

As part of the Project Realisation the contractor should develop maintain and by formal procedure update an Installation Plan. This plan should include a schedule relating time tasks and resources and should serve as a vehicle for co-ordination of the efforts of purchaser and contractor in the areas of facility preparation, service and supply systems, installation, installation testing and commissioning.

The Installation Plan should be submitted to the purchaser for review and approval in accordance with the contractual schedule.

The following activities are included in the installation phase:-

- unpacking and delivery checking
- equipment montage
- connection of all necessary cables
- connection to the telecommunication equipment
- installation verification

Following a successful installation the Field Installation and Acceptance Test (FIAT) will be initiated.

#### 4.8 Commissioning

##### Verification Concept

Testing and function monitoring needed to demonstrate conformance with requirements will be performed during different periods of a verification process. Verification therefore is an integrated concept implying successful completion of all periods. Any acceptance relative to a period of the verification is thus conditional up to the point of final Acceptance.

The verification process will include the following elements:

- Factory Verification (FACT)
- Field Verification (FIELD)
- Final Verification

Factory Verification and Field Verification will be performed for each RCC and will be scheduled for different periods in accordance with the contractual schedule.

Final Verification will be scheduled for a period following the acceptance of all other verification periods. This verification will be performed for the entire system to finally cover system performance and total integration and interaction aspects. System test shall be performed during the Final Verification Period.

##### Conditions for Acceptance

The following are the criteria for acceptance and successful completion of a verification period.

- All requirements subject to test have, after evaluation, been proved to be fulfilled in accordance with criteria given in the Test Specification.

and

- All events logged and handled in accordance with the Event Procedure have either been classified as non-relevant or the Power Company and the Contractor have agreed upon conditions and measures to correct the causes of the Event.

It shall be noted that Verification acceptance is a necessary but not sufficient condition for acceptance of delivery as defined in the contract.

#### 4.9 Maintenance

The following items are an example of a Power Company's long range objectives concerning maintenance and support of the information system's hardware.

- (a) Systems owned by the Power Company should be maintained and supported by the company.
- (b) Systems, components etc. acquired by the Power Company should be provided with built in functions for automatic fault monitoring and fault alarm.
- (c) Principally maintenance should be required only when faults occur in the system. This means that the future need for preventive maintenance (inspections, test etc. on a scheduled basis) will be drastically reduced.
- (d) System faults should be eliminated by the replacement of LRUs (Line Replaceable Units).

#### Information System Maintenance

The Information System should monitor itself as far as faults are concerned. The resulting fault indications should be individually classified in several alarm categories.

Certain categories go to the Operator who calls the Maintenance Personnel. One category alarms the Operator even if the Control Centre is unmanned.

All alarms are printed out in the information system log.

System Maintenance consists of the following elements:-

- A. Examination of the Information System functions.
- B. Fault location.
- C. Measures for restoring functions upon a fault.
- D. Evaluation of the Information System statistics.

Maintenance Personnel should trace faults in the following steps:-

- (a) Fault Monitoring and Localisation, FL1

All system components shall be included in the FL1 function.

By using FL1 procedures it should be possible to localise a fault to a faulty system part and the geographical place of that part (this could also be interpreted as the room in which the part is situated) in no more than 30 minutes.

(b) Fault Isolation, FL2a

By following the FL2a procedure the Power Company maintenance technician shall be able to perform a complete system repair at a system mean down time of no more than three hours for 90% of the product faults.

System mean down time includes, in general, time elements for:-

- preparation at site
- fault isolation to faulty LRU
- disassembly
- exchange of faulty LRU
- reassembly
- system restart
- putting the site back to original shape
- system check-out

Logistic delay time is not included in these three hours.

By using FL2a the maintenance technician should be able to decide if FL2b procedure must be used at a mean time of no more than three hours.

(c) Fault Isolation, FL2b

By following the FL2b procedure the maintenance technician shall be able to diagnose a fault to either software or hardware and to eliminate at least 90% of the 10% of the hardware faults that cannot be eliminated by following FL2a. The system mean down time - excluding logistic delay time - shall for these faults be no more than 12 hours. The system mean down time includes the same time elements as stated for FL2a.

## 4.10 Facilities

### 4.10.1 General

In order that the Remote Control Centre can carry out its Functions in an efficient and secure manner certain facilities have to be provided which are not directly connected with the Electrical Network that is being controlled. These facilities include:-

- Power Supplies
- Air Conditioning
- Fire Protection
- Security

Each of these facilities must be provided in such a way that the main Remote Control Centre Equipment is completely secure in operation. But it must not be allowed to interfere with the the Operation of the Remote Control Centre.

The Monitoring and Control of these systems is a significant Control problem. The best and most logical method of overcoming this problem is to use an RTU in the RCC to gather the information. This RTU can be interrogated in a similar manner to all the other RTUs in the system with the information presented to the Operator in the normal way using standard formats.

#### 4.10.2 Power Supplies

All the equipment should have battery backed no-break power supplies. The Power Supply should be as secure as can be economically justified. Two Mains Supplies and a diesel are a reasonable basis to obtain.

It is important that the standby diesel generator is of sufficient capacity to power all essential services. These include not only the Computer Systems and peripherals but also the Air Conditioning especially for the Computer Room and in some cases the Control Room as well.

For the d.c. equipment one Battery with duplicate chargers should be provided. With the reduced power consumption of most modern equipments separate batteries and chargers for each piece of equipment may well become standard in the future and is an alternative to the single large battery and chargers.

All batteries should be capable of supplying the equipment connected to it for a period of not less than one hour.

Computers which are generally a.c. operated should be supplied from no-break supplies. These should be provided by dual Inverters each supplied from a separate Battery and Charger with the system automatically reverting to the Mains in the event of a failure of both Inverters.

In the near future there is liable to be a marked trend to d.c. operated Computer Equipment thus alleviating the requirement for large no-break a.c. supplies. To get the full benefit from this change VDUs and Printers will also have to be capable of operating from a d.c. supply if Inverters are to disappear completely.

All the Power Supplies will have to be provided with suitable monitoring equipment (eg Power Supply Fail and Low Volts alarms). Battery Chargers require alarms for Mains Fail, Low Volts, High Volts and where an unearthed battery is used an Earth Fault Alarm is also needed.

If separate fusing arrangements are used (eg on the Mimic Board) the fuses should also be monitored as failure of a fuse especially on a Discrepancy diagram can have serious consequences.

The Standby Diesel Generator also has to be monitored and Alarms such as Fail to Start, Diesel Set Running, etc will be required.

All these alarms will be input to the RCC Computer via the Local RTU.

#### 4.10.3 Air Conditioning

Most modern Computer Equipments consume large amounts of power and give off a great deal of heat. They usually incorporate some type of Disk system which requires a clean environment and a very closely controlled temperature.

The temperature of the equipment may well differ considerably from the ambient temperature of the Computer Room. It is therefore important to ensure that the Computer Equipment itself is adequately cooled.

The Air Conditioning equipment must be capable of meeting these requirements. The Computer should be housed in an Air Conditioned Room with the Temperature and Humidity carefully controlled.

The Computer Room should be kept at a positive pressure as compared to the rooms round it in order to keep it dust free.

Any Disk Cartridges that are required (eg blank disks for archiving or spare system disks) should also be kept in the Computer Room in order to reduce the problem of Temperature differential between the actual disks and the disk drives.

The following are typical requirements for the Computer Room and Control Room:-

|                             |              |
|-----------------------------|--------------|
| Temperature (Computer Room) | +18 to +24 C |
| Temperature (Control Room)  | +18 to +22 C |
| Relative Humidity           | 40 to 60 %   |
| Max Rate of Change of Temp  | 5 C/hour     |

With the present high energy costs and energy conservation schemes, the heat produced by the Computer Systems should be recovered to heat other parts of the Remote Control Centre.

#### 4.10.4 Fire Protection

Modern Computer Equipments contain much less stored energy than those of the recent past (eg no power supplies with large capacitors).

The fire risk and the requirement for fire protection equipment is thus lessened. The minimum requirement is smoke detection and portable Fire Extinguishers.

The Smoke Detection Equipment will bring up the appropriate alarms via the Control Centre RTU and also initiate a separate Fire Alarm.

Fire Extinguishers used in the Computer Room should be carefully chosen so as to do as little permanent damage to the Equipment as possible. The factors which have to be taken into account are:-

- Low Toxicity
- No Residue
- Non Conductive
- Non Corrosive

A suitable Extinguisher which fulfills these requirements is Halon 1211.

The Computer Equipment will also be equipped with some form of protection to detect excessive temperatures. This could take the form of Thermal Cut-Outs which would switch off the appropriate supplies. As most problems with over heating in the Computer Equipment are caused by the failure of Cooling Fans, monitoring of the Fans gives warning before the actual over heating problems develop.

If more protection is required then the Computer and Equipment Rooms should be equipped with Sprinklers.

It is essential that all the Rooms equipped with Smoke Detectors are 'No-Smoking' Areas. This also helps to keep a clean atmosphere in the Computer Room.

#### 4.10.5 Security

A Remote Control Centre exercises complete control over a large part of an Electricity supply Network. The complete failure of the RCC could lead to the greatest difficulty in operating and maintaining a secure stable and safe system. It is therefore extremely important that the RCC which comprises the actual Control Room together with its associated Communications and Computer Rooms is treated as an area of high security. The following actions should be taken to ensure this security:-

- No entry to the RCC for Unauthorised Personnel
- Comprehensive Intruder Alarm System with the Alarms input via the local RTU
- Control and Computer Rooms should be secure windowless rooms
- Precautions to prevent unauthorised or inadvertant operation of the Computer System

## APPENDIX 1

### RESPONSE TIMES

#### (a) Analog Measurements

|                                    |         |
|------------------------------------|---------|
| 1 Electrical Quantities            |         |
| Pump/Generator MW and MVAR         | 4 secs  |
| Pump/Generator Current (ac and dc) | 10 secs |
| Pump/Generator Volts               | 10 secs |
| Transformer Current                | 10 secs |
| Line Current                       | 10 secs |
| Line Volts                         | 10 secs |
| Busbar Volts                       | 10 secs |
| Frequency                          | 10 secs |
| 2 Physical Quantities              |         |
| Generator Speed                    | 10 secs |
| Temperature                        | 30 secs |
| Wind Speed                         | 4 secs  |
| Wind Direction                     | 4 secs  |
| 3 Hydraulic Quantities             |         |
| Water Levels                       | 30 secs |
| Head Loss                          | 10 secs |
| River Flows                        | 30 secs |
| Gate Openings                      | 10 secs |

#### (b) Indications

|                                          |         |
|------------------------------------------|---------|
| 1 Electrical Quantities                  |         |
| Circuit Breakers                         | 4 secs  |
| Isolators                                | 4 secs  |
| Tap Positions                            | 10 secs |
| Other Inds. associated with Controls     | 4 secs  |
| Other Inds. not associated with Controls | 10 secs |
| 2 Hydraulic Quantities                   |         |
| Gate Positions                           | 10 secs |
| Valve Positions                          | 10 secs |

#### (c) Alarms

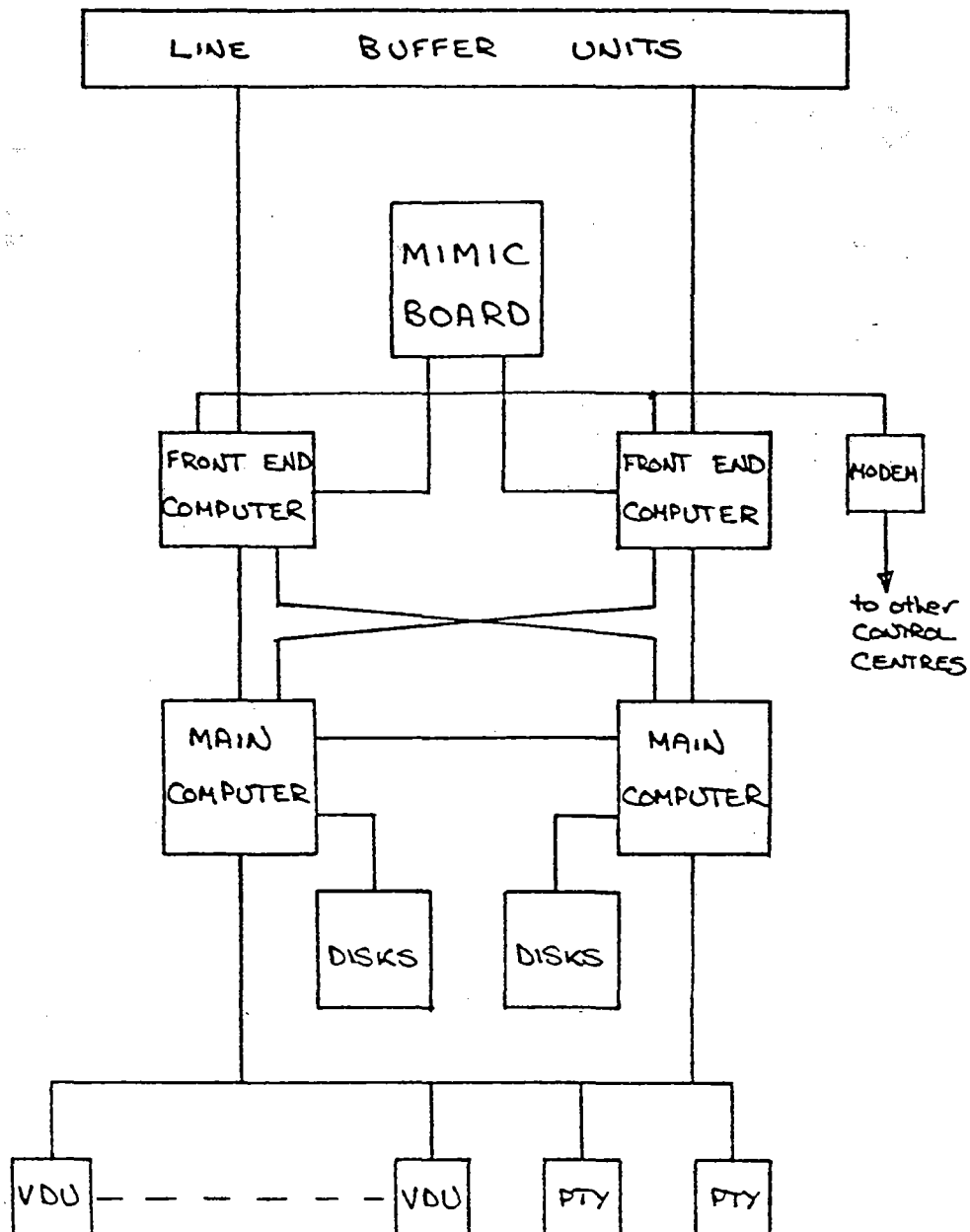
|                         |        |
|-------------------------|--------|
| 1 Electrical Quantities |        |
| Trip Alarms             | 4 secs |
| Non- Trip Alarms        | 4 secs |
| 2 Physical Quantities   |        |
| All Types               | 4 secs |
| 3 Hydraulic Quantities  |        |
| All Types               | 4 secs |

#### (d) Digital Measurements

|                         |         |
|-------------------------|---------|
| 1 Electrical Quantities |         |
| Integrated Readings     | 30 mins |
| Frequency               | 10 secs |
| 2 Hydraulic Quantities  |         |
| Water Levels            | 30 secs |
| Gate Openings           | 10 secs |

## APPENDIX 2

### HARDWARE CONFIGURATION



### APPENDIX 3

#### WORST CASE CONDITIONS

With regard to the RCC worst case conditions the following one hour contingency must be considered.

- (a) All the RCC equipment operates normally.
- (b) The data exchange with the RTUs and the other Control Centres operates normally.
- (c) 20% of all the teleindications are coming from the RTUs with uniform distribution during the hour.
- (d) 10% of all the telemeasurements are in excess of their limits with uniform distribution during the hour.
- (e) 40% of the measurements vary between two consecutive acquisition cycles.
- (f) 50 teleswitching commands are transmitted to the RTUs through the VDUs with uniform distribution during the hour.
- (g) Normal operations are carried out by the operators at their work stations (ie acknowledging alarms, calling up displays etc.).

© CIGRE



3-5 rue de Metz - F-75010 PARIS