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TELECOMMUNICATION NETWORK MANAGEMENT IN POWER UTILITIES

Working Group 02
of Study Committee 35
(Power System Communication & Telecontrol)

February 1994

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SECTION 1 DEFINITIONS

Telecommunication Management Network (TMN)

A TMN supports the management requirements of operators to plan, provision, install, maintain, operate and administer telecommunication networks and services. It provides management functions and services for telecommunication networks and services and offers communication between itself and the telecommunication networks. Open Systems Interconnection (OSI) Systems Management services (see e.g. X.700) and protocols represent a subset of the management capabilities that can be provided by the TMN (CCITT Recommendation M.3010). It should be noted that CCITT was replaced by the ITU Telecommunication Standardisation Sector in March 1993.

Network Management

A generic term referring to any type or aspect of network management, for example TMN or OSI management or any data network management.

Open Systems Interconnection (Network) Management

The OSI network management standards define the information structure, services and protocols required for OSI management. These standards also define the software tools required to monitor, control, operate and administer the network components in OSI environments.

Integrated Network Management

In the telecommunication sector this usually means a higher level management (system) that combines/connects separate specialised management systems, providing a unified view of the whole telecommunication network.

In the corporate network management sector this term means combined management of corporate information technology resources, e.g. computers, Local Area Networks (LAN), and data networks.

SECTION 2 FOREWORD

The growth in the size and complexity of telecommunication networks and the trend to more versatile services set demanding conditions for effective network management. The power utility network planner is facing many questions, e.g. what are the requirements for network management?, what are the trends in network management techniques and how are integrated network management standards evolving?

As a result of a decision reached at the SC35 meeting in 1989, WG02 was directed to prepare a report on present use and future requirements for telecommunication network management in power utilities. The terms of reference specified that the report should include :

- A description of telecommunication networks and their use in power utilities to the extent of that which is required to treat telecommunication network management aspects.
- The needs, reasons and requirements for telecommunication network management.

- Descriptions of existing telecommunication network management systems and future plans of power utilities based on a questionnaire. Special attention should be paid to the relationship between telecommunication maintenance organisations and telecommunication network management systems.

- A description of trends in telecommunication network management, the concept of an integrated network management system and its suitability to a power utility environment, the standardisation situation and an estimate of the applicability of such solutions to power utilities.

In order to enhance the information base for the preparation of the report, WG02 prepared and distributed a questionnaire to get an overview of the present situation and the plans which power utilities have for the future.

This report is intended to assist telecommunication network planners by giving them an insight into this fast developing area.

SECTION 3 SUMMARY

Power utilities have developed and use their own telecommunication networks for several reasons. Some of the more important reasons are,

- The nature of the electrical service which demands communication services with a reliability and availability which are normally higher than those provided by a PTT or other third party carrier.

- In emergency conditions, (flood, earthquakes, etc.) power utilities cannot rely on systems shared with other services and utilities which may themselves be overloaded by the same emergency conditions.

- Difficulties related to EMC (electro-magnetic compatibility) in a power equipment environment.

- Telecommunication carriers have not been prepared to provide all the required communication facilities in a cost effective way.

In general, the requirement for these types of telecommunication services can be expected to continue in the future.

The trend in power utility telecommunication networks is towards more flexible and efficient use of the telecommunication infrastructure. At the same time the privatisation of national telecommunication operations and the liberalisation of the telecommunication market have created new opportunities for power utilities to supply telecommunication services to other parties.

Power utilities now operate complex, high performance networks. This sets demanding requirements for the management of these telecommunication networks. Working Group 02 has analyzed these issues in subsequent sections of this report.

Section 4 contains a short description of telecommunication networks and their use in power utilities. Future services are also discussed. The relationship between SCADA and telecommunication network management systems is examined. The challenges to efficient network management during transition from existing to future telecommunication systems are presented.

Section 5 introduces the requirements for telecommunication network management. These requirements arise from the need for efficient maintenance and also from the need for flexible use of telecommunication networks. Maintenance policies including the centralisation/decentralisation issue are presented first and some recommendations are made. Various concepts related to availability of networks are introduced. The steps required to introduce network management functions into existing networks are presented. The benefits of close co-operation between the maintenance and network management organisation is stressed.

Flexible and more efficient use of digital transmission networks is becoming possible with the use of network elements having remote control capability. The increased requirements on network management due to these new possibilities are presented also in this section. Finally, the issues of capacity and availability of telecommunication management networks (TMN) are discussed. Because TMN may be introduced to support a wide variety of applications, only general guidelines are given.

In section 6 a description of existing telecommunication network management systems in power utilities is presented. It is based on a questionnaire, to which WG02 received responses from 59 utilities. The summary presented in this section contains general information on the companies who have answered, descriptions of their existing and future telecommunication networks, management system requirements, maintenance organisation and telecommunication management centres.

In section 7 the need to integrate management systems is presented. The meaning and benefits of integrated network management are discussed. Included are the issues of multi-vendor equipment, the growing trend to internetworking between different power utilities and problems with separate management systems e.g. inability to locate faults quickly. The main approaches to integration are presented.

Section 8 is devoted to a description of the architecture and technical requirements of integrated network management. The position of telecommunication network management in the overall management system of power utilities is presented first. The degree of TMN integration with other control systems is discussed. The effect of organisational structure and division of responsibility on the architecture of TMN is described. The architecture is also heavily influenced by the degree of decentralisation. The functions of network management are grouped into two main categories, general functions and application functions. General functions include data-acquisition, transfer and storage. These general functions must pay special attention to man-machine interaction requirements. The application functions are based on CCITT recommendation M.3010. The questions of why and where standardisation is needed in network management systems is addressed. Methods of connecting existing management systems to integrated systems are presented. Database integrity, an important issue, is also discussed.

Section 9 describes the essential aspects of important network management standards. The most important are the CCITT TMN recommendations. Close co-operation exists between CCITT and ISO in the network management field. A subsection is devoted to the description of ISO/OSI management.

In section 10 future trends in telecommunication network management systems are examined. The main factors which influence these predictions are analyzed. These include technical developments in networks and in management systems, standardisation, changes in the power utility industry, deregulation of the telecommunication market and the type of telecommunication services required by utilities including the demand for high capacity communication routes.

Features which a power utility TMN may require during the next five years are described. Power utilities are entering a highly competitive business environment during this period. Deregulation in the telecommunication area will continue. The exploitation of this opportunity to enlarge the business area will depend on the ability to provide a cost effective and high grade service. This implies a sophisticated TMN. In relation to TMN the main process over this period is a continuation of the movement towards management systems which comply with recognised standards.

Conclusions on the issues treated in this report are introduced in section 11. The main conclusion is that after analyzing and estimating the role and trends of telecommunication in power utilities, network management is considered an essential tool with growing importance for successful and efficient operations. The standardisation process in the telecommunication network management field will also benefit power utilities because they can utilise solutions developed for larger markets.

Acknowledgements and references are in sections 12 and 13. Appendices include a collection of relevant standards, examples of typical structures, existing implementations of telecommunication network management systems and a list of abbreviations.

SECTION 4 DESCRIPTION OF EXISTING /FUTURE POWER UTILITY TELECOMMUNICATION NETWORKS

Many power utilities have developed and manage their own telecommunication networks. This is a consequence of the special operational requirements which the management of a power network imposes on the utility. In order to manage a power network efficiently and safely a variety of telecommunication services of very high reliability and availability are required. Experience has shown that these have not generally been available from either public, or other third party carriers.

Traffic carried on these facilities has often been limited by regulation or agreement to that specifically involved in the operation of the power network.

In general, the requirement for these high priority services still exists, and can be expected to continue into the future.

In some countries in recent years, telecommunication services have been deregulated to varying degrees, and in these countries, power utilities have been taking the opportunity to carry more of their administrative traffic on their own systems with significant resultant cost savings.

In some cases, deregulation enables power utilities to develop a business case to provide telecommunication services to others as a profitable service.

4.1 Transmission Systems

4.1.1 The Purpose of Power Utility Telecommunication Media

Telecommunication networks are provided by power utilities to carry the various facilities required to administer and operate the power networks including:

- Signalling to assist protection of the power system.
- Connection of the remote terminal units of the supervisory control and data acquisition systems (SCADA).
- Collection of statistical data for power network planning.
- Operational telephone and intercom connections
- Data exchange between districts, regional and national control centres.
- Data interchange between network control centres (possibly requiring international circuits).
- Links for mobile radio networks.
- Telephone circuits carrying administrative traffic
- Connection of remote data terminals to corporate computers.
- Data interchange (including trading information) between mainframe corporate computers and between LANS.

As technology advances, new services continue to improve the remote communication and supervision capacity of power utilities, and recently the following functions have been added:

- Meteorological data from transmission line mounted sensors.
- Remote reprogramming of power line protection equipment.
- Remote maintenance monitoring of primary power network equipment.
- Slow scan video supervision of unmanned sites
- Remote video conferencing.
- High speed, high quality facsimile transmission.
- Photographic image transfer.

- Class room written "white board " transmission.
- Substantially increased speeds of computer data interchange (multi megabit).

Undoubtedly additional service needs will develop in the future.

4.1.2 Transmission

A fundamental requirement of telecommunications is the transmission link between sites. Power utilities use both equipment installed by themselves specifically for the purpose, and circuits leased from public telecommunication carriers.

For operational purposes, utility owned equipment is usually preferred so that circuit availability can be provided at a higher order than that which is commonly available from public carriers. However, in some countries, legal restrictions require utilities to use the public infrastructure, and leased circuits may have to be used for some operational needs.

Historically, the administrative telecommunication services of many power utilities have been carried over leased circuits, and although deregulation in some countries has encouraged the use of utility owned transmission media for administrative purposes, most of these needs are still carried by the public carriers. In this context by public carrier is meant a telecommunication service provider who offers services to the general public whether publicly or privately owned.

4.1.3 Externally Provided Transmission Circuits

Circuits leased from a public telecommunication carrier of the country/region/area can be specified for the particular need, but it is not universally possible to specify the particular type of transmission media to be used. Most PTTs and other telecommunication providers, offer circuits for lease on a "technology transparent" basis, and requests for circuits with direct current signalling are now not accepted.

The introduction of "second carriers" in countries where deregulation is proceeding, provides alternate sources for leased circuits.

Digital technology, more sophisticated public network switching, and the introduction of ISDN services have brought about an increased offering of "virtual circuits" for lease, and for some offerings of this type, customer monitoring and control of public network components is available. This makes new demands on the network management facilities and infrastructure of the utility.

Network management is also applied to leased circuit facilities where utility owned, remotely controllable multiplexing equipment is added to the terminations of the circuits.

In some countries, typically for very large distances, satellite transmission has the potential to resolve some previously difficult or excessively expensive circuit provision problems.

4.1.4 Transmission Media Provided by the Utility

It is widely accepted in power utilities that the lifetime of assets must be extended to get the maximum return on capital expenditure. As a result, aged systems are still retained and a wide range of transmission media is now in use.

Copper pair or coaxial cables, are still used extensively particularly in metropolitan areas. Whilst originally installed for services which required the metallic continuity, many now carry multiplexed bearers, both analogue and digital. The introduction of highly supervised digital multiplexing equipment on cables has substantially increased the potential to remotely monitor their availability.

Radio links have been the major multichannel bearers for more than three decades. Until the early 1980's these links were analogue, and although extensively alarmed, generally had no capacity for remote testing or reconfiguration. With the introduction of digital techniques to both radio link design and channel multiplexing, a range of remote equipment management tools have been included.

Optical fibre cables have gradually been introduced as a transmission medium of significance for power utilities. Again, the necessary digital multiplexing associated with optical fibre cables provides a high potential for remote monitoring and control of this telecommunication media.

Power line carrier (PLC) is used extensively, particularly for long distance transmission line protection signalling needs. It is useful for circuit configurations where minimal numbers of circuits are acceptable, or where financial justification prohibits higher capacity bearers.

Until now PLC transmission has been analogue, and most equipment configurations only have simple alarming of failed or failing modules. However, digital PLC is becoming available and PLC has a continuing place for long distance, low capacity routes.

Future development of transmission systems will follow the established digitalization path with radio and optical fibre cables likely to be the predominant media.

4.1.5 Cross Connect Systems

Digital cross connect systems are now available to permit the reconfiguration of circuits in transmission networks.

Reconfiguration in cross connect systems is included to aid network flexibility, particularly in times of fault restoration or maintenance outages and this is almost always provided with remote operation.

4.1.6 Transmission Media Topology

The topology of interconnection of transmission media is as varied as imagination can create, often integrating old and new technologies, analogue and digital bearers and wide and narrow band equipment.

Specific requirements and geography of the service area and associated power system, usually dictate the network configuration.

However the development of power utility networks usually demands regular change, and ease of network reconfiguration is a prime requirement. Since the introduction of digital technology, more and more equipment has appeared with the capability of being reconfigured from remote management facilities.

Highly sophisticated cross connecting network nodes are used in intermeshed networks which may have duplicate path circuits, and ring configurations carrying a wide variety of traffic, whilst current vintage digital multiplexers add to the flexibility with their highly reconfigurable, remotely manageable format. For further details see Ref.[1]

4.2 Mobile Radio Systems

4.2.1 Purpose of Mobile Radio Systems

Systems are provided in most power utilities to enable communication with field units, either mounted in vehicles or hand held.

By the very nature of power system operations, there is a considerable amount of field activity in the construction, operation and maintenance of transmission and distribution power lines, and also in directly servicing customers.

Communication may be from fixed or office locations such as control centres, service despatchers, maintenance depots or design offices to mobile stations, to or from switched telephone services, or between two mobile stations.

4.2.2 Some Characteristics of Mobile Radio Systems

Equipment complexity has increased rapidly in the last decade, and with synthesised frequency control has come the ability to provide remote control of channel assignment and other features.

The more complex the network the greater the need for real time management. Since mobile radio services are very often the front line communication medium during times of storm damage or other natural disaster, the integrity of the mobile systems is often critical. The need for network management of these systems will clearly grow in the future.

Systems vary widely in complexity from simple single station dispatch facilities through a variety of interconnected networks with or without talk-through repeating, to multistation, multichannel trunked systems catering for many mobile stations over extended areas. Mobile radio systems are used with various modulation and bandwidth formats.

Calling maybe by voice call, simple selective calling, or telephone style dialling for open or closed communication.

Where telephone type calling is provided, connections may be provided for calls to utility PAX or PABX telephone extensions, or into the public switched telephone network.

Systems of the future are expected to grow along the development path already established, until digital transmission becomes sufficiently mature in the public arena to allow an economic variant suitable for the smaller private market.

The wide variety of possible configurations are specifically detailed in Ref.[2] and Ref.[3]

4.3 Power System SCADA Networks

SCADA networks are provided to enable efficient management of the primary power system and are thus a network management facility in their own right.

The concept of remote control and management of power systems has of course been in use for much longer than the network management of telecommunication equipment.

SCADA networks consist of :

- Primary control centre computing equipment.
- Secondary control centre computing equipment.
- Remote terminal units.

- Links between RTU's and control centre(s).
- Links between control centres (including centres of different utilities).

Alarms and management of the SCADA equipment itself, are built into the SCADA control centre systems and accordingly are not normally extended to TMN as well, although such extension is possible.

The need for this arrangement will be dictated by the organisational arrangements of the utility.

SCADA systems usually also monitor the availability of the transmission links used, and again the need to independently present this information to the TMN will depend on the utility's organisational arrangements. For this equipment, however, it is more likely that the transmission links will be monitored by the TMN because it will be separately derived, and the link will normally also be carrying traffic other than SCADA.

4.4 Telephone Switching Systems

4.4.1 Purpose of Telephone Switching Systems

4.4.1.1 Administrative Systems

Switching systems in telephone networks have been integral network components for many years.

In the administrative networks of power utilities Private Automatic Branch Exchanges (PABX) provide the in house extension switching capacity and access to the public network. They now provide the capacity for switching both telephone speech traffic and data terminal traffic.

Specialised forms of PABX can be configured to queue high densities of incoming calls into order, and distribute them automatically to groups of attendants. This function may be used to answer callers reporting supply failure, account enquiries or any other high density traffic function.

In larger utility networks switches may be installed simply to provide transit switching between traffic routes, although this is more commonly incorporated into PABX jointly providing normal extension traffic functions.

4.4.1.2 Operational Systems

In networks used for operational purposes, exchanges are often quite small and may be located in substations where they will switch both a variety of trunks and serve a limited number of station extensions.

These switches may have specialised facilities inbuilt to provide for the unique traffic requirements of the power utility, eg automatic knock down of established connections for subsequent priority traffic.

4.4.1.3 Radio Systems

Telephone type switching is also used in the interlinking of trunked mobile radio networks. These switches generally differ from other telephone exchange equipment in that they require dynamic data bases to track the location of the mobile terminal units.

4.4.2 Types Of Telephone Switches (Exchanges)

Telephone exchanges can be categorised by age and function. For normal telephone traffic, relay and crossbar electro-mechanical switches can still be found in service. These units dating from the 1950's and 1960's, have no memory capacity and can only respond and switch as dial pulses are received in real time.

During the 1970's electronic (or second generation) switches with memory became available enabling switching to be performed on a "store and forward" basis. These electronic switches also enabled incoming address information in tone or pulse form to be analyzed and converted, if necessary, before switching.

Modern exchanges use both processor controlled switching and digital bus architecture. All three types can still be found in some networks. Future developments in the use of telephony exchanges are likely to follow developments in the public arena.

All current generation switches have facilities for remote management, reconfiguration and maintenance monitoring.

4.5 Packet Switched Data Networks

4.5.1 Purpose of Packet Networks

Data packet networks in power utilities are provided for:

- The interconnection of administrative corporate computers to one another and to various data terminals, for both interactive sessions and file transfer.
- Intra-company connection between different hierarchical levels of control centres for data acquisition and interchange.
- Inter-company connection between control centres.
- SCADA connection between substations and control centres.

4.5.2 Packet Network Topology

The prime value of packet networks comes through highly meshed multiple circuits, multiple node networks, allowing alternative path choice for traffic. Recent papers (Ref [5]) show that the mixing of administrative and operational traffic presents severe difficulties in network control, and even 'SCADA only" networks need very careful design to avoid traffic blocking during avalanche traffic likely to be experienced during major power system disturbances.

The performance required from Packet Switched Networks when used for SCADA is detailed in Reference [4].

Packet switch nodes are typically provided with extensive management facilities.

4.6 Local, Metropolitan & Wide Area Networks

LANs

During the last 10 years many organisations, including power utilities, have installed LANs to serve business needs. These have generally been installed to deal with local intercommunication needs and to service the increasing numbers of PCs and workstations which are being used by power utility personnel. In some cases these LANs have not been part of the planned telecommunication network. Power utilities are now in the position where LANs exist in many of their major business and operational centres. Management of these LANs in some cases is inadequate even though they are important elements in the business communication system. Many of these systems are based on Simple Network Management Protocol (SNMP), ETHERNET and TCP/IP protocols.

Local Area Networks (LANs) provide high speed data communication for workgroups in a single location, or in a number of locations. Users share programs, files or other computer resources. In these cases dedicated circuits are used between different sites. [An ETHERNET network can bear OSI and TCP/IP standards. The connection to the hosts installed on these local networks is made with gateways for OSI systems and bridges for TCP/IP systems]

MANs

Metropolitan Area Networks (MANs) are high bandwidth networks which link local networks of personal computers, workstations minicomputers and mainframe computers over a metropolitan area. They are related to LANs in that they expand a user's ability to take advantage of software and applications geared to work sharing.

WANS

WANs transport the data between cities or around the world. The introduction of broadband technologies in local and wide area networks will allow the development of new applications and services in the near future. Increasing communication speed and the quality of new transfer modes will support the integration of different digitized media. This will result in improved performance of existing services and the development of new multi media applications.

Some manufacturers are developing high speed packet switching systems based on broadband data transport and switching standards for metropolitan and wide area data networking and broadband ISDN.

National and international standards bodies are preparing new standards for increased levels of information transport capacity and flexibility, including Frame Relay and Cell Relay standards. They are based on high speed packet switching and fibre technology. These differ from conventional X.25 packet switching technology in that they are based on fast packet technology which can switch and deliver connectionless packets as well as connection oriented packets.

The requirement for existing services which are used by power utilities and described in section 10.3.1 will continue for the foreseeable future. However the way in which the service is provided may change. For example, integrated digital communication networks for power system substations are already in use. These are based on high speed fibre distributed data interfaces (FDDI) or co-axial LANs. In many instances these LANs are operating at higher speeds than the backbone network. It seems likely that this situation may not continue and there will be a need for high capacity, high speed circuits to substations.

New bandwidth intensive applications such as: graphics, image processing and video conferencing will place greater demands on existing networks. Users also expect faster response times which in turn is increasing network speed. It is estimated that the next generation of networks will be 20 times faster than present systems.

All of the above service requirements imply a high availability, high speed, large capacity business wide network. In order to effectively manage such a network a TMN with similar characteristics will be required.

4.7 Problems Associated with the Transition from Existing to Future Systems

As identified in subsection 4.1.3 & 4.1.4, networks often consist of equipment from a wide age range.

In particular, more recent development, or replacement, will use digital equipment, often processor controlled with extensive monitoring and control facilities, whilst equipment more than ten years old will be analogue equipment, with limited alarm functions, and almost certainly no management control facilities.

Significant problems arise as network redevelopment proceeds, particularly as user requirements demand end to end digital circuits.

It is rarely economic to replace whole network sections with new digital equipment and a variety of techniques are used to interface old and new equipment (See Ref [1])

Logical uniform network management is impeded when the network consists of mixed components because:

- The information available differs widely.
- Graphical presentation cannot be uniform.
- Circuits for management data cannot be multi-drop continuous circuits on a given route.
- Non-standard alarm units are needed at analogue terminals.
- Control is only available over sections of the route and operators have to deal with different equipment responses.
- Older equipment cannot be reconfigured - remote rerouting is limited.

In a way, network management becomes even more critical during transitional network development because of the limitations of the equipment itself and the need for very careful control.

SECTION 5 THE POWER UTILITY REQUIREMENT FOR TELECOMMUNICATION NETWORK MANAGEMENT

5.1 General

Network management may include a wide variety of functions which cover the operation, administration, maintenance and provisioning of a telecommunication network. A basic function is to co-ordinate and direct the maintenance actions and resources.

Maintenance involves all of the operations required for the setting up and maintenance, within prescribed limits, of any element affecting the establishment of a connection. In order to properly plan and program the maintenance operations required to establish and maintain an analogue, digital or mixed network, the following general strategy is recommended by CCITT (M.20).

It should provide for the maintenance of the network systems, equipment and circuits during the following activities:

- Installation and acceptance testing.
- Commissioning.
- Keeping the network operational.

It should have as a major aim to minimize both the occurrence and the impact of failures and to ensure that in the case of failure:

- The right personnel can be sent to
- The right place with
- The right equipment and
- The right information at
- The right time to perform
- The right actions.

To apply this general strategy in a network, the following principles can be used:

Preventive maintenance

- Performed at predetermined intervals or according to prescribed criteria with the intention of reducing the probability of failure or degradation of the function of a system.

Corrective maintenance

- Performed after fault recognition and intended to restore a system to a state in which it can perform a required function.

Controlled maintenance

- A method of sustaining a desired quality of service by the systematic application of analysis techniques using centralised supervisory facilities and /or sampling to minimise preventive maintenance and to reduce corrective maintenance.

The operation and maintenance functions in a network should be planned in such way that the life cost will be minimum. For a defined level of service the total cost will include:

- Capital investment.
- Operations.
- Maintenance.
- Loss of communication.
- Loss of traffic in the case of third party traffic.

5.2 Telecommunication Network Maintenance Policies

The different policies adopted by power utilities are typically decided by the size and structure of the utility, the size of the telecommunication networks and the equipment volume, geographical considerations, and the availability of skilled personnel especially in local areas, for instance,

- The maintenance organisation is fully centralised and every task in the network such as locating and repairing faulty equipment is handled by centrally based personnel who travel to the location of the fault.

- The maintenance organisation is centralised, but for locating faulty units in the field, personnel in the local organisation are used. These personnel may be unskilled in respect of the actual equipment and are guided by a central expert during the work. Also simple repairs such as change of sub-units may be performed by the local personnel. If spare parts are needed they will be sent to the site from the central store.

- The maintenance organisation is partly centralised, and for local work there are personnel for locating faults and completing repair work. The personnel are trained to maintain the actual equipments and they have the required tools and spare parts in a local store. They handle most faults on their own, but if assistance is needed there is access to experts in the central group. These centrally located experts may also assist on-site if required.

- The maintenance organisation is fully decentralised. The local groups have the full responsibility for the status and quality of the network and equipments in their area. There may be a central group for operational and policy coordination, spare part support and liaison with manufacturers and contractors.

Traditionally, maintenance work required skilled personnel for detection and repair of faulty equipment. Normally, maintenance occurred on site and involved repair at component level. Locating the faulty site and equipment was based on information from the users and the maintenance personnel's knowledge of the network and the equipment. These personnel brought any required tools and spare parts with them. In the case of very difficult faults they replaced the faulty unit which was then returned to the workshop for repair.

To ensure more efficient maintenance and to reduce network down time and improve availability, modern equipment is built up of modules of easily replaceable sub-units.

This means that field work now involves the replacement of faulty sub-units and the return of these units to a central workshop in the utility, or to a contractor. Modern equipments have alarm indications which enable easy identification of faulty units.

If this alarm information is transferred to one or more supervision centres it enables centralised monitoring of the network and coordination and direction of the maintenance personnel.

It also means that the requirements on field experts may be reduced, and the aim for field staff training will be to read and understand the alarm information, and to replace sub-units while making any needed adjustments. A local supply of spare parts is required to make this method of maintenance work efficient.

Modern telecommunication networks are becoming more and more complex. They are often built in a meshed configuration which enables redundant routes, either fixed or reconfigured when needed. Introduction of dynamic nodes will allow increased flexibility but will also increase complexity. There is also the evolution of the network from the present mostly analogue environment to the future almost wholly digital environment. In doing this, one must consider the new services and functions offered by the networks and the maintenance tools and capabilities becoming available.

In general for all three types of network (analogue, digital and mixed), the use of controlled maintenance principles is recommended, i.e. the maintenance actions are determined on the basis of information generated in the maintained system or coming from auxiliary supervision systems.

The advantage of the controlled maintenance approach is that it directs maintenance activity to those areas where a known improvement in service to the customer may be achieved i.e. the majority of failures are both detected and remedied without the customer having been aware of them.

In order to reduce total lifetime costs and to improve the efficiency of maintenance, new systems should be provided with internal supervision and fault localization functions. Such functions reduce the number and type of external test equipment to a minimum, and make it possible to omit most external routine tests.

When a new system is being evaluated, early consideration should be given to operational and maintenance requirements. The maintenance organisation and maintenance facilities (including test equipment) should be considered early enough to ensure their availability when the system is introduced.

Network management is the function of supervising the network and taking action when necessary to control the flow of traffic. Network management requires real time monitoring and measurement of current network status and performance. It also encompasses all of the activities which are needed to identify conditions which may adversely affect network performance and service to the customer and includes the application of network controls to minimise the impact of these adverse conditions.

The introduction of network management into an existing network should be viewed as a long term project. This long period is required :

- To gain knowledge and experience of network management.
- To carry out studies on the requirements of an individual network.
- To write specifications for network management requirements and hold discussions with manufacturers.
- To oversee the introduction of facilities and to organise and train suitable network management staff.
- To introduce limited facilities in existing older technology equipments.

As an important first step, the responsibility for network management should be identified and assigned within an organisation. Network management is highly technical in nature and depends on the skill and creativity of those who share an understanding of network management philosophy, objectives, terminology, tools and techniques.

The decision on whether or not to take network management action, and what action will be taken is the responsibility of the network management personnel. This decision will be based on their knowledge of the source of the difficulty and their experience and knowledge of the network.

Considerable benefits may be obtained by close cooperation between the network management organisation and the network maintenance organisation. For this reason, power utilities often integrate the management organisation into the maintenance organisation which amongst other benefits gives more efficient use of resources.

5.3 Availability Requirements.

5.3.1 Quality of Service

An important concept in the consideration of a maintenance philosophy is that of Quality of Service (QOS). This is defined by CCITT (M.21) as the collective effect of service performance which determines the degree of satisfaction of a user service.

QOS comprises a number of factors. Some of these are:

- Availability.
- Reliability.
- Maintainability.
- Maintenance support.

One reason which supports the case for power utilities having their own telecommunication networks, is the high availability requirement for communications involving relay protection, remote control, operational calls and data communication.

Availability is defined by CCITT as the ability of an item to be in a state to perform a required function at a given instant of time or at any instant of time within a given time interval, assuming that the external resources, if required are provided.

Availability of connections and equipment depends on the reliability of the equipment, the maintainability of the equipment or system and the organisations maintenance support. The relationship between these factors is indicated in Fig 5.3.1

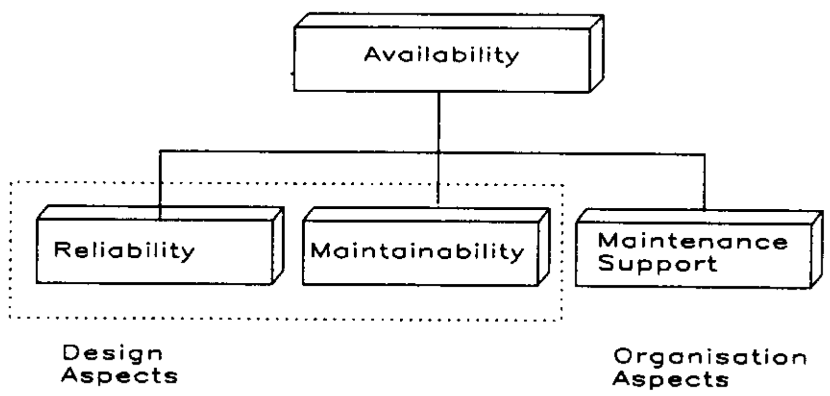

FIG. 5.3.1 FACTORS AFFECTING AVAILABILITY

The reliability of a single unit of a transmission equipment or of a complete transmission system is defined by CCITT as the probability that this item can perform its required function for a given time interval.

Reliability is a parameter which deals with the quality of the equipment and depends on the manufacturer's circuit design, quality of components and construction. The reliability can be calculated and represented numerically as the Mean Time Between Failures (MTBF).

The maintainability depends on the equipment design and the manufacturer's consideration of the need to locate and repair equipment failures. The presence of alarm indications and supervision facilities has a considerable influence on maintainability.

Maintenance support depends on the maintenance organisation, fault location facilities and spare parts availability. The skill of the maintenance personnel may also be an influential factor.

Maintenance support covers the functions identified below:

- Management of information regarding network equipment in operation.
- Management of operating data (routine data mainly).
- Fault correction instructions for hardware and software.
- Repairing of removable items.
- Network and equipment documentation.
- Management of maintenance stocks.

The quantity of spare parts held depends on:

- The organisation of maintenance entities.
- The failure rate of an item.
- Turn around time (actual repair time, transport).
- The risk that a spare part is unavailable.
- Number of items in operation.

Maintainability and maintenance support determine Mean Time To Repair (MTTR), which is normally expressed as the average time taken to return the faulty equipment or system to service.

Network design and network redundancy may also influence availability. The most important services have normally two independent routes and one fault should not sever communications.

Network redundancy may reduce both the requirement for a short MTTR, and the costs associated with having personnel on duty or in readiness outside normal working time.

Both MTBF and MTTR have a direct bearing on system availability.

$$\text{SYSTEM AVAILABILITY} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}} \times 100\%$$

The power utilities must define their requirement for system availability and based on that they may define requirements for MTBF and MTTR.

The most effective way in which a power utility may influence availability is through maintenance support which affects MTTR.

Reliability (MTBF) and maintainability (part of MTTR) are consequences of the manufacturers design and construction. Power utilities can only influence these parameters by specifying their requirements before contract signing. The contract may include procedures for testing the equipment or system during factory acceptance tests and/or during site acceptance tests. Maintainability may be tested by representatives of the utility maintenance personnel who simulate fault location and repair for a number of typical faults. These maintenance personnel should receive appropriate training and use the specified management tools and documentation.

5.3.2 Documentation

Documentation is an important tool for personnel in the telecommunication network management centre. Up to date information on network configuration and services is necessary for identification of routes, destinations and/or services. This information will guide network management actions in the case of network reconfiguration/restoration and will therefore influence the availability of the network or services.

It is recommended that there should be a network plan which includes information about temporary alternative routings which may be used to bypass failed nodes or sections of the network. This plan should define the actions to be taken for fault correction and also the actions to be taken following restoration of the network to its normal configuration.

The plan should also include procedures which the operator may use when managing any connected networks. Relevant information on customers, other network management centres or utility administrations should also be included in the plan.

All this information can be covered by manual registers, or a data base system. If there is a network construction data base, considerable benefits may be obtained by integrating this with the network configuration data base (e.g. partly using the same data base).

Transmission restoration functions are often implemented in the modern telecommunication network to improve the availability and quality of services, by minimising the effects of a transmission failure, and to make maintenance operations easier. See section 5.4.1.

The introduction of dynamic network components, with their own network management systems may create problems because of a lack of standardisation. The difficulties arising from the interconnection of these normally vendor specific systems and also their connection to existing network management systems will have to be resolved on an individual basis.

A task which may be underestimated is the transition from a manual register or an old data base to a new system. This will require very careful preparation and analysis of all expected requirements and services. The larger and more complex the network topology the more sophisticated the required data base.

5.4 Flexible Use of Telecommunication Networks

5.4.1 Transmission Networks

Flexible and more efficient use of the basic telecommunication infrastructure, that is the digital transmission network, is becoming possible in power utility networks with the use of network elements having remote control capability. These network elements include both new SDH (Synchronous Digital Hierarchy) transmission equipment and also newer generation PDH (Plesiochronous Digital Hierarchy) equipment, particularly flexible multiplexers, branch and cross-connect equipment. With such network elements, use of transmission channels (time slots in digital lines) is no longer determined by cabling but can be controlled by network management.

This control capability makes the addition of new transmission connections, as well as modification of existing ones, a fast and easy task, compared to older equipment where all changes required travelling to actual sites(s) and cabling changes. Thus the transmission network operation changes and the operation of the installed facilities can be much more flexible, which in turn means that utilisation of the capacity becomes more efficient and less reserve capacity and "prewired" possible future connections are needed in the network. These types of transmission networks are often referred to as flexible or dynamic transmission networks or managed transmission networks (MTN) due to these features.

However, these new possibilities impose increased responsibilities on the network management, as it now has to control the logical configuration of the transmission network, in addition to the more traditional supervision tasks (alarm handling and possibly some quality supervision). The transmission network operator will have an accurate and up-to-date picture of the actual connected transmission channels and will even be able to look at a particular end-to-end circuit (e.g. to check routing or performance). This means that a network level management system which supports at least the most common daily operations becomes a necessity for any large network, and an element level management system is sufficient only for smaller networks (a few nodes) and as a temporary solution for a transition period.

A related issue is that of network documentation. For the 'hard wired' transmission networks it is possible to base network configuration information on drawings, typically using a CAD system. Even here it can be difficult to guarantee actual one to one correspondence of the data base (drawings) and the real network situation after a number of minor changes in various parts of the network. However, in a dynamically configured network this manual method is no longer feasible and the network documentation is instead based wholly on the network management system. It will have full information on the real network situation and the master network drawing is now electronic and based on the network management systems data base. Paper copies of this master document may be made as needed. It should be noted that they only represent a snapshot of the network situation at a particular moment.

5.4.2 Service Networks

Similar, if less dramatic, changes are happening also in other parts of the telecommunication network. In voice networks (switching systems for normal administrative and operational telephony) and in data networks (e.g. packet networks) as well as in private mobile radio networks (PMR Switching Systems) the remote control capabilities and the configurability of the systems are increasing. Network resources can therefore be better utilised. Network management systems must also be adaptable to new equipment features, to enable their efficient remote control.

In many cases the need for network level management is not as urgent as in the case of transmission networks and in these cases element level management (e.g. one exchange is managed at time) is still a viable alternative. However, even if element level management is adequate the complexity of the management system may still increase as there is a strong desire amongst operators to have some automated tools to help with frequent operations.

5.5 The Need for Local and/or Centralised Management

The need for centralised and local (e.g. regional) telecommunication management depends wholly on the organisation and working practices of the power utility. The supervisory functions, such as performance supervision and especially fault monitoring and fault location capability must be available at the appropriate maintenance location. No 'universally best' solution exists.

If there is only a centralised maintenance centre from which the maintenance staff are dispatched, then there is clearly only a temporary requirement for local network management. This may be provided by using portable equipment connected to the telecommunication equipment at the visited site. If on the other hand there are regional maintenance centres, there is clearly a need to have access at least to the above mentioned fault related information in these centres. This access can be implemented either by having a distributed management system or by simply using terminals connected to a centralised system at each centre. The former solution is better suited to big networks as it tends to be more complex and expensive, and the latter for smaller networks - its disadvantage is that the access to information depends on links to the central location. These links may be protected in several ways, e.g. using two alternative routes and/or public network backup line.

It may be worth noting that independently of the solutions discussed above (i.e. one or more supervisory TMN centres), some network management functions are often best carried out centrally. For example logical transmission network configuration (connection of channels) and overall network performance evaluations may be easier to handle from just one centre.

Centralisation may also have other benefits such as a more flexible and efficient organisation of maintenance operations and administration. This will improve maintenance effectiveness and increase network availability, but also decrease maintenance costs. Also, other functions such as accounting management are better performed centrally. The main network documentation could also be based on the data base of a centralised management system (on drawings which are based on the information kept in that data base).

5.6 TMN Capacity Considerations

A TMN is intended to support a wide variety of application functions which cover the operations, administration, maintenance and provisioning of a telecommunication network. The TMN can vary in size from a very simple connection between a management system and a single network element to very large networks interconnecting many different types of management systems and network elements.

The TMN is functionally a separate network that interfaces with the telecommunication network at several different points to receive information from it and to control its operation. The TMN may be implemented in several ways. It may use parts of the telecommunication network which it supports to provide its communication, either by using free capacity in various transmission frames or by a standard data communication channel. Separate communication media may also be used.

The TMN should be designed such that it has the capability to interface with several types of communication elements. This will ensure that a framework is provided which is flexible enough to allow for the most efficient communication between different elements and the TMN, and also within the TMN. The TMN architecture must provide a high degree of flexibility to meet the various topological conditions of the network itself and the organisation of the utility. It should also make possible the implementation of open standards and also the adaptation and use of network management applications from various vendors.

A failure in the TMN should not have an adverse impact on normal traffic flow in the telecommunication network, it may restrict the possibility of making changes to network configuration and may temporarily disable alarm and performance monitoring (these data can typically be retrieved later from the history files of the network elements or the lower level management systems).

Utilities must define their requirements for TMN availability based on the degree of importance the TMN will have to the supervised telecommunication network and the maintenance and operational organisation.

Where the TMN is a key function, it has to be carefully designed in order to provide the required degree of availability. A single fault on the network should not inhibit receipt or transmission of information over the TMN. In some cases, it may be prudent to carry the normal traffic which is being supervised and the TMN traffic in different communication media.

There are several types of capacity considerations needed for any TMN. These are related to different parts and aspects of the management system(s). All capacity considerations are closely related to the cost of the TMN. The total costs for the whole TMN have to be taken into account. One aspect is the cost to transport data between the TMN operation system(s) and the telecommunication network. The cost for required communication links has to be considered and minimised where feasible. Another important cost aspect is the design and size of the TMN itself, operation system(s) and possible lower level management systems, such as mediation devices.

The capacity of the management system itself and also the underlying computer systems, including those needed for the data network(s) interconnecting these systems should be considered. However, these capacity evaluations are very difficult to perform in practice with any degree of accuracy or reliability, and often only "order-of-magnitude" checks for normal situations and for some selected reasonable "worst cases" are practical.

5.6.1 Management Systems

In considering the management systems themselves, there are some "static" issues, related for example to the amount of data to be stored, and many "dynamic" issues related to performance (response times) and maximum tolerable load of the system(s).

The most obvious "static" requirements are various memory capacity requirements for the computer system(s), including both working memory (typically RAM) and memory for permanent data storage (e.g. hard disks). Both are to some extent related to the required performance and closely related to the size and complexity of the telecommunication network to be managed. The network size, together with the amount of data to be stored per equipment, determines to a large extent the size of the system date bases; they are, however, also affected by the amount of historical information stored (duration of history and time resolution).

The "dynamic" requirements are related mainly to processing power of the computer systems, compared to the number and complexity of tasks to be executed. This area is most difficult to estimate or calculate without practical experience (test measurements) as it depends so much also on the software applications in use.

5.6.2 Data Network(s)

The overall performance of the management system may well be limited also by the data network(s) if their throughput does not correspond to the capabilities and needs of the computer systems. In fact, potential peak loads due to fault reporting are so high during major network failures that without lower level message filtering any data network is likely to become congested. Also, in normal operations requiring large data transfers such as downloading large cross-connect tables or new software modules, data transmission determines the speed of operation.

It is almost impossible to state any general "recommended" data link minimum speeds, as needs depend so much on the number of elements and amount of data used for operations. At the lower end of the management network, e.g. for supervision only, low speed data channels, say 1200 - 9600 bits/s may be adequate while between upper level systems 64 kbit/s may be just enough or even too little (e.g. for interconnecting large LAN based management systems).

5.7 Data Base Structure

According to CCITT recommendations and ISO standards, an object-oriented data base interface should be used to describe the TMN. The information model of the TMN describes the various entities which constitute the overall system. The model also defines the classes of objects to be managed, the attributes and the actions that may be performed on each network element (NE). The Management Information Base (MIB) of a TMN is part of the Management Information Tree (MIT), which aggregates the information relating to the various managed equipments.

The use of object oriented data structures makes it possible to manage distributed application processes, and to easily store, access and modify the MIT data.

To protect the high investment in existing company information systems (IS) and in order to integrate it with the TMN functions, it is important to ensure access to the existing company IS data base from the Operations System of the TMN.

The IS data base describes each equipment in a "static" way and therefore it is not suitable for the "dynamic" description necessary for real-time management of the telecommunication network.

A possible approach to solve the above problem is to migrate static data base structures towards relational DBMS, conforming to de facto standards. SQL (Structured Query Language) allows an easy and effective access to the relational data bases.

SECTION 6 DESCRIPTION OF EXISTING TELECOMMUNICATION NETWORK MANAGEMENT SYSTEMS IN POWER UTILITIES

6.1 General Comment

This section is based on the responses to a questionnaire Ref.[8] which was sent by Working Group 02, in 1990, to SC35 members in 24 countries. SC35 members distributed the questionnaires to power utilities within these countries. Responses were received from 59 utilities.

The utilities which have responded vary greatly in size, as can be seen from Fig. 6.1.1.

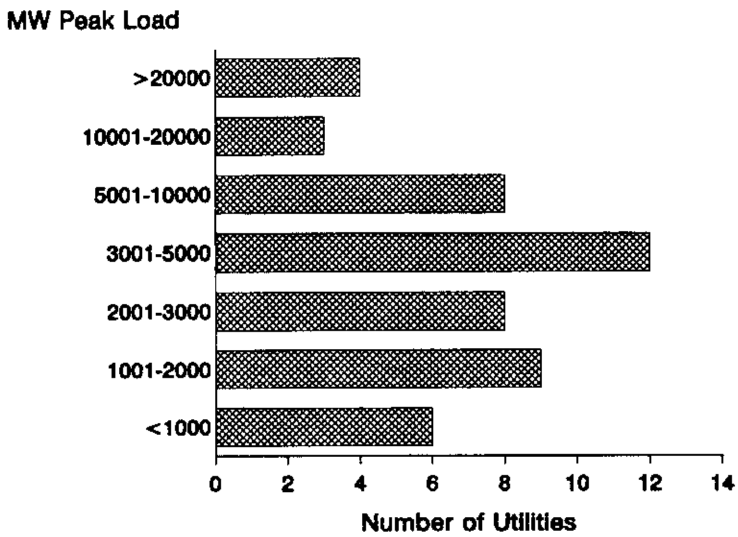

FIG 6.1.1 PEAK LOAD DISTRIBUTION OF UTILITIES WHO RESPONDED

The responses show that practically all of the power utilities have one or more control centres to monitor and control their power systems. Of these, approximately 20% have only one central control centre, while the rest have central as well as regional control centres. One might expect that there is a connection between the size of the utility measured in MW or km^2 and the structure as regards control centres, but this is not the case. There are large as well as small utilities in both groups.

Fig 6.1.2 shows the number of control centres as a function of the number of utilities.

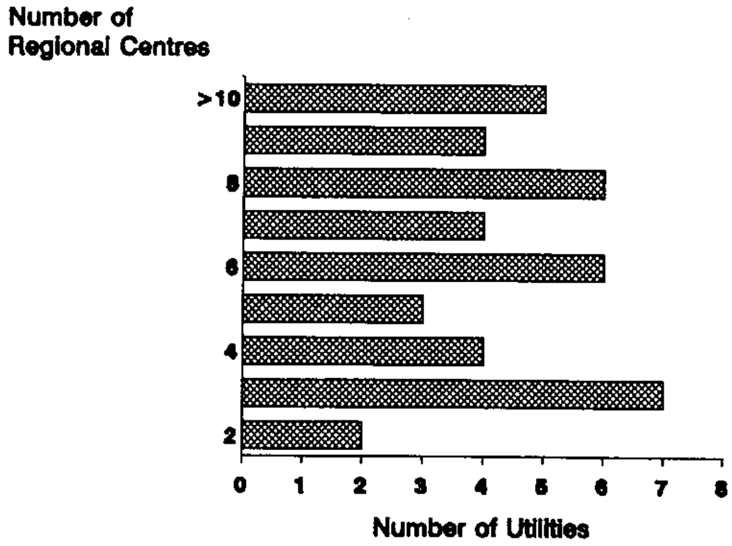

FIG 6.1.2 DISTRIBUTION OF REGIONAL CONTROL CENTRES AMONGST RESPONDING UTILITIES

6.2 Telecommunication Systems Managed

In contrast to the fact that practically all of the utilities have one or more power system control centre, only approximately half of the utilities have telecommunication network management control centres.

The questionnaire did not provide any guidelines for how advanced a control centre has to be to be called a telecommunication network management centre. Therefore, there may be a great difference from utility to utility in their assessment of whether they have such a centre.

6.2.1 Fixed Transmission Network

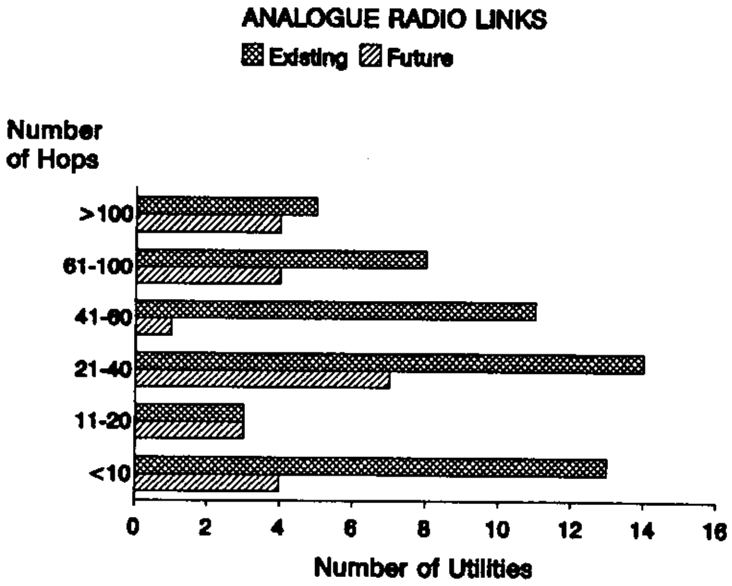

FIG 6.2.1 NUMBER OF ANALOGUE RADIO HOPS AS A FUNCTION OF THE NUMBER OF UTILITIES

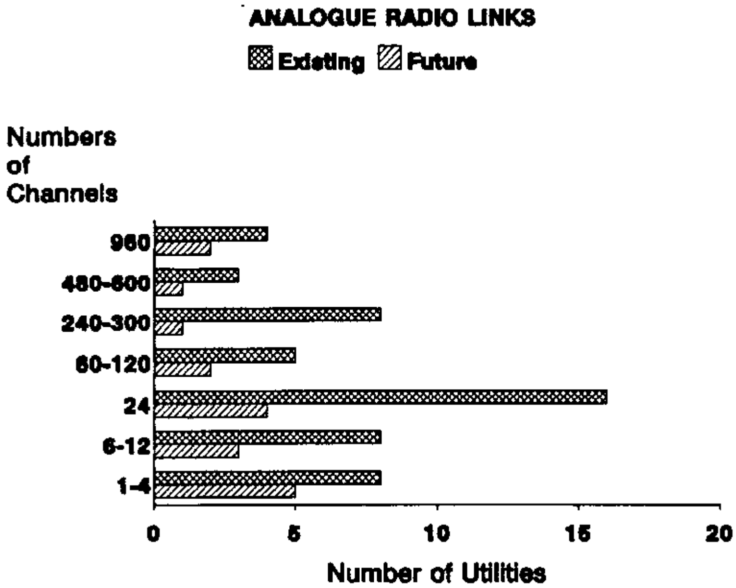

FIG 6.2.2 TYPICAL CAPACITY OF ANALOGUE RADIO LINKS AS A FUNCTION OF THE NUMBER OF UTILITIES

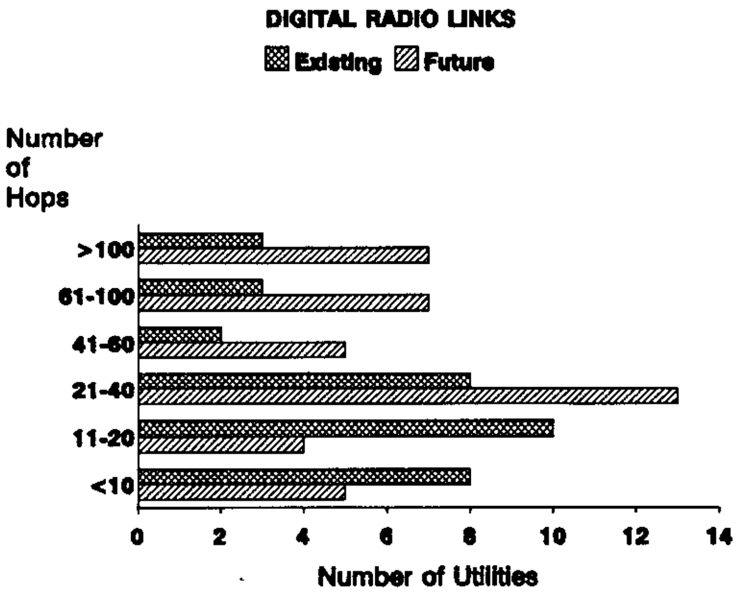

FIG 6.2.3 NUMBER OF DIGITAL RADIO LINKS AS A FUNCTION OF THE NUMBER OF UTILITIES

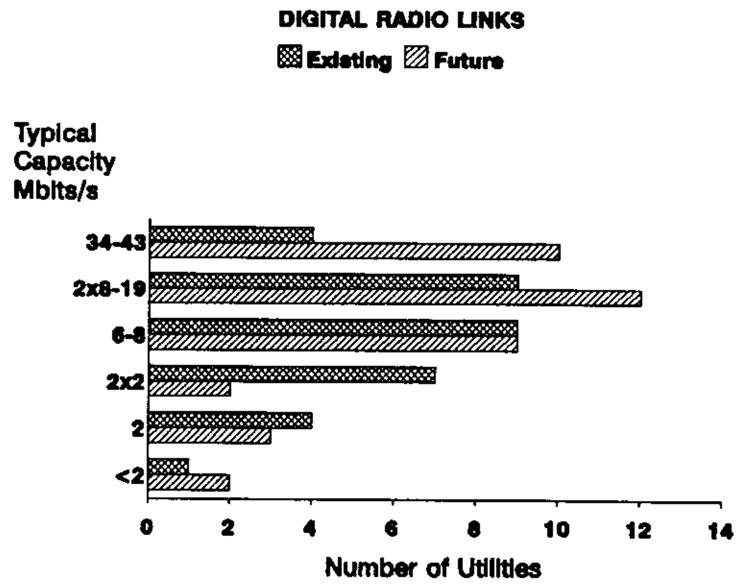

FIG 6.2.4 TYPICAL CAPACITY OF DIGITAL RADIO LINKS AS A FUNCTION OF THE NUMBER OF UTILITIES

As can be seen from fig. 6.2.1 the number of analogue radio links will reduce significantly in the future, and this is also reflected in fig. 6.2.2, which shows that the number of utilities using analogue radio equipment is generally on the decline. This decrease in analogue radio capacity is offset by an increase in digital radio capacity - fig. 6.2.3 indicates that a large number of utilities propose to increase the number of digital radio links. Fig. 6.2.4 shows that this large increase applies to multi-channel equipment, while the use of equipment with only a few channels is decreasing.

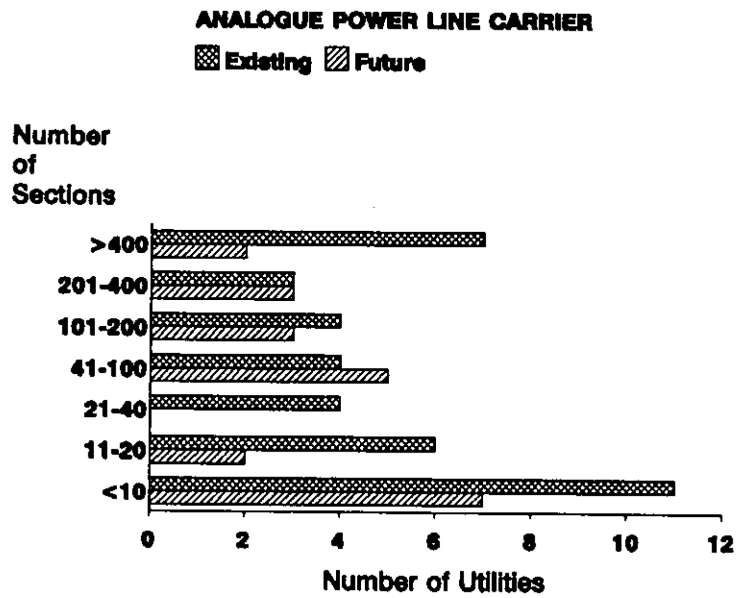

FIG 6.2.5 NUMBER OF SECTIONS OF ANALOGUE PLC AS A FUNCTION OF THE NUMBER OF UTILITIES

Fig 6.2.5 shows the present situation in relation to analogue PLC. Typical capacity is 1 or 2 PLC-links per section. Digital PLC is not yet widely used, only one utility had one single section in operation. However, there are 6 utilities which plan to use digital PLC with a capacity of 32 kbit/s or 64 kbit/s.

As regards optical systems there are only two utilities which employ high-speed transmission (at least 140 Mbit/s), while low to medium-speed transmission is quite common as can be seen from Fig. 6.2.6. This figure only shows low to medium capacity systems.

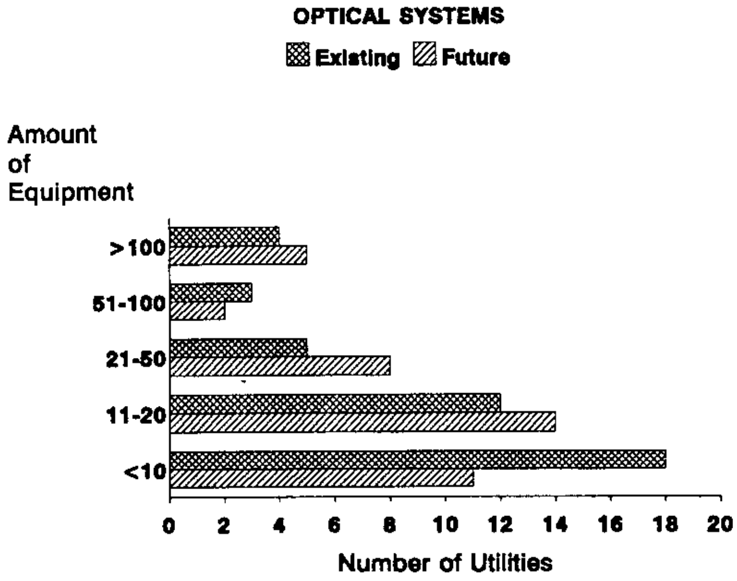

FIG 6.2.6 QUANTITY OF LOW TO MEDIUM CAPACITY OPTICAL EQUIPMENT AS A FUNCTION OF THE NUMBER OF UTILITIES

What is perhaps surprising is that there is no obvious tendency towards an increase in the amount of equipment, in 2 to 34 Mbit/s systems. The trend toward high capacity systems is growing with 10 utilities planning high speed transmission.

From the responses it can be concluded that only approximately half of the utilities use analogue transmission on their own copper cables and that in future this will be reduced to approximately one third. What might be more surprising is the fact that only one third of the utilities use digital transmission on copper cables and that this will remain more or less unchanged in future.

In the case of analogue transmission the utilities mainly use equipment with a capacity of 12 channels. For digital transmission 2 Mbit/s or 1.5 Mbit/s is used.

Rented analogue circuits are used very extensively at present, but the number will decrease significantly in the future.

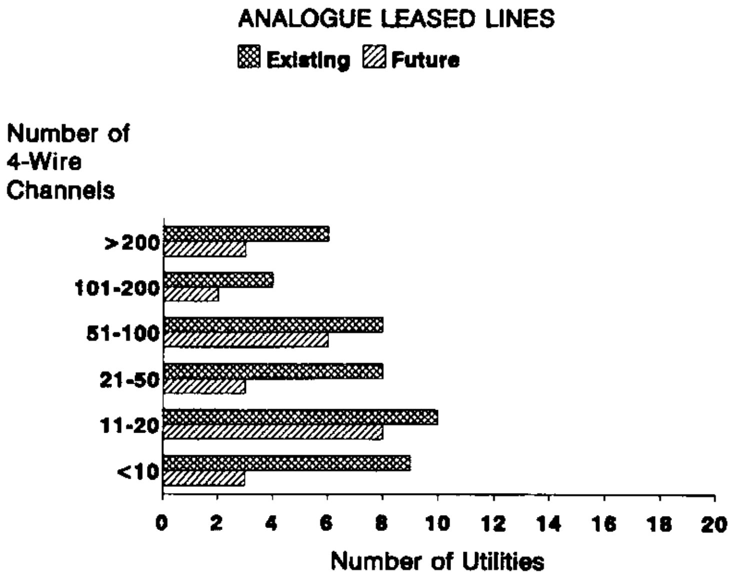

FIG 6.2.7 NUMBER OF 4 WIRE LEASED LINES AS A FUNCTION OF NUMBER OF UTILITIES

As for digital rented circuits these are only used by one third of the utilities, and this will not change in future.

All these circuits form communication networks which are typically structured in a hierarchical way, which means that there is a "backbone" system with a large capacity together with local "distribution" systems with a lower capacity. The topology is typically a mixture of a star and meshed networks and it seems that this will also be the case in future. As regards the backbone system approximately 20% have a capacity of less than 20 channels, 30% have a capacity of between 20 and 120 channels and finally approximately 45% have a capacity of more than 120 channels.

Approximately 90% of the utilities who responded use their own network for the transmission of SCADA signals and approximately 30% use PTT as well.

The percentages for teleprotection and operational telephony are more or less the same as those in the case of SCADA, while there are up to 50% who use PTT for administrative information exchange and administrative telephony. These figures apply to both existing and future systems.

Approximately 50% of the power utilities have other users on their telecommunication system. The responses indicate that this will continue in future. Typically, these users are other utilities, but in 15% of the responses this is not the case.

The telecommunication network is often interconnected with the networks of others, but normally only to ensure information exchange. Only in approximately 15% of the cases is real cooperation taking place.

In about 40% of the responses, the telecommunication network of the utility constitutes an integral part of the telecommunication network of other utilities. However only in 10% of these has a joint telecommunication network management system been established, the remaining 30% state that they have their own telecommunication network management system.

The utilities were also asked which PTT facilities were used. 50% use the PTT's X.25 network, while only about 5% obtain telecommunication network management information from PTT.

6.2.2 Mobile Radio Network

The use of mobile radio systems is shown on fig. 6.2.8

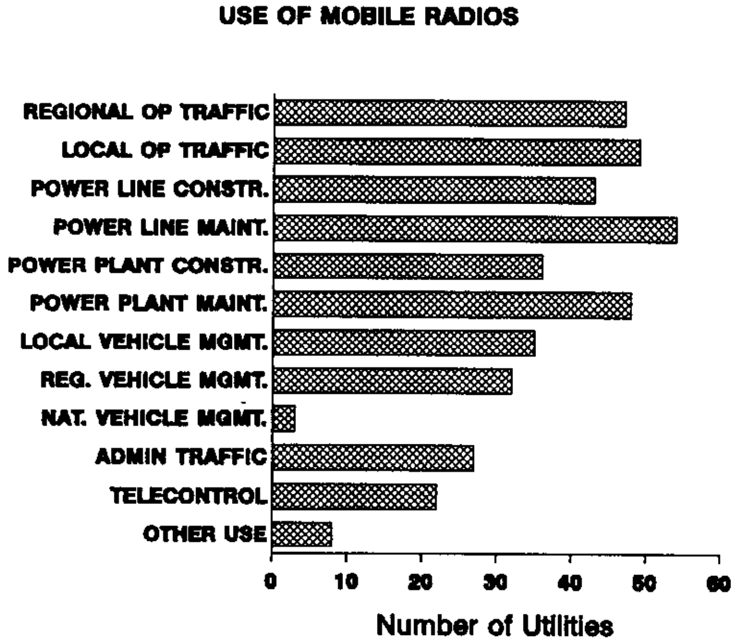

FIG 6.2.8 THE USE OF MOBILE RADIO AS A FUNCTION OF THE NUMBER OF UTILITIES

Fig. 6.2.8 shows that operational traffic and maintenance are the dominating applications.

The power utilities use both public and private mobile radio systems. 33 utilities use public networks, and of these 31 use cellular systems. The number of mobile radios connected to public systems varies from 10 to 2500 with an average of 230.

If we consider the private systems, a somewhat different picture emerges as they are much more common. The number of mobile radios installed in vehicles varies from 30 to 20,000 with an average of approximately 1,150. The number of transportable radios held by power utilities range from 5 to 4,000 with an average of approximately 340. In the case of handportable radios the numbers range from 10 to 8,500 with an average of 590. As regards call receivers the numbers are 20 to 13,000 with an average of 740.

Only one utility uses pagers to a large extent.

The reasons for choosing a privately owned system are shown on Fig. 6.2.9

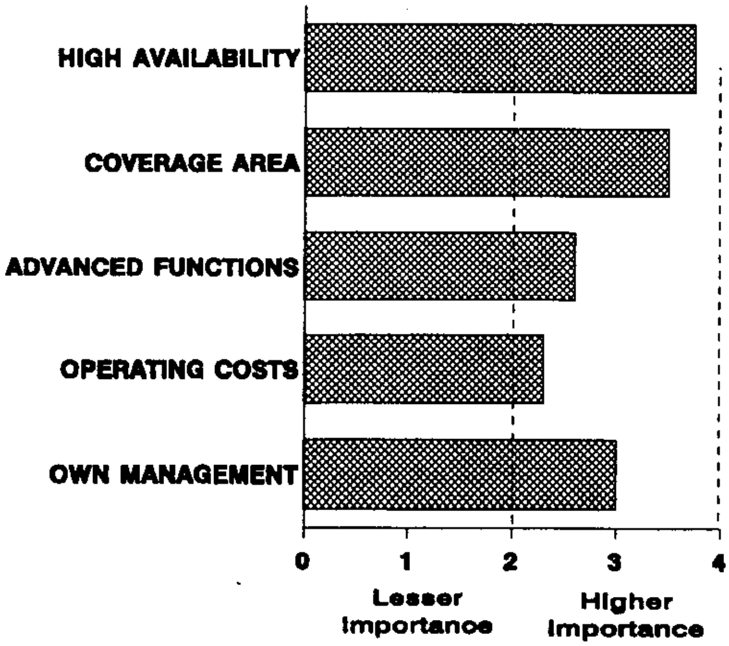

FIG 6.2.9 RELATIVE IMPORTANCE OF REASONS FOR OWN MOBILE RADIO SYSTEMS

The valuation scale used in Fig 6.2.9 ranges from 0 to 4, where 0 means of no importance and 4 means very important. In their responses, utilities have stressed the importance of high availability and good coverage. The fact that privately owned systems are more common in power utilities may to some extent indicate deficiencies in the public systems.

6.3 Management Requirements and Functions

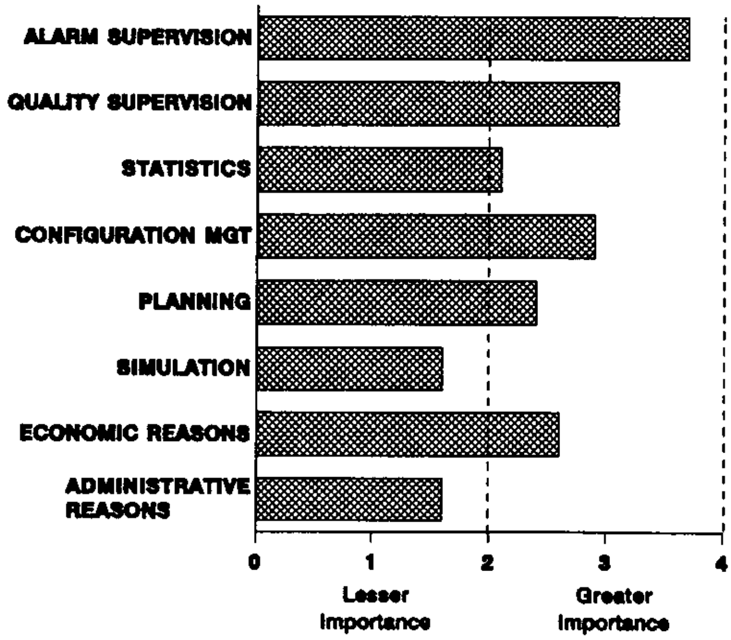

FIG 6.3.1 RELATIVE IMPORTANCE OF TMN REQUIREMENTS

Fig. 6.3.1 shows which reasons are important for the introduction of telecommunication network management systems, and it appears that alarm supervision is the most important factor with an average valuation of 3.8, while simulation and administrative reasons are the least important with an average of 1.6. (The scale goes from 0 to 4, 0 meaning of no importance and 4 very important).

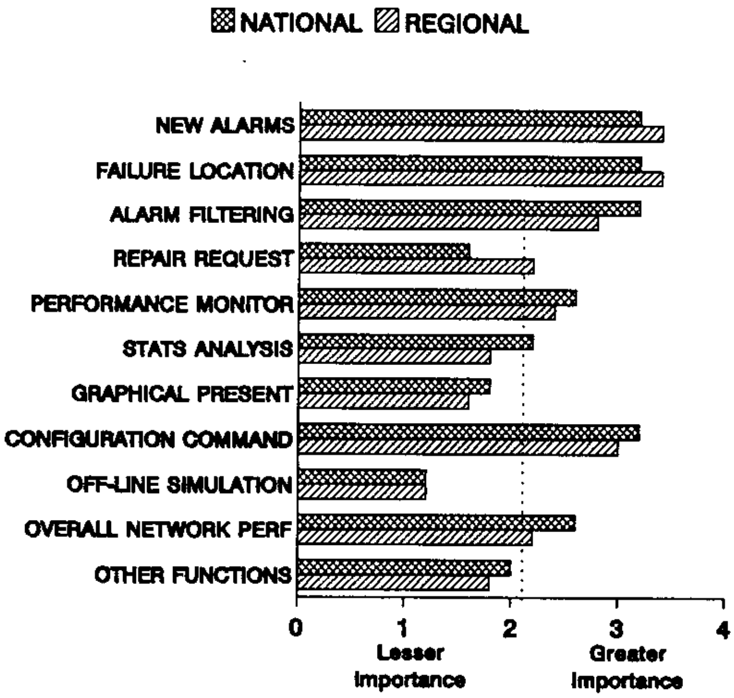

FIG 6.3.2 RELATIVE IMPORTANCE OF TMN FUNCTIONS

Fig. 6.3.2 shows which functions are considered of greater or lesser importance at both national and regional level. It is worth noting that there is little difference in the requirements nationally and regionally. (In Fig 6.3.2, 0 means not so important and 4 is a "must").

The questionnaire also dealt with telecommunication network management database systems. Power utilities were asked whether their present telecommunication network management had a database system. 85% responded, of which approximately 45% had a database system. As regards future systems, 77% answered and approximately 88% propose to have a database system.

It is significant that very few utilities have defined the interface and the response time of the database.

The next group of questions concerned the size of the database, but the responses were so few that it is not possible to use these as a statistical base. The database must be accessible by using a query language such as SQL, allowing a complementary analysis of the data. However only 10 utilities have defined the interface to the database for future TMN. An analysis of the received responses is shown below,

INFORMATION TYPE	PRESENT	FUTURE
Indications & Alarms	30 - 20,000	120 - 30,000
Measurements	10 - 3,000	30 - 10,000
Object Types	4 - 100	5 - 200

6.4 Implementation of TMN

6.4.1 Structure and Hierarchy of Network Management

Already approximately 56% of the utilities who have responded have a telecommunication network management centre and this number is expected to increase to 74% in future. Of the utilities which have telecommunication network management centres at present the manning level is as follows,

TYPE OF OPERATION	PRESENT SYSTEMS	FUTURE SYSTEMS
24 HOUR BASIS	31%	28%
NORMAL WORKING HOURS	52%	62%
AS NEEDED	17%	10%

Almost 80% of the utilities asked have considered whether it would be possible merely to rely on a central telecommunication network management system, and of these a little more than 50% have answered in the affirmative, while a little less than 50% think that regional telecommunication network management systems are also necessary.

6.4.2 Local versus Centralized Functions

If one looks at the tasks which these utilities consider the regional centres should deal with, they are almost identical with those of the central telecommunication network management centres as can be seen from Fig. 6.3.2.

However so few responses were received in connection with central versus regional telecommunication network management systems that it is impossible to draw any conclusions based on these statistics.

An obvious possibility would be to use the normal SCADA system to supervise the telecommunication network, and at present 51% of those using telecommunication network management do so partly and 15% do so completely. In future the figures will be 34% and 15%, respectively.

As the majority use the SCADA system for telecommunication network management wholly or partly, it is reasonable for the telecommunication network management centre to be co-located with the SCADA control centre and it is also the case in approximately 50% of the cases, both today and in future. But even though the two centres are often co-located it does not mean that the same personnel perform both functions. This applies in only 15% of the cases, however, in 27% of the cases the same personnel perform both functions after normal working hours, and it seems this will not change significantly in future.

6.5 Interfaces

6.5.1 Man Machine Interface (MMI)

Regarding the MMI requirements Figure 6.5.1 shows that the most important features required for the display system are a single screen, colour, graphics and windows. It is considered most important that a global view of the network is possible with a slight preference for zooming to enhance details.

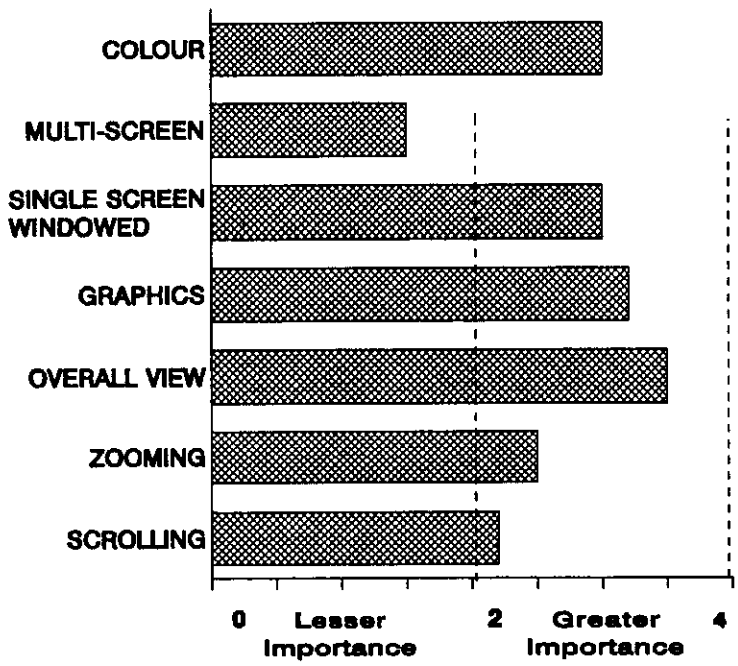

FIG. 6.5.1 RELATIVE IMPORTANCE OF MMI REQUIREMENTS

6.5.2 Interface to Network Elements :

Not many utilities responded to this question however the responses of those who did indicates that,

- An X.25 interface must be provided or is desirable for 33 utilities.
- Q2 and Q3 interfaces are little known (the significance of the responses is very low (19% of the Utilities responded on the Q3 interface and 55% responded on the Q2 interface).

It is important for utilities that the connection to the TMN is similar to the connection of a network element. This allows the TMN control centre to be set up anywhere in the network (e.g. in an X.25 network). A standard interface is desirable for this reason.

6.5.3 Interface to Other Management Systems

Fig 6.5.2 shows how utilities rate various interfaces to other management systems. The results have a low significance, however they indicate that the TMN should be able to interface to both X.25 for geographically large networks and to ETHERNET for smaller networks. A preference for OSI compatibility is clearly shown, which may indicate future trends. ETHERNET seems to be the most commonly used LAN at present.

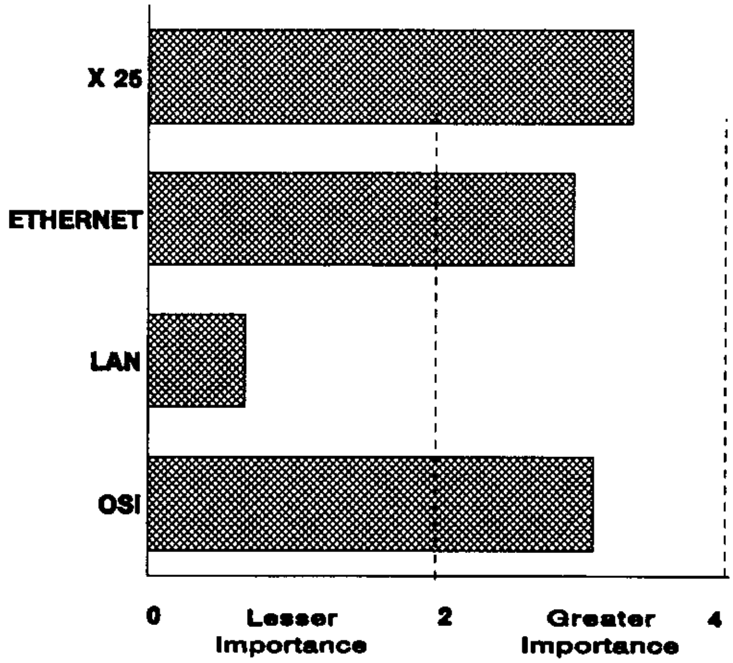

FIG 6.5.2 TYPE OF INTERFACE TO OTHER SYSTEMS

6.6 Maintenance Organisation

6.6.1 Staffing and Location

The replies to these questions provide an insight into how power utilities manage the maintenance of their telecommunication systems at present. There were fewer responses in relation to future maintenance management policy and as a result it is difficult to identify future trends. However, it appears that the future will bring little change in either the number of maintenance staff or in their deployment at regional and central locations.

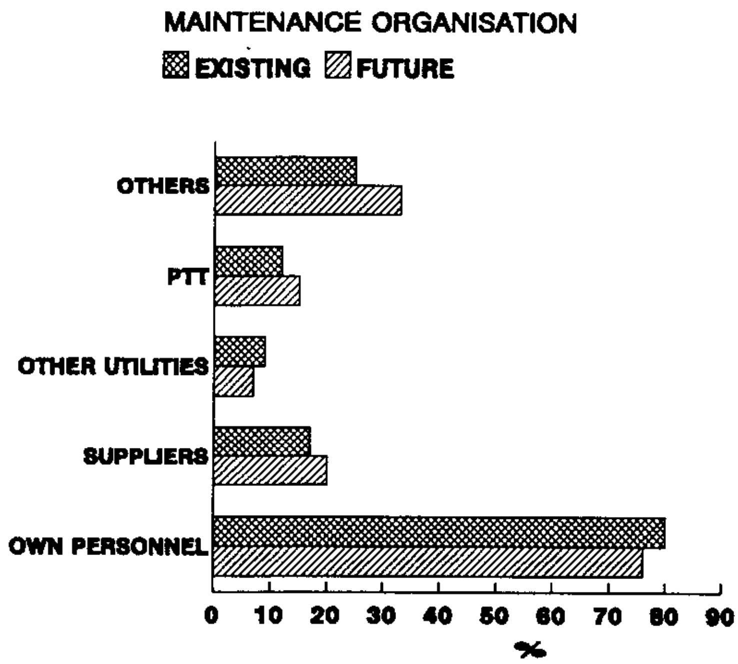

FIG 6.6.1 MAINTENANCE PERFORMANCE

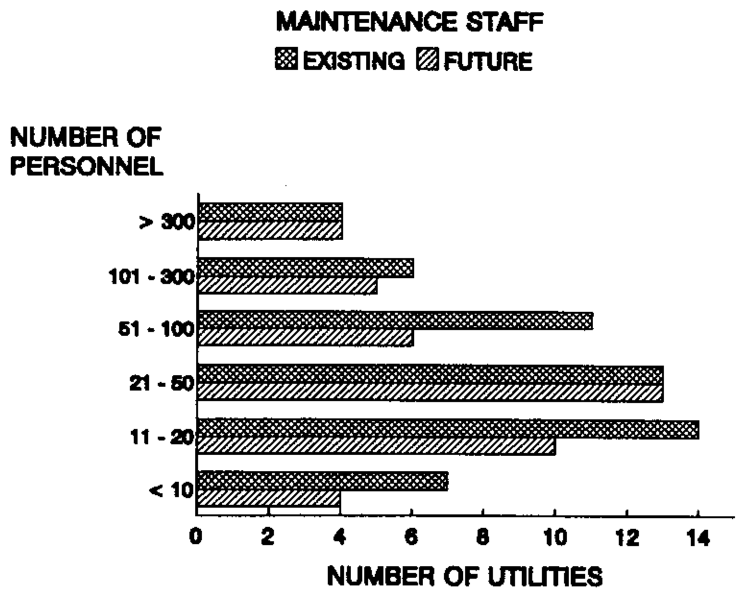

FIG 6.6.2 MAINTENANCE STAFF

6.6.2 Use of External Maintenance Services

Responses to the questionnaire indicate that power utilities use both their own personnel and those from external agencies i.e. suppliers, PTT, other utilities.

The replies show that power utilities use their own personnel for 70% of maintenance tasks. Analysis of the responses using the weighted average according to the size of the utilities shows that at present 76% of all maintenance is performed by the utilities own personnel and 10% by equipment suppliers. In future, indications are that 71% of all maintenance will be performed by the utilities own personnel and 15% by suppliers. This shows a trend towards using external services.

6.6.3 Availability, Response and MTTR Requirements

28% of the power utilities have formulated MTTR requirements for their TMN and these vary from 4 to 48 hrs. with an average of 20 hrs. SCADA (including RTUs) have somewhat more stringent requirements at an average of approximately 11 hrs. It seems utilities have no plans to change these MTTR requirements in future.

Generally, the power utilities do not have very stringent requirements in regard to time tagging of indications from TMN systems, typically an accuracy of about 10 seconds is acceptable. However, there is a trend toward higher accuracy in future with a requirement of +/-1 second becoming standard.

The required response time for top priority information is typically below 10 seconds, however a great many utilities find response times of up to one minute acceptable. Again there appears to be a trend toward shorter response times in future. Lower priority information has much less stringent requirements.

At present the annual availability requirements for a TMN are typically 99.0%, in future the availability requirement may increase to 99.9%.

SECTION 7 JUSTIFICATION FOR INTEGRATED TELECOMMUNICATION MANAGEMENT NETWORKS

7.1 Multi-Vendor Environment Problems.

All current telecommunication networks used by power utilities, whether large or small, require some level of network management support if they are to provide a high-quality service to their customers. The tools and systems which provide this support are generically known as TMN.

As explained in section 6.3 one of the more important reasons for acquiring a TMN relate to the fault management aspects. Configuration management, i.e inventory and connectivity of network elements, is the underlying foundation for all network management functions.

However, the increasing complexity of networks which :

- Support different services voice, data, video, etc.
- Include different service networks: telephony, data, ISDN, etc.
- Depend on different technologies: analogue, digital.
- Have different levels of ownership: private, hybrid, rented.
- Have different classes of equipment: switches, modems, etc.
- Have different suppliers of equipment.

The fact that private networks of power utilities are very different because:

- No two networks are alike or at precisely the same stage of development and customized applications are often needed to suit network requirements.

- The technical, business and political environments in which the networks operate differ from power utility to power utility.

and also recent changes

- Technology change
- Mergers and acquisitions of telecommunications equipment suppliers,

have contributed to the creation of an environment of multi-vendor, world-class suppliers.

This has resulted in a wide selection of TMN, supplied by various vendors, but most of these TMN only support specific equipment/systems and may not interoperate even for other products provided by the same vendor. This could imply for a large utility several terminals and /or workstations and printers connected to various TMNs. This is not only costly in terms of equipment, personnel and training to manage the utility's TMN, but network management is done in a fragmented and nonintegrated manner. Essentially, all integration is provided by the human operator.

Nevertheless, the telecommunication industry is trying to respond to the customer needs in several ways:

- Improving the capabilities in both existing and new TMN systems (usually through the use of microprocessor based test units), and implementing sophisticated graphical presentation systems for network managers.

- Alliances and acquisitions, stimulated by the fact that, although working to establish TMN standards the industry cannot wait until these standards are established before taking action to meet customer demand for interoperability of the TMN. Such alliances and acquisitions may result in some interoperability of the TMN capabilities of these vendors' products.

- Development of a set of management standards for TMN, specification of implementation agreements, and provisions for conformance testing capability.

However, establishing TMN standards is difficult for four reasons:

- The majority of today's TMN products and services were originally developed and optimized for the particular proprietary requirements of each vendor or utility without anticipating the need to support open interoperability.

- Because TMN is a complex system and must satisfy many requirements, a successful solution for interoperable network management requires careful and detailed work in defining the necessary open architecture, protocols, distributed management mechanisms, and structuring of information about managed components.

- The work must be done so that minimum constraints are placed upon the way vendors and network managers will implement the standards. This makes it possible to implement standards across a wide variety of equipment types - from small, relatively simple and inexpensive systems to large, complex systems. This approach will speed the acceptance of standards by all suppliers of TMN products and services as well as shorten the time and cost in their implementation.

- Standards must be designed in a flexible manner that anticipates their evolution needs. They have to evolve to accommodate both new technologies as well as ever expanding capabilities which develop to meet user needs.

As explained in more detail in Section 9, the world's main telecommunication standardization bodies have been working towards a standard view of network management interfaces since 1985.

ISO is promoting standardization of network management for Open System Interconnection (OSI) in computer communication in general. CCITT is also working on TMN standards for management of public networks. In accordance with OSI they are tending toward the use of Object Oriented Design (OOD) techniques.

OOD is a powerful methodology for understanding and documenting complex software applications. OOD focuses on the essential requirements of a software system, avoiding some of the limitations of traditional methods (e.g. concentrating on particular aspects of system requirements: information modelling in respect of data, behavioral aspects of real-time systems and process aspects in respect of the computational characteristics of applications).

OOD systems benefit from three characteristics:

- Inheritance: this allows the specification a new object class which is similar to an existing object class without having to specify the known similarities.

- Encapsulation: only the operations of an object class have access to its internal data. The main benefit is that the implementation of the object is independent of the applications that use the object class.

- Polymorphism: a polymorphic function is one that can be applied to more than one object. (Based on the fact that object class can respond differently to the same message allowing rapid addition of new object classes to evolving applications).

These characteristics place OOD in the mainstream of modern design concepts as an excellent tool for managing multivendor devices and for building reusable software system.

Areas where rules and definitions are necessary for network management are as follows:

- Definition of models and concepts: in particular, what types of managed objects?
- Management functions: for what purpose?
- Managed objects: what is managed?
- Management data: what kind of information?
- Protocol: how to transfer management information?
- Service functions: to do what?

Except for the last item, which differs from network to network the above items are suitable standardization subjects.

Standards, when they are available, are the first step to TMN interoperability. The next step is to specify implementation agreements, also known as profiles. Profiles specify which particular option of the many protocol options at each OSI layer must be implemented. They include conformance statements related to these selections and many implementation details not included in the standards.

Full adoption and implementation of the OSI standards with vendor specific enhancements seems to be on the horizon.

7.2 The Need to Integrate Management Systems.

As previously described, power utility telecommunication networks are heterogeneous. They are composed of network elements from different suppliers, supporting different levels of network functionality with different network architectures and protocols. In these circumstances, management of such networks is a complex task which may result in increased operating costs and reduced availability.

To avoid these undesirable consequences the capabilities required for managing such networks can be summarized as:

- The ability to manàge all sub-networks in the network, regardless of the OSI profile or protocol suite used.
- The ability to manage a combination of telecommunication and local networks.
- The ability to manage a wide range of network resources from low-level devices to end-systems.
- The ability to provide a set of basic management functions such as those defined by international standardization bodies.

All of these requirements combined with the fact that sharing information among different network management products often requires customized applications, protocol conversion or even re-entry of data suggests an integrated TMN.

But, what do we understand by "integrated"? This term means having one tool, or a set of tools for managing all of the network resources within a network, regardless of the type of subnetwork. This drives additional aspects such as:

- The network management tools must generate reports that are easily understandable.

- The network management tools must be very easy to learn and use so that less human skill is needed.

- The network management tools should decrease the network manager's work load providing a single set of tools for all networks to be managed. The tools should emphasize consistency to reduce the operator's memory burden.

Full integration requires integration of four different aspects:

- The user interface displays and commands should be consistent for all management systems existing in the network.

- The management functions should use common meanings and procedures for the tasks performed.

- The objects managed by the different TMN should conform to a consistent, common set of definitions, structures and naming conventions.

- The networks for communication between the management systems and the managed objects, as well as between TMNs must be specified and consistent.

An integrated TMN could solve many of the management problems experienced in today's networks. Some additional benefits that may be provided include the following:

- The network manager need only learn a single user interface.

- A single management vocabulary for network managers to learn.

- A single set of common management functions for all networks.

- Automatic translation between managed object definitions in different networks, reducing the expertise needed for managers.

- Automatic maintenance of the relationship between managed objects.

As previously stated the major communication and computer vendors are beginning to address the lack of integration in current TMNs.

In general, these efforts provide integration via one of three main approaches:

- The integrator approach is where the separate management tools are integrated by adding a new "supersystem", the main function of which is to integrate the others.

- The translator approach is where one or more of the TMN systems translates its management information and functions to those of another proprietary system. The proprietary system's main function, however, is to manage its own proprietary networks, but it will permit other management systems to connect to it.

- The open system, standards-based approach is where all network elements and the TMN implement a common language and a common set of functions. The emphasis in this approach is on interoperable network management.

Unfortunately it is unlikely that this last approach will provide a specific comprehensive solution, at least in the near future. Nevertheless, it should be recognized that no standard will be able to satisfy all specific or user-oriented requirements. Consequently, the best approach to network management is to consider the standards as a platform from which to develop other network management capabilities. In the mean time, those involved in the management of networks are faced with three basic choices:

- Buy off-the-shelf products.
- Sit back and do nothing, waiting for vendors to introduce more advanced alternatives.
- Strategic planning, to ensure that the utility's TMN will evolve to provide the capabilities needed. Areas that should be considered in strategic planning include the following:
  - Selecting networks and systems that support protocol suites or profiles offering rich management capabilities.
  - Investigate the use or development of proxy management tools for those components not directly manageable.
  - As an interim measure use translators to provide limited management functions for those profiles or protocol suites not yet supported by the Integrated TMN platform.

7.3 Benefits of Integrated Telecommunication Management Network Systems

As stated previously, the reasons for using an Integrated TMN system are:

- Private networks are becoming more complex. In addition to the fact that network elements such as Private Automatic Branch Exchanges (PABXs), Time Division Multiplexers (TDMs), LANs etc. are becoming more varied and sophisticated, there is a strong multivendor trend whereby various types of equipment supplied by a variety of vendors exist within a single network. This situation makes it difficult for maintenance personnel to cope with new technologies if a separate management system is used for each equipment type or vendor. The shortage of skilled maintenance personnel is also becoming a serious problem.
- The increased size of private networks having large-capacity communication channels connecting key points in a wide area. Incidents have occurred where a communication line or network equipment problem has affected the entire network. Network maintenance costs have risen as a result of network expansion.
- As networks become more complex and increase in size operating conditions also become more stringent in terms of high network reliability and quality of service. In these circumstances, if separate management methods dedicated to each network component were used, it would be difficult to quickly respond to network problems i.e. for trouble-shooting, detailed fault localization and work assignment to the maintenance/repair division.
- The growing trend towards internetworking, (networks made up of interconnected networks) both inside and outside the power utility's own area and business. This trend points to the need for internetworking management systems.
- To reduce the cost of interfacing different systems of network management.

- To allow automatic reconfiguration of the telecommunication network and bandwidth management.

- To reduce the cost of software (not just acquisition and/or development, but in the maintenance), for example through the use of OOD techniques.

At present, most TMN systems which are in use in power utilities provide fault management, see subsection 6.3. However what most utilities require is a TMN which will perform the management tasks of configuration, fault, performance, security and accounting easily and efficiently using maintenance personnel of low/medium technical background thus releasing more technically sophisticated people to manage the network.

Another important issue is that of the investment and operating costs of the integrated TMN. Customers have long regarded maintenance and operation tasks as basically an overhead to be minimised, if possible. Customers would like to see management costs minimized. It is difficult at present to identify the effect of a TMN in helping to reduce operating costs, however defining the cost benefit of a TMN cannot be ignored.

Fortunately in the future the introduction of expert system tools in Integrated TMN may provide a series of technical, economic and management advantages (see Section 10.5.3).

7.4 Other Considerations

Power utilities could be considered as potential telecommunication service providers because they:

- Possess important private telecommunication networks that cover a whole country (one or several inter-connected power utilities).

- Are capable of the planning, installation and management of telecommunication networks.

- Have expertise in commercial relationships with millions of customers (many of these might also be customers for a telecommunication business).

Nevertheless the present situation in many countries is:

- Most telecommunication service is still provided by monopoly operators.

- Competition is limited to alternative services.

- There is not yet a general trend to cost-based pricing of basic services.

- Some national governments are reluctant to open basic services to competition.

But social, political and technological trends such as:

- Deregulation.

- Liberalisation.

- Privatisation.

- Standardization and Open Network Provision (ONP).

- Digitalization of the networks.

- Personal communications and broadband services as the driving market forces.

- The increasing use of optical fibres.

probably will change the future market environment, opening it to real competition. Power utilities that decide to enter this market must take into account the following key factors for success.

- Fast provision of as many new services as required to generate additional revenues and provide a competitive edge.

- Reduction of operating costs.

- Investment protection, by ensuring an evolutionary development path from present to future networks.

- Provision of a good QOS.

As explained previously, TMN systems are a must to achieve these goals, therefore TMN must be considered also as a strategic and necessary investment for those power utilities which decide to enter the telecommunications market.

SECTION 8 THE ARCHITECTURE AND TECHNICAL REQUIREMENTS OF TELECOMMUNICATION MANAGEMENT NETWORKS.

8.1 The TMN's Position in the Total Control System Picture

The technical installations and corresponding activities of a power system organisation are normally spread over a large geographical area. This in turn results in distributed technical systems and suborganisations. In order for these to function smoothly, interconnecting information handling systems are established. These again may in turn require some sort of coordinated monitoring and control, to ensure that they meet some predefined quality criteria. Some of the systems that may require coordinated control are:

- Primary systems
  - Power production
  - Power transport

- Secondary/ support systems
  - Network protection system
  - Communication carrier system
  - Operational telephone system
  - Process data communication network
  - Mobile radio systems

- General administrative systems
  - Administrative telephone systems
  - Administrative/ business data communication network

In most power utilities, coordinated control systems for the primary system have been implemented, i.e. for the production, transport and distribution of power. Some power utilities have also coordinated monitoring and control systems for some of the other areas mentioned. One of the areas that is currently attracting attention is the monitoring, control and management of telecommunication systems. Eventually, most of the areas mentioned previously may require some sort of coordinated monitoring and control. Clearly, it will be very costly/difficult for a company to support such a large number of separate systems. Some of them may require monitoring 24hrs a day. Consequently, some sort of merger of these systems may be required, both technically and organisationally.

One likely solution is to establish two separate systems, one for the control of the power system, and one for the control of all secondary/support systems, i.e. those related to voice and information transport. Some degree of information exchange between the two systems is however needed, due to the dependency of the power control systems on these support systems.

8.2 Systems Monitored and Controlled by TMN

The monitoring and control span of a TMN is a matter of definition, and may vary among power utilities. However one approach is to define the monitoring and control of all information exchange systems, regardless of type, as the domain of TMN. A specific implementation of TMN, however, may only include subsets of the complete TMN domain, as defined above. To obtain generality in the ensuing discussion, the broad definition of TMN is adopted in the following. Given such a definition, a TMN system may for instance include:

- Transmission systems.
- Operational telephone systems.
- Mobile radio systems.
- Business telephone systems.
- Process data communication networks.

- Business data communication networks.

For a description of the various subsystems, see section 4.

8.3 TMN Functions

The purpose of a TMN is to enable the power utility to obtain maximum availability from the total communication system, and to impose priorities in the situation where the telecommunication system is degraded. The TMN is also used to support the management requirements of the operators to plan, provision, install, maintain, operate and administer the telecommunication network and it's services. Consequently, the TMN functions that are implemented must reflect this.

The TMN functions may be grouped into the following main categories:

- General Functions.
- Application Functions.

8.3.1 General Functions

The general functions are all those that are necessary in order to implement and utilize the specific applications functions. The general functions include:

- Data acquisition, transportation and storage.
- Data output.
- Man machine interface.

8.3.1.1 Data Acquisition, Transportation and Storage

The data acquisition is either done in remote terminal units (RTUs), or within the telecommunication equipment itself (network elements, NE). The latter technology is typical for more modern equipment. In the following descriptions these technologies will commonly be referred to as RTU/NE.

The data that are acquired may be for instance:

- Status indicators.
- Alarm indicators.
- Measurements.

When designing the acquisition system, it is very important to adapt the system solution to a worst case information input situation, in order to avoid the possibility that the system cannot handle the information flow in a critical situation when many faults are occurring.

As an example, one may mention cyclic acquisition of information, as opposed to event driven status/alarm information acquisition and gradient (hysteresis) - driven measurement acquisition, both of which may 'flood' the TMN with information under emergency conditions, and cause it to break down. However, the present CCITT TMN recommendations assume event report based information transfer instead of a polling approach; overflow situations are assumed to be handled by specifying suitable transmit filters in the data sources (NEs or intermediate level management systems).

Depending on the philosophy which is adopted, these data may or may not be recorded locally, for instance on a printer or on a magnetic recording device. The 'raw' data, or in some instances aggregated information, is sent from the RTU/NE to the next level in the control hierarchy, and so on all the way to the top level.

To enable this transportation of data, it is necessary to have a data communication system that is as separate as feasible from the one that is monitored. In practice however, usually the same transmission facilities are used for management data transmission as for other (user) signal transmission, and availability of data links have to be ensured by alternative routings.

Furthermore, it is necessary to have a communication protocol that allows the various units, i.e. NEs/RTUs, network management centres, external information providers, and external information receivers to exchange information. The choice of communication protocol has great implications, and should be given great attention within the power utility. Existing and likely future standardisation of network management interfaces (CCITT and ISO/OSI work, see section 9) should also be taken into account.

Another important issue is the choice of data base tools. Generally speaking, one may say that this consists of two parts, the database as such and the interface routines to the database. The requirements to the database(s) may vary depending upon the structure of the TMN system, and between the various control levels of the TMN. Also, the requirements may vary over time, depending upon the expansion/contraction of the system. Consequently, there is a general need to be able to replace databases in an installed system. This can be done if the routines that interact with the databases have been standardised, e.g. SQL query language. This is the current trend in the 'market', and a standardisation at the query language level should be carefully considered by the power utility.

The structure of the management database will have a major impact on the effectiveness and performance of the TMN system. Data regarding the network and the organisation must be stored, readily accessed and easily modified. The distributed relational database which enables the data to be distributed to a number of nodes and to be retrieved in related sets offers advantages for a network management system.

OOD also have significant advantages for TMN. The OSI management information model is based on an object oriented design which supports distributed management processes. Object classes can be reused e.g.where objects share common properties a generic class may be established. Duplication associated with separately specifying the shared definitions can be avoided.

8.3.1.2 Data Output

Aside from the man machine output, which is treated separately in subsection 8.3.1.3, there are two main categories of output from the TMN.

These are:

- Output to the telecommunication network and equipment, such as commands, controls etc.
- Output to recording devices, i.e. printers, plotters etc.

The output to the equipment is normally in the form of digital command signals, for instance when equipment settings, connection tables (routing information) are changed, e.g. in a rerouting situation or when turning on/off auxiliary equipment. The basic format of these signals in the standardised management interfaces is going to be standardised too. The transmission of output commands from a TMN centre to a TMN RTU/NE poses the same requirements for the transmission protocol and database as described previously in subsection 8.3.1.1.

The output to recording devices is in this context only mentioned for the sake of completeness, and will not be expanded upon further.

8.3.1.3 Man Machine Interface

The facilities that are included in the man machine interface (MMI) will depend heavily on the scope of the TMN, and may range from simple PC based message oriented systems to sophisticated work station (or mini-machine) based windows oriented graphical systems. This again will depend upon the size and complexity of the communication system to be controlled, or the level in the control hierarchy where the MMI is located. Consequently it is not possible to define one single set of MMI requirements for a TMN.

Since the availability and quality of the telecommunication system may have great implications on the power control systems, information from the TMN is of interest to the power system operators. Therefore the question of information sharing with the SCADA-EMS system arises. Theoretically this could be solved by integrating the MMI of the TMN with the MMI of the SCADA-EMS. A more likely scenario, however, is to establish TMN with its own MMI, and data communication links to the SCADA-EMS system for the exchange of selected information between the systems. Similar information exchange may also be established to other telecommunication user systems.

Regarding the MMI, there is a set of areas for which some ground rules have to be established. In this set may be included:

- Uniformity of MMI interaction.
- MMI information selection.
- Picture structure.
- Dialogue structure.
- Fault and warning indication.
- Presentation forms.
- Colours.
- Response requirements.
- Initiation and maintenance.

Uniformity of MMI Interaction:

When an operator moves from one part of the MMI, for instance from one picture to another, it is very important that these parts are constructed in the same manner - and that the operator interaction is similar - in order for the operator to feel comfortable with the system and avoid errors in a stressed situation.

A set of rules for the layout of the pictures, the use of symbols, the layout of symbols, the MMI response to the operator, input rules to the MMI, colours, etc. should therefore be defined. All parts of the MMI should conform to these rules.

MMI Information Selection:

The selection of specific MMI information, e.g. pictures, may in principle either be done by stepping through a selection tree (i.e. a menu system), or by allocating single choices (i.e. push buttons), or in some instances combinations thereof. The menus may either be separate pictures, or pull-down menus in regular pictures. The menus should be self explanatory, either from content or context. Exit to help information should be possible at any point of selection.

Picture Structure:

Generally speaking, one may say that at least three separate types of information have to be shown on the screen of a TMN system at any given time.

These are:

- The chosen picture.
- The dialogue part, including information about the current selection path.
- Indication of incoming alarms.

'Windows' technology may tempt one to allow a larger number of picture partitionings. Since the presentation of many pictures on the screen simultaneously may imply overlaying the pictures, one should possibly be somewhat restrictive in the use of these techniques in monitoring and control systems where quick access to the pictures are required.

'Panning' and 'Zooming' are other techniques which may be alternatives to excessive use of windows. These techniques are already quite common in certain types of monitoring and control systems.

Dialogue Structure:

The dialogue system has to include at least the three following basic parts :

- Information about current location in a selection structure.
- Method for identifying a new selection.
- Method for specifying actions.

Stepping from one picture to another requires exact information about current location in the selection (menu) tree. Consequently it is necessary to display (a 'coded' string of) information that gives this exact location. In 'conventional' MMI systems this has typically been a dialogue line for instance at the bottom of the screen. In 'windows' oriented systems, this identification must be present in each window.

The selection of an object by an operator in a displayed picture must always be followed by an immediate acknowledgement in the picture. This acknowledgement must be done both in conjunction with the selected object in the picture, and the complete selection tree on the dialogue line.

Fault and Warning Indication:

Certain incoming fault or warning messages must attract the immediate attention of the operator. These should therefore be displayed in a designated picture area, regardless of what is otherwise shown on the screen. If a network diagram is displayed on the screen, and this diagram contains symbols that either directly or in an aggregated form represents equipment with associated fault or warning messages, then this should be indicated in the displayed symbol, for instance by a colour change.

Presentation Forms:

It is important that the TMN is equipped with powerful presentation tools so that the various types of information may be presented in ways that are easily grasped by the operator. Typical presentation forms that may be required are:

- Message lists.
- Tabular presentation of data.
- Graphical presentation of data.
- Bar graphs.
- Network diagrams.
- Custom designed symbols.

Network diagrams etc. should be dynamic such that changes in the telecom system are reflected directly in the diagrams.

The operator should be able to establish custom designed pictures in an easy manner.

Colours:

A general rule of thumb in the process control systems is to predefine all use of colours, leaving no freedom of choice to the individual operator. This is recommended also for TMN systems, and it implies that an unambiguous set of rules for the use of the various colours has to be established. This set of rules may for instance be company wide or local to one TMN installation.

Response Requirements:

Different response requirements apply to different aspects of the MMI system, such as:

- Update time of process information on displayed pictures.
- Response time following an operator input.

The required update time of process information depends on the information category, for instance process status would have different requirements to statistical information. Maintaining a quick response to operator inputs is very important, since excessive delays cause operator dissatisfaction with the system.

Initiation and Maintenance:

Both the initial construction of the MMI system, and maintenance while in service requires powerful software tools. It should be possible for instance to create network diagrams and various types of reports directly via the MMI system. All linkage between network diagrams and process information in the database should be handled via the MMI system.

However to avoid errors in normal operation, the operator should have to enter a certain function or user mode before being allowed to perform changes in the system. Entering this function\mode should be restricted by use of a password or other security measures.

8.3.2 Application Functions (Based on CCITT Rec. M3020)

Application functions are all those functions that are implemented in addition to the previously described general functions, in order to enable proper monitoring and control of the telecommunication system.

These functions may be grouped as follows :

- Performance management.
- Fault management.
- Configuration management.
- Accounting management.
- Security Management.

8.3.2.1 Performance Management

Performance management provides functions to evaluate and report upon the behaviour of telecommunication equipment and the effectiveness of the network or network elements. Its role is to gather statistical data for the purpose of monitoring and correcting the behaviour and effectiveness of the network, NE/RTU and to assist in planning and analysis.

Examples of performance management functions are :

- Performance monitoring.
- Traffic management and network management.
- Quality of service (QOS) observation.

Performance Monitoring:

Performance monitoring involves the continuous collection of performance data from the network. While acute fault conditions will be detected by alarm surveillance methods, error conditions which occur intermittently or at low frequency in complex equipment may interact resulting in poor service quality. Performance monitoring is designed to measure the overall quality based on the monitored parameters in order to detect such deterioration. It may also be designed to detect characteristic patterns before signal quality has dropped below an acceptable level.

Traffic Management and Network Management:

The TMN collects traffic data from the RTU/NE to reconfigure the telecommunication network or modify its operation to adjust to extraordinary traffic. The TMN may request that traffic data reports be sent from the RTU/NE, or such reports may be sent upon threshold triggering, or periodically, or on demand. At any time the TMN may modify the current set of threshold and/or periods in the network. Reports from the RTU/NE may consist of raw data which is processed in a TMN, or the RTU/NE may be capable of carrying out analysis of the data before the report is sent.

Quality of Service (QOS) Observation:

The TMN collects QOS data from the RTU/NE and supports improvements in QOS. The TMN may request QOS data reports to be sent from the RTU/NE, or such a report may be sent automatically on a schedule or threshold basis. At any time, the TMN may modify the current schedule and/or thresholds. Reports from the RTU/NE on QOS data may consist of raw data which is processed in a TMN, or the RTU/NE may be capable of carrying out analysis of the data before the report is sent.

Quality of service includes monitoring and recording of parameters relating to :

- Connection establishment, e.g.call set up delays, successful and failed call requests.
- Connection retention.
- Connection quality.
- Billing (if applicable).
- Keeping and examining of logs of system state histories.
- Cooperation with fault or maintenance management to establish possible failure of a resource and with configuration management to change routing and load control parameters/limits for links etc.
- Initiation of test calls to monitor QOS parameters.

QOS data could be provided to the customer as part of the service.

8.3.2.2 Fault Management

Fault management is a set of functions which enables the detection, isolation and correction of abnormal operation of the telecommunication network and its environment.

Examples of fault functions are :

- Alarm surveillance.
- Fault localisation .
- Testing.

Alarm Surveillance:

A TMN must have the capability to monitor network failures in real time. When such a failure occurs, an indication is made available by the RTU/NE. Based on this, the TMN determines the nature and the severity of the fault. For example it may determine the effect of the fault on the services supported by the faulty equipment. This can be accomplished in either of two ways: a database within the TMN may serve to interpret binary alarm indications from the RTU/NE, or if the RTU/NE has sufficient intelligence, it may transmit self explanatory messages to the TMN. The first method requires little of the RTU/NE beyond a basic self monitoring capability. The second method requires additionally that both the RTU/NE and the TMN support some type of message syntax which will allow adequate description of fault conditions.

Fault Location:

Where the initial failure information is insufficient for fault location it has to be augmented with information obtained by additional failure location routines. The routines may employ internal or external test systems, and may be controlled by the TMN.

Testing:

Testing may be carried out in one of two ways. In one case, the TMN directs a given RTU/NE to carry out analysis of circuit or equipment characteristics. Processing is executed entirely within the RTU/NE, and the results are automatically reported to the TMN either immediately or on a delayed basis.

Another method is where the analysis is carried out within the TMN. In this case, the TMN merely requests that the RTU/NE provides access to the circuit or equipment of interest, and no other messages are exchanged with the RTU/NE.

8.3.2.3 Configuration Management

Configuration management implies functions to exercise control over, identify, collect data from and provide data to the RTU/NE.

Examples of configuration management functions are :

- Provisioning.
- Status and control.
- Installation.

Provisioning:

Provisioning consists of procedures which are necessary to bring an equipment into service, not including installation. Once the unit is ready for service, the supporting programs are initialised via the TMN. The state of the unit, e.g. in service, out of service, stand-by, reserved, channel configuration and selected parameters may also be controlled by provisioning functions. Provisioning may need an interface to the accounting management function.

Over the spectrum of network elements, the use of the provisioning functions may vary widely. For small transmission elements, these functions are used once and rarely again. Digital switching and cross connect equipment may require frequent use of these functions as circuits are put up and dropped.

Status and Control:

The TMN provides the capability to monitor and control certain aspects of an NE on demand. Examples include checking or changing the service state of the element or one of its sub parts (in-service, out of service, standby) and initiating diagnostics tests within the element. Normally a status check is provided in conjunction with each control function in order to verify that the resulting action has taken place. When associated with failure conditions, these functions are corrective in nature (e.g. service restoral).

Status and control functions may also be part of routine maintenance when executed automatically or on a scheduled periodic basis. An example is switching a channel out of service in order to perform routine diagnostic tests. The TMN will enable the exclusion of faulty equipment from operation, and as a result it may rearrange equipment or reroute traffic.

The TMN should also be capable of checking a proposed configuration change prior to implementation.

Installation:

The TMN may support the installation and commissioning of the telecommunication network. Changes in existing systems (expansion or reduction) could also be supported. Some RTU/NEs call for an initial exchange of data between themselves and the TMN. An example of another function is the installation of programs into the RTU/NE from database systems within the TMN (down line loading). In addition, administrative data may be exchanged between the RTU/NE and the TMN.

Acceptance testing programmes can be performed under the control of, or supported by, the TMN.

8.3.2.4 Accounting Management

Accounting management provides a set of functions which enables usage of network services to be measured and the costs for such usage to be determined.

It provides facilities to:

- Collect accounting records.
- Set billing parameters for the usage of service.

In the future accounting management may also allow the operator to accurately calculate the true cost of providing a service to customers and hence facilitate the determination, where appropriate, of profit levels. As mentioned previously the Accounting and Provisioning functions may be linked. It would then be possible to automatically bill the customer at the correct contracted rates for the time period the service was used.

8.3.2.5 Security Management

Security management in the TMN context involves at least two distinct areas:

- Physical access to network components
- Electronic access to network components (system)

Physical Access:

Some parts of the telecommunication system that is monitored by the TMN system are unmanned and located in remote areas. This is for instance often the case with radio relay stations. Monitoring of unauthorised access to such locations/buildings is desirable and may in some case be necessary.

Various types of signalling devices can be installed at such sites, and information from these devices should then be relayed to the TMN system for proper action.

Electronic Access:

A fully integrated TMN system implies the monitoring and control of several different types of subsystems, for instance radio relay, operational telephone, data networks - both process and business.

The implementation of some of these subsystems, and their corresponding TMN, may in part be based on external systems, for instance the PTT.

Consequently the access control problem involves :

- External access control ("hackers").
- Internal access control.

In most utilities the external access control problem will be limited due to limited use of external systems. However where these systems are used, countermeasures should be taken.

Such countermeasures could be :

- Automatic registration of the number of the calling party where this is possible, and automatic reporting to the TMN system.
- Automatic return call to authorised modems.
- Automatic shutdown after a limited number of access trials, and automatic reporting to the TMN system.

Internal access may involve several personnel categories, each of which may need access to the integrated TMN system to interact with their respective subsystems - while they should be denied access to other irrelevant subsystems.

Depending upon company policy, those responsible for the TMN as such may not have the authority to change settings or configuration on actual subsystems, e.g. Radio Link parameter settings.

Consequently, an integrated TMN could be divided into functional sectors, e.g. radio relay, operational telephone, data networks, etc., to which different categories of personnel are given access rights. Within each functional sector there could be layers of access rights depending upon the personnel categories.

As an example of this access rights division, one might envisage the following two kinds of operators:

- Network manager, who has access rights to all the functions provided by the TMN, including those allowing:
  - Configuration.
  - Enabling the respective operators to use terminals connected to the TMN system.
- Maintenance operators, who have access rights only to functions within their personally designated supervision and maintenance areas.

All accesses to the TMN should be registered with parameters such as: operator identifier, date, time, connection time and function used.

8.4 General Technical Considerations

Depending on the control span of the TMN system, i.e. the number of subsystems and their sizes, the TMN system may become rather large and complex. Furthermore, the establishment of a TMN system may be a 'continuous' process, partly by stepwise integration of already existing subsystems and partly by the addition of new subsystems as the need arises and budgets become available. Consequently, it is very likely that the total TMN system eventually will consist of subsystems from various vendors and of various ages, with a corresponding need for partial replacements or additions of functions as time elapses. To be able to handle such a scenario, it is important to introduce proper standards in the TMN system that in a reasonable way allow replacement of parts of the system and addition of new modules.

The main areas of standardisation are:

- Communication protocols between subsystems and the respective higher and lower lying control layers.
- Software in the TMN system.

Communication Protocols :

Standardisation of the protocols will allow replacement or addition of whole TMN subsystems for instance a new radio link or telephone system, without significant alterations to the overlying control system. CCITT is working on such standardisation, i.e. the Q protocols.

Software in the TMN system:

The software in a control system could conceptually be considered to consist of layers, similar to that of the ISO protocol division. One such layered division is shown in Fig. 8.4.1.

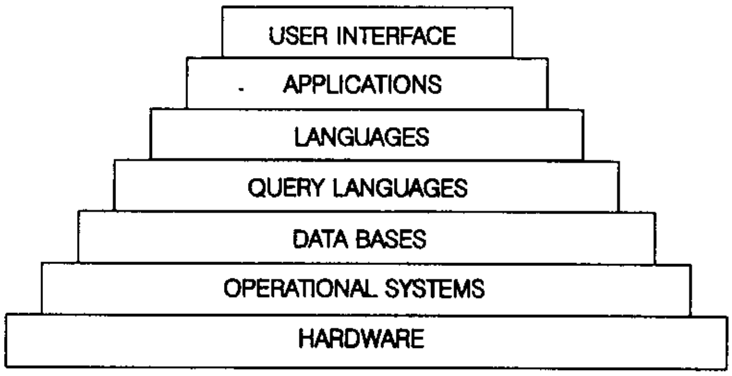

FIG 8.4.1 SYSTEM LAYERS DIVISION

The idea here is that if there is a standardisation at the various levels, portions of the system may be exchanged or additions may be brought in without having to redesign the entire system.

To illustrate the idea, consider the situation if the vendor/utility had standardised on a UNIX operational system. This would allow the exchange of hardware, possibly involving different vendors, without too much difficulty. Similarly, a standardisation at the database query language level would allow the exchange of data base without 'insurmountable' problems.

Yet another example that could be mentioned here is the standardisation at the user interface level, which would allow the exchange of application programs without too many problems regarding the MMI system. The whole idea here is that an increasing share of the investments are in the software sector. To ensure payback of these investments, steps must be taken to prolong the life of the software system, even if changes have to be made to the TMN system as such. Given such a layered standardisation, modules may be exchanged or added depending on needs, without having to scrap the entire system. The further up in the layered model that the standardisation is pushed, the better system survivability will be.

The problem however, is that there are a number of 'standards' available at some of these levels. Mostly these standards are industry or de facto standards. The problem of the vendor/utility therefore becomes to select the 'standard' at each level that gives the largest degree of freedom. Some of the available 'standards' are:

- User Interface:
  - MS-Windows from Microsoft
  - MS-Presentation manager from Microsoft
  - Macintosh GUI from Apple
  - New wave from HP

Most of these are based on the X-Windows technology.

Other 'standards' also exist.

- Applications: TMN specific
- Languages:
  C
  Other older ones like FORTRAN, COBOL, etc.
- Query Languages
  SQL
- Operating System
  UNIX (several dialects)
  MS-DOS
  OS/2

Others of course also exist, but the question is whether or not these can be considered industry or defacto standards.

8.5 Connection to Existing Management Systems.

The power utility may desire to connect an existing Management System to a new Integrated TMN, for the following reasons:

- the available functions and/or the hardware/software capabilities and reliability of the in-service systems are still acceptable.

- the existing systems manage telecommunication equipment which was manufactured before the development and implementation of TMN standards. This telecommunication equipment is not fitted with the new standard interfaces.

These in-service Management Systems may perform functions related to:

- specific equipment (transmission, switching, data transmission, control equipments, etc.)
- regional networks.

The way the connection is implemented largely depends on the technology of the existing system, since the new Integrated TMN is probably more flexible and capable of interfacing with several types of unit.

In any case the interface problem can be solved by one of the general solutions for interworking among different sub-networks types, that is the application of:

- Specific Q-Adapter units, performing the connection of the integrated TMN to sub-networks, Maintenance or Support Entities which do not provide standard TMN interfaces, (Ref Section 9.3.3.4 & FIG. 9.3.3) or

- Mediation Devices, to perform protocol or message conversions at the boundary with the existing management systems, or

- Integrated TMN Operations System access network (a DCN), which can provide data communication paths among the integrated TMN Operations Systems and other sub-networks Operations Systems.

In regard to application of the last solution, it is possible that the DCN accessing the OS may be one of several network types, such as LANs, WANs and ISDNS. Examples of these are ETHERNET and X.25 packet switched networks.

Of course the use of the OSI Reference Model is advisable, due to the common interaction of a wide variety of computer and terminal equipments.

The internetworking scenario can include:

- Network Layer Relay/Gateway,
- Transport Layer Relay/Gateway,
- Application Layer Relay/Gateway,

using the gateways as interworking units.

These three technologies have their own advantages and disadvantages Ref [33], the first solution being the recommended one, because the OSI Reference Model principles are adhered to, the standards are available or emerging, the implementation complexity is low to medium and the solutions can be extended to include ISDN protocols.

8.6 Architecture

The architecture of a TMN system will to a large extent depend upon:

- The organisational structure of the utility and the corresponding division of responsibility within the organisation.

- The control span of the TMN system.

Organisational Structure:

The TMN system should facilitate the presentation of information and enable control inputs appropriate to each relevant level of the organisational structure. At the lowest level of the TMN hierarchy, i.e. the actual telecommunication installations/sites there will have to be RTU/NEs that:

- Collect information
- Do some basic information handling
- Transmit information to the next control layer
- Enable control outputs
- Enable basic man-machine interface

For older telecommunication equipment these RTU/NEs may be separate physical units, i.e. RTU's, connected to the site equipment via a traditional I/O system. In modern telecommunication equipment, however, the RTU/NE may be integrated into the equipment as such, i.e. NE's.

Larger utilities may for geographical and/or other reasons be divided into regional areas with some regional responsibilities for the telecommunication system, for instance the responsibility for operation and maintenance. In this case it is natural to assume that the area/regional administration will be equipped with a man-machine system that allows them to;

- Monitor the general condition of the regional part of the telecommunication system.
- Identify faults, etc., to a sufficient degree of detail to dispatch service personnel.

- Initiate control actions as countermeasures to faults, e.g. rerouting.
- Monitor security.

The TMN system at the regional level may be of a 'subcentral' type to which all RTU/NEs are connected, and which in turn is connected to the corporate level - as indicated in Fig.8.6.1

Previous sections have presented the case for a TMN database. Such a database is necessary to get in an organized manner, the data required to manage the network properly. In the situation described in Fig. 8.6.1. data transactions will be required between databases (regional and corporate level databases) and special care will have to be taken due to the fact that these are likely to be proprietary databases.

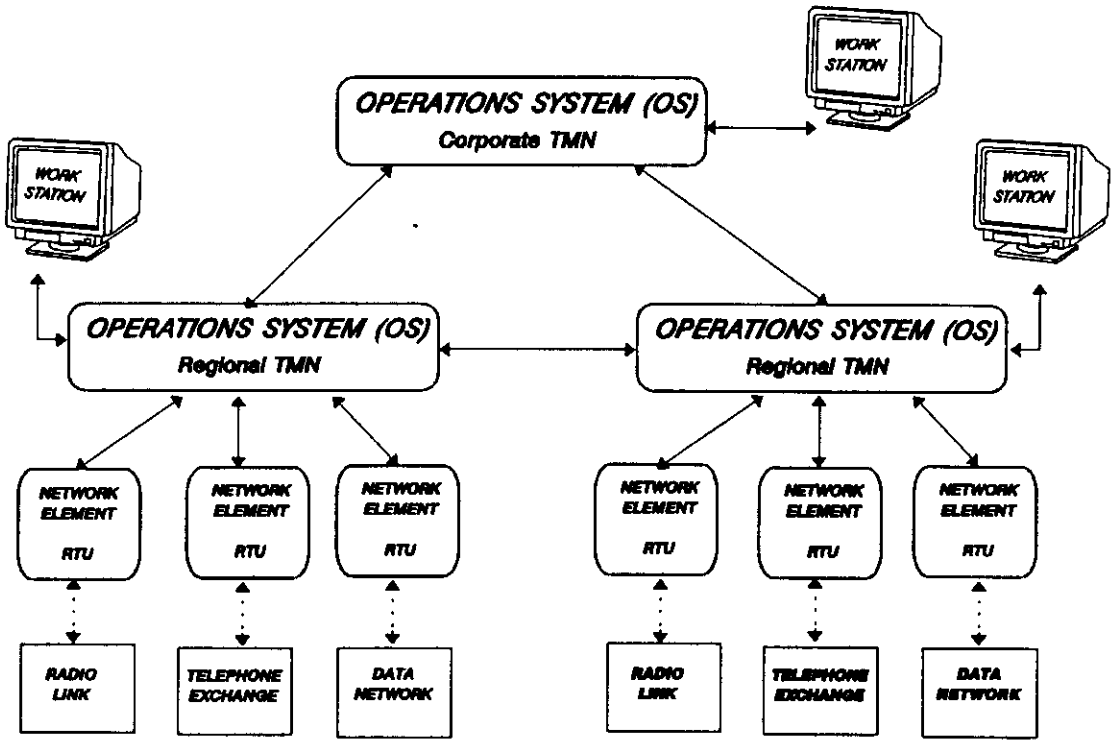

FIG 8.6.1 NATIONAL/REGIONAL SYSTEM

Another alternative is that all the RTU/NEs are connected directly to the corporate level, and the man-machine interaction at the regional level is provided for by terminals to the corporate TMN level as indicated in Fig. 8.6.2.

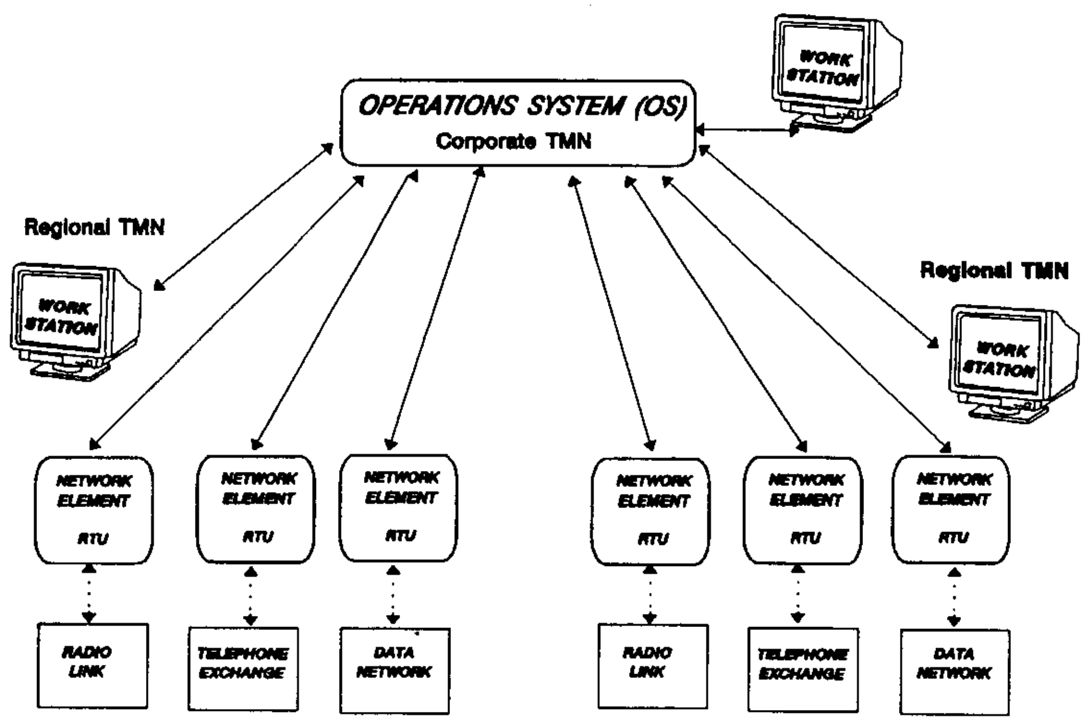

FIG 8.6.2 CENTRALISED SYSTEM

At corporate level, the TMN system will have to facilitate:

- Communication to the underlying systems
- Overviews of the total system controlled by the TMN
- Statistics and other aggregated reports of various types
- Control actions (if organisationally applicable to this level)
- Billing (if applicable)
- Security monitoring

If the maintenance crews are centralised, or local - but dispatched from the corporate level, the TMN system at the corporate level will have to include detailed fault information that otherwise (with a regional dispatching) would have been presented at the regional level.

In this configuration, the Operations System will be able to handle all data coming from every NE/RTU, the Mediation Devices and Interface Adapters (not shown in fig. 8.6.2) playing an important role in the reformatting of data information, whenever required.

Control Span of the TMN :

The architecture of the TMN system will also be dependant on the control span of the TMN.

It is likely the RTU/NEs for each control area site, i.e. transmission system, telephone switch, data network node, etc. will be connected directly to dedicated information handling modules at the area/regional level, see Fig. 8.6.3. These dedicated modules may either be software modules or separate physical units. The integration will most likely be at the man machine level (possibly at the database level), either by software within the computer or via LAN that interconnects the man machine system with the actual telecommunication information handling modules.

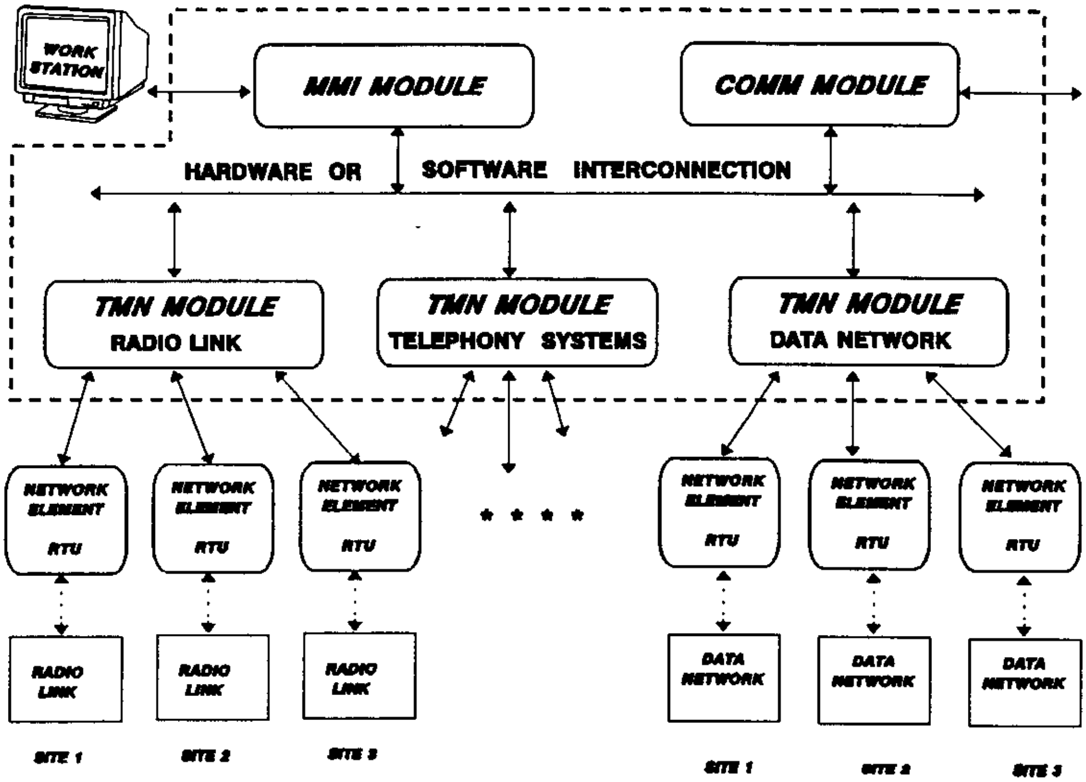

FIG 8.6.3 CONTROL SPAN OF THE TMN

At the corporate level the architectural considerations will have to be the same as those at the regional level.

The idea behind such an architecture is to be able to include new subsystems in a given TMN system depending upon changing needs. This will be possible if there is standardisation at the various structural layers, as indicated in Fig. 8.4.1. In particular this requirement will apply to the user interface level. If this last level is standardised, new subsystems may be efficiently included, being the management information easily transferred amongst them and the Operations Systems.

8.7 Software Support

It is important to assure the integrity of the TMN database, as well as its ability to evolve in order to:

- Have complete and proper correspondence in the relationship among the telecommunication network equipment, the transmitted information and the functions which are performed.
- Provide for the expansion of the telecommunication network both in variety (system / equipment types and interconnections) and quantity (number of equipments in service).

To satisfy these basic conditions, it is desirable to have a designated TMN Manager whose responsibility is to maintain integrity and evolution of the databases. Special software tools, such as a configuration package and interpreter or compiler packages, may also be required. Alternatively, the power utility may establish the necessary agreements with the suppliers to guarantee database expansion and adaptation whenever the telecommunication network grows and changes topologically.

SECTION 9 SURVEY OF NETWORK MANAGEMENT STANDARDS

9.1 Introduction

Since they are the channels through which all information flows, heterogenous communication networks perform such an important basic function in a commercial enterprise that their failure is entirely unacceptable. Effective network management should ensure that a communication infrastructure of adequate quality is available at all times. This section describes the essential aspects of the most important network management standards issued by CCITT, ISO/IEC, IEEE and IAB.

Particular recommendations and standards for telecommunication networks are being developed in CCITT and ETSI. An important organization within network management activities is the Network Management Forum.

The situation in informatics at present is characterised by rapid expansion of the communication infrastructure. 'The right information, at the right time, at the right place' is the maxim.

In view of this vital dependence by companies on a modern communication network, the heterogeneity and complexity of which are steadily growing, general interest is focusing more and more on one topic: Network management.

It has become one of the most important subjects in standards organisations and considerable effort and resources are being devoted to devising a standard network management system for the increasingly complex communication networks. Because of the significance of the standards which are under preparation and the perceptible trend towards a consolidation of concepts, this section presents an up-to-date survey of the relevant network management standards. Readers who are not familiar with the most important standards organisations may wish to refer to Ref [34].

Section 9.2 explains the CCITT network management in some detail. In section 9.3 an introduction to the TMN concept based on CCITT Recommendation M.3010 is given.

In a further section the ISO/OSI management is addressed. The subsections which follow explain system management, management information structure and management services. Further sections deal briefly with the network management documents connected with TCP/IP and the IEEE network management activities.

Telecommunication standards are based on the OSI approach.

9.2 Overview of CCITT Network Management

During the past few years CCITT has been actively developing TMN recommendations and this work will continue. CCITT has especially concentrated on general TMN standards. The basic recommendation for network management is CCITT Rec. M.3010 (formerly M.30), which presents the general principles for planning, operating and maintaining a TMN. Rec. M.3010 as well as a number of other general TMN recommendations in M.3000 series were approved in 1992. CCITT has also been working on more specialised areas of network management (e.g. Q3 protocol profiles and SDH management).

Close cooperation exists between ISO and CCITT in the network management field. CCITT have agreed to develop joint texts with ISO for OSI management standards. These documents have corresponding CCITT numbers in the X.700 series. Other CCITT network management recommendations (e.g. in the G and Q series) have references to X.700 series recommendations. Table A1 in appendix A lists ISO network management documents with corresponding CCITT X.700-series numbers. Further CCITT TMN recommendations in M,G and Q series can be found in Table A2 of appendix A.

9.3 Introduction of the TMN Concept Based on CCITT Rec. M.3010

9.3.1 General

CCTTT Rec. M.3010, presents the general architectural requirements for a TMN to support the management requirements of telecommunication operators to plan, provision, install, maintain, operate and administer telecommunication networks and services.

The basic concept behind a TMN is to provide an organized architecture to achieve the interconnection between various types of Operations Systems (OS) and/or telecommunication equipment for the exchange of management information using an agreed architecture with standardized protocols and interfaces. ISO Systems Management services and protocols represent a subset of the management capabilities that can be provided by the TMN.

9.3.2 Relationships of a TMN to a Telecommunication Network

Fig. 9.3.1 shows the general relationship between a TMN and the telecommunication network which it manages. A TMN is conceptually a separate network that interfaces a telecommunication network at several different points to send/receive information to/from it and to control its operations. A TMN may use parts of the telecommunication network to provide its communications.

A telecommunication network consists of many types of analogue and digital telecommunication equipment and associated support equipment such as transmission systems, switching systems, multiplexers, signalling terminal, front-end processors, mainframes, cluster controllers, file servers, etc. When managed, such equipment is generically referred to as network elements (NEs).

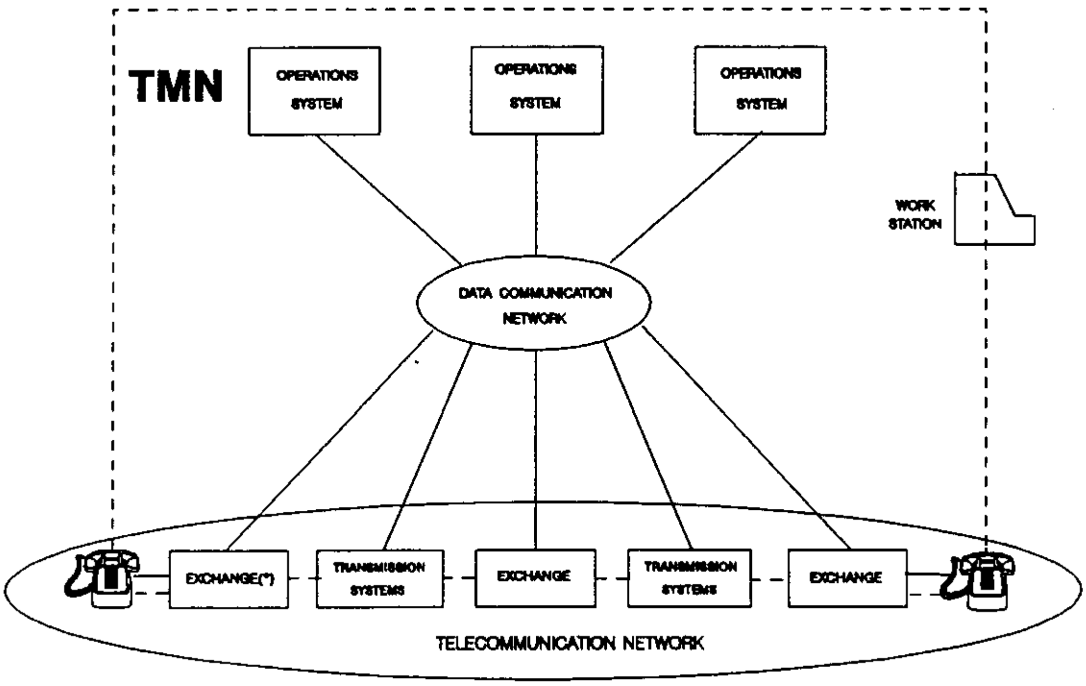

FIG 9.3.1 GENERAL RELATIONSHIP OF A TMN TO A TELECOMMUNICATIONS NETWORK

9.3.3 Architectural Requirements

Within the general TMN architecture there are three basic aspects of the architecture which can be considered separately when planning and designing a TMN. These three aspects are the:

- Functional Architecture.
- Information Architecture.
- Physical Architecture.

The functional architecture describes the appropriate distribution of functionality within the TMN to allow for the creation of building blocks from which a TMN of any complexity can be implemented.

The information architecture, based on an object oriented approach, gives the rationale for the application of OSI systems management principles to the TMN principles.

The physical architecture describes realisable interfaces and examples of physical components that make up the TMN.

9.3.3.1 The TMN Functional Architecture

The TMN functional model will be composed of function blocks such as the Operation Systems Function (OSF) which allows management of the Network Element Functions (NEF) and the Workstation Functions (WSF) which allow the management information user to interact with the OSF. Other complementary functions and function blocks are identified that allow interworking in various scenarios. There are the Data Communications Functions (DCF) used for the transfer of information between function blocks, the Mediation Functions (MF) and the Q Adaptor Functions (QAF) that allow interworking between function blocks. Figure 9.3.2 illustrates the function blocks.

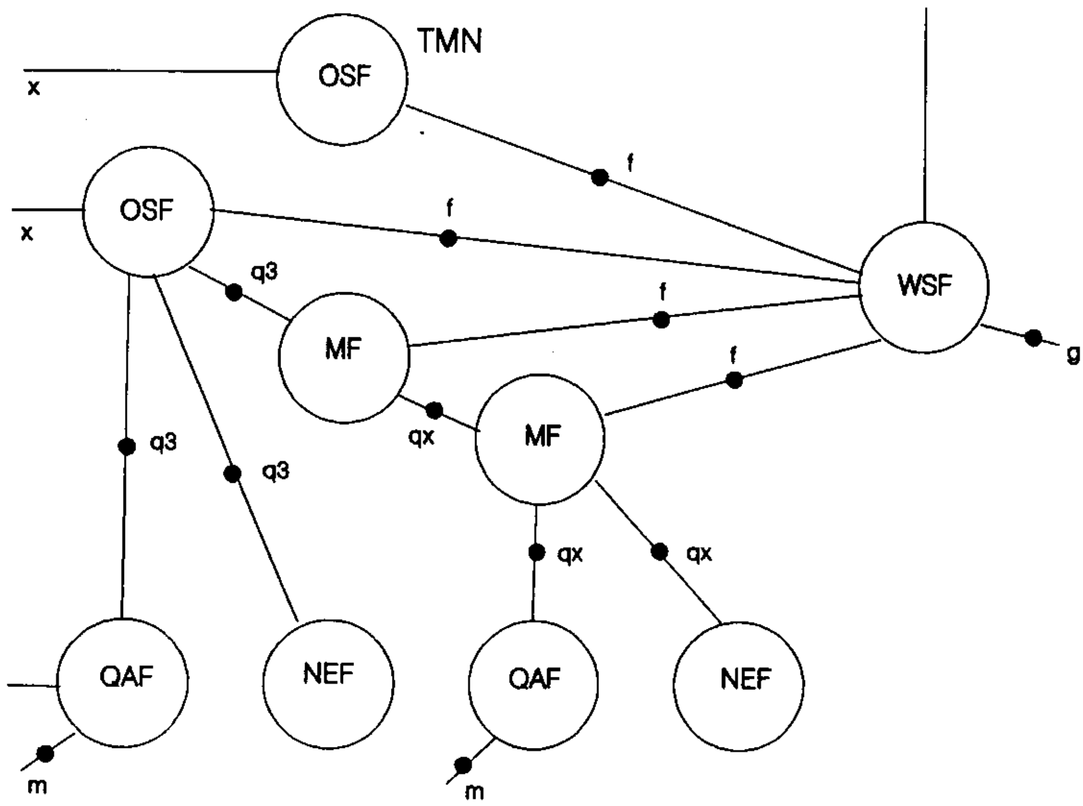

FIG 9.3.2 TMN FUNCTIONAL MODEL

In order to delineate management function blocks, the concept of reference points is introduced. Reference points define service boundaries between two management function blocks. Three classes of TMN reference points are defined, these are:

- q: class between OSF, QAF, MF and NEF
- f: class for attachment of WSF
- x: class between OSFs of two TMNs or between the OSF of a TMN and the equivalent functionality of another network.

In addition there are 2 further classes of non-TMN reference points shown which are relevant to consider:

- g: class between WSF and users
- m: class between a QAF and non-TMN managed entities

The q reference points are located between the function blocks NEF and OSF, MF and MF, NEF and MF, QAF and MF, MF and OSF, QAF and OSF, and OSF and OSF either directly or via the DCF. Within the class of q reference points:

- qx: the qx reference points are between NEF and MF, QAF and MF and between MF and MF.

- q3: the q3 reference points are between NEFs and OSFs, QAF and OSFs, MFs and OSFs, and OSFs and OSFs.

9.3.3.2 The TMN Information Architecture

The Manager/Agent concepts such as those developed for OSI management, are introduced.

The management information is considered from two perspectives:

- The management information model presents an abstraction of the management aspects of network resources and related support management activities. The model determines the scope of the information that can be exchanged in a standardized manner.

- The management information exchange involves Data Communication Functions.

In order to allow effective definition of managed resources, the TMN methodology makes use of the OSI system management principles and is based on an object oriented paradigm.

9.3.3.3 Functional TMN Hierarchy

For operational purposes, the management functionality may be considered to be partitioned into layers.

- Element Management Layer.
- Network Management Layer.
- Service Management Layer.
- Business Management Layer.

9.3.3.4 The TMN Physical Architecture

Figure 9.3.3 shows a simplified physical architecture example for the TMN. The following are the definitions for basic TMN building blocks containing mandatory TMN functions and function blocks.

- Operations System (OS)
- Mediation Device (MD)
- Interface Adaptor (QA)
- Data Communication Network (DCN)
- Network Element (NE)
- Work Station (WS)

Mediation is a process within the TMN which acts on information passing between an NE or QA and OS and provides local management functionality to the NE(s). Mediation uses standard interfaces and can be realised in a separate Mediation Device or be shared among NE(s).

Processes of mediation include:

- Processes involving information conversion between information models.
- Processes involving higher order protocol interworking.
- Processes involving data handling.
- Processes involving decision making.
- Processes involving data storage.

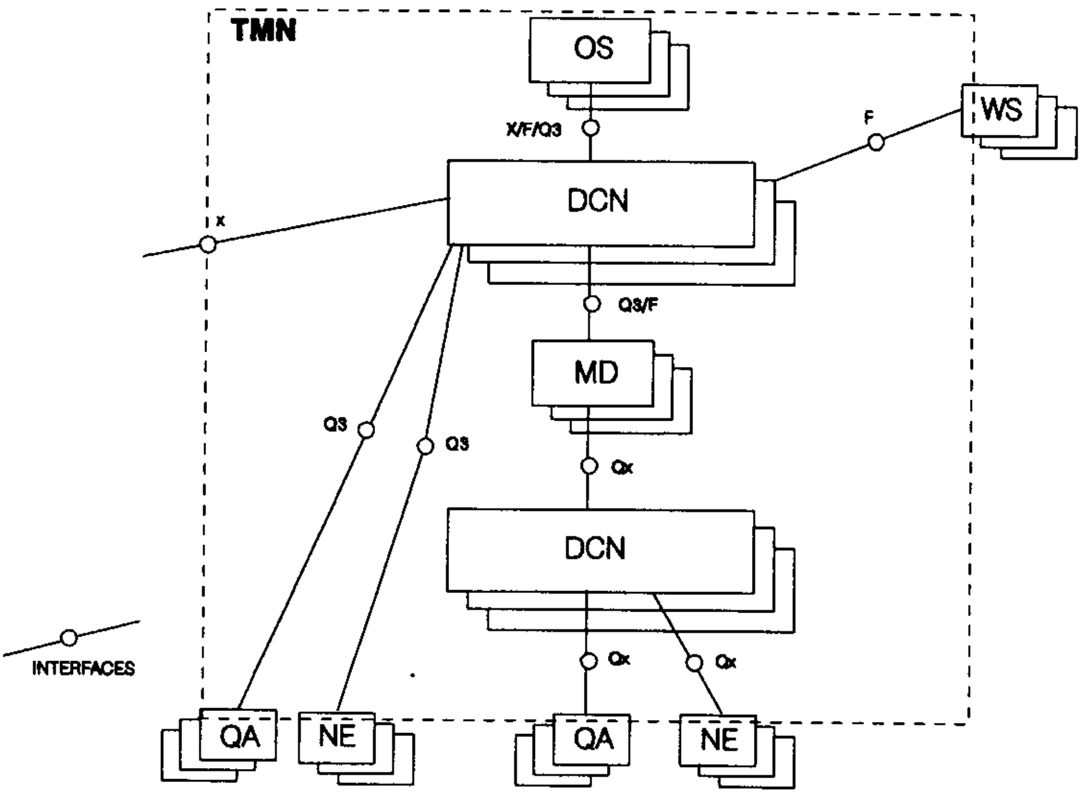

FIG 9.3.3 DEFINITION OF TMN BLOCKS

9.3.3.5 TMN Standard Interfaces

TMN standard interfaces provide for the interconnection of NEs, QAs, OSs, MDs and WSs through the DCN. The goal of an interface specification is to assure compatibility of devices interconnected to accomplish a given TMN function independent of the type of device or of the supplier. This requires compatible communication protocols and a compatible data representation method for the messages, including compatible generic message definitions for TMN management functions. A minimum set of protocol suites to be applied to TMN standard interfaces should be determined according to the recommendation M.3020.

To provide flexibility of implementation, the class of Q interfaces is made up of the following subclasses (at reference points where a physical interface appears, this is denoted by a capital letter):

- Interface Qx, is applied at the qx reference point.
- Interface Q3, is applied at the q3 reference point.

The X interface is applied at the x reference point. It will be used to interconnect two TMNs or to interconnect a TMN with another management network which accommodates a TMN-like interface.

9.3.3.6 TMN Protocol Families

There is a family of 4 protocols for each of the TMN interfaces: Q3, Qx, X and F.

The protocol suites to be applied to the Qx interfaces may be chosen from any of the CCITT recommended communication protocols. Details of one of the chosen Qx interface specifications and a Qx family of protocol suites will be found in network specific Recommendations.

For the Q3 family it is recommended that each set of TMN application functions with similar protocol needs are supported with unique protocol selections for layers 4 to 7 as defined by the OSI Reference Model (Recommendation X.200). Protocol options will likely be required for the Q3 family for layers 1, 2 and 3 in order to permit the use of the most efficient data transport. Details of the Q3 family of protocols will be given in Recommendation Q.811 and Q.812.

9.3.3.7 TMN Data Communication Considerations

A data communication network (DCN) connects NEs, QAs and MDs to the OSs at the standard Q3 level. Data communication links will also be used to connect MDs to NEs and QAs. The use of standard Q type interfaces enables maximum flexibility in planning the necessary communications. A DCN for a TMN should, wherever possible, follow the reference model for open systems interconnection for CCITT applications as specified in Recommendation X.200.

9.4 ISO/OSI Management

9.4.1 General

The OSI standards on network management issued by the ISO include at present the following documents (Fig 9.4.1):

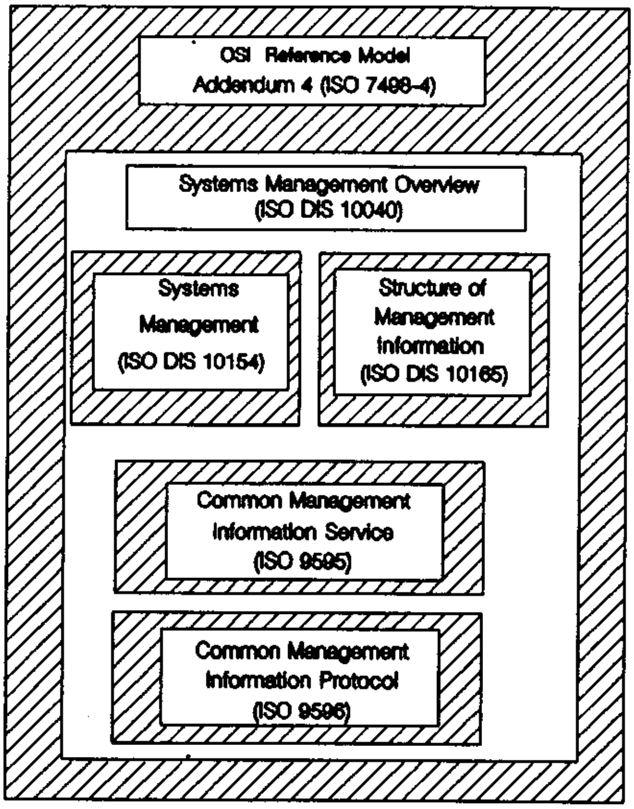

FIG 9.4.1 ISO/OSI NETWORK MANAGEMENT STANDARDS

The ISO standards concerning network management, however do not define a complete management system. Their main objective in accordance with OSI philosophy is to enable network management products from different manufacturers to work together. OSI management must thus be looked upon as an architectural model, which embodies the relevant concepts and principles, but does not take account of details regarding implementation nor is a user interface from a network manager defined within the scope of the OSI management concept. Questions related to planning a network are also not dealt with, instead the main thrust is directed at the management of existing heterogenous networks.

Before approval as an international standard (IS), every ISO proposal evolves through a number of stages: working document (WD), draft proposal (DP), draft international standard (DIS) and finally international standard (IS).

Table A1 in appendix A lists the ISO network management documents -and their status as of January 1993. Because of the close cooperation between OSI and CCITT the corresponding CCITT documents of the series X.700 are also given. Further CCITT Recommendations related to Telecommunication Management Network are to be found in Appendix A, table A2.

9.4.2 Management Framework

The OSI management framework (ISO-7498-4) forms the basis of the OSI management system. It contains guidelines for coordinating further work on existing OSI management standards, defines OSI management terms and describes basic concepts.

One such concept is the manager/agent model (organisation model), according to which the basic relationship between two open systems is resolved by one assuming the role of the managing system and the other the role of the managed system or agent.

The management environment includes all the tools and services needed to control and monitor communication activities and managed objects. The management environment enables the system manager to gather data, carry out control functions, check managed objects and determine their status.

The functional model divides the OSI system into five functional areas (refer to section 9.4.3)

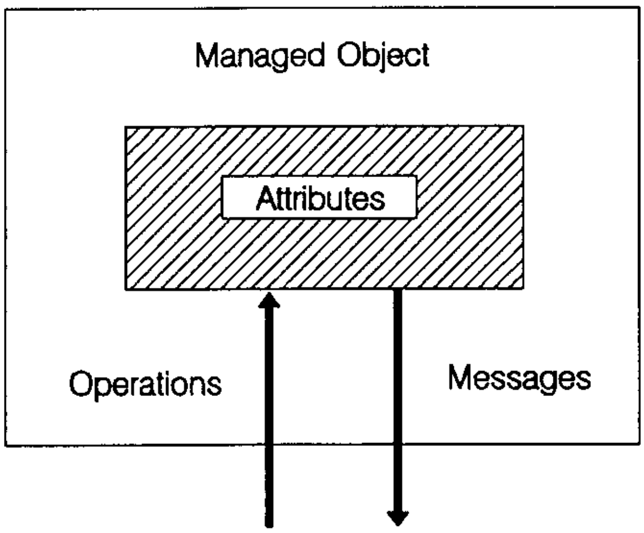

FIG 9.4.2 MANAGED OBJECTS

The managed objects are defined as the basic elements of the system. This is an abstraction of the real resources, which only includes the most important parameters needed to manage them. The definition of the managed objects (Fig. 9.4.2) is clearly object oriented. Accordingly, a managed object is determined by attributes apparent at its interface, by management operations applicable to it, its response to management operations and by the messages to be expected from it.

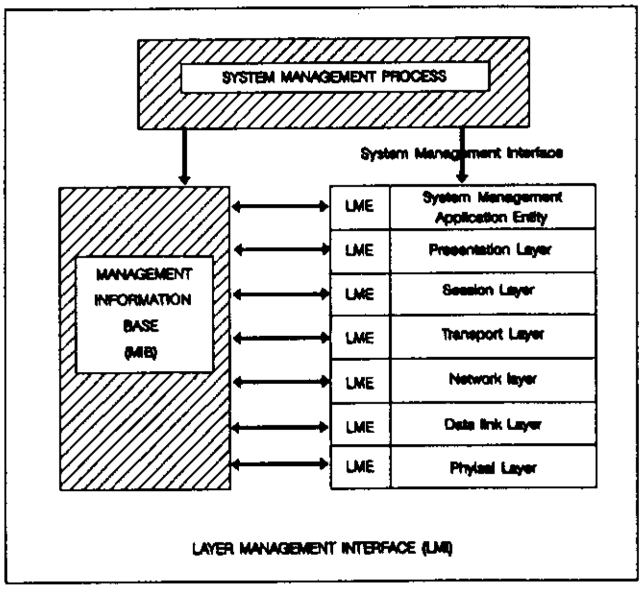

FIG 9.4.3 OSI MANAGEMENT MODEL

The management framework also defines the three groups, which make up the OSI management structure (structural model):

- The system management function provides facilities for monitoring, checking and coordinating all the managed objects in an open system. The main exchange of management information takes place via the system management function. Communicating parties are 'system management application processes' (SMAPs), which form part of the system management function and use the services of system management application entities' (SMAE). In regard to systems management all seven layers are used. These management functions are those which are necessary for the operation of the overall system and include:

  - The local environment.
  - The physical communication media.
  - Communication equipment.
  - Communication protocols.
  - Communicating entities.

- The layer management function provides facilities for monitoring, checking and coordinating each of the seven layers of the OSI reference model, i.e. it serves to control and monitor the objects of a layer. Communication parties are the (n)layer management entities (LME's). This kind of communication should only be used for operations limited to one layer. Layer management functions affect the operation of the layer entities. These functions operate at a single layer and include:

  - Layer services
  - Layer tests
  - Modification of layer parameters
  - Reading layer parameters

- The protocol management function provides facilities for monitoring, checking and coordinating a single communication transaction. It regulates the exchange of information between (n) protocols. The communicating parties are thus (n) protocol entities (PE).

The framework operates according to the MIB (management information base) principle. The MIB represents the quantity of all the managed objects in an open system and should only be looked upon as a conceptual data store without any specification for finally saving the information. The MIB is used by the entities (system, layer and protocol, see Fig. 9.4.3) concerned in the network management. Figure 9.4.3 gives a complete survey of the model of an OSI system enlarged by the network management functions.

9.4.3 System Management Overview

The "system management overview" (ISO DIS 10040) describes the division of a system management model into manager and agents and the interaction between them. A more precise specification of the managed objects and their descriptions (attributes, operations and messages) is also given.

The management areas defined for the basic reference model are gone into in more detail in the functional area documents. These describe the requirements, which led to the definition of the system management functional areas (SMFA), together with the functions derived from them.

System management as such comprises the SMAP and the SMAE. The system management application process represents the location at which the system management functions are performed. It provides an overall view of all the system parameters. The SMAP can function either as a 'managing process' or a 'managed process'.

The "system management application entity" is responsible for the communication between different system management entities. To this end, it makes use of protocols of the application layer, via which information relating both to individual layers as well as to the entire system are transferred.

Since system management protocols operate on layer 7, they require the complete OSI protocol stack. Difficulties occur where a system does not have all 7 layers (e.g. bridge, router). In order to be able to integrate systems of this kind in the OSI management model as well, the definition of a minimum subset for the operation of a system management function is currently under discussion.

While ISO DIS 10040 provides a survey of system management, ISO DIS 10164 defines a group of system management functions. These individual functions can be assigned to a system management functional area (SMFA):

- Fault Management
  - Alarm reporting.
  - Event report management function.
  - Log control management function.
  - Test management function.
  - Time management function.
- Configuration management
  - Object management function.
  - State management function.
  - Relationship management function.
  - Software management function.
- Performance management
  - Workload monitoring function.
  - Measurement summarization function.
- Accounting management
  - Accounting meter function.
- Security management
  - Security alarm reporting function.

- Security audit trail function.

A relatively detailed description of these management functions is to be found in Ref.[9].

9.4.4 Structure of Management Information

Document ISO DIS 10165 comprises at present three sections:

- The Information Model (ISO DIS 10165-1) describes the managed object model, the operations carried out by the system management on the objects and the principle of the message system. Finally a diagram is defined for assigning names to managed objects.

- The document entitled Definition of Management information (ISO DIS 10165-2) describes managed objects, which are required by the system management function (system managed objects), as well as a series of data types, which can be uses to describe classes of managed objects.

- Finally, the Guidelines for the Definition of Managed Objects (ISO DIS 10165-4 DIS) are intended to be of assistance in defining new classes of managed objects. They contain definitions of the requirements, methods and notations, which must be taken into account when defining a new class.

9.4.5 Management Services

The services available at the system management interface (SMI) are accessed with the aid of the "common management information protocol" (CMIP, ISO 9596). CMIP defines communication standards for network information on, Faults, Configuration, Accounting, Performance and Security (FCAPS).

The exchange of data on layer 7 is governed by the "common management information service" (CMIS, ISO 9595). The document defines a number of fundamental concepts upon which the exchange of management information is based. CMIS defines the functions which are provided by the manager. These can be divided into different categories (Fig. 9.4.4).

Common to all services is their purpose of serving to modify objects and their attributes. Objects are identified by names, it being assumed that the names conform to a hierarchical structure in the form of a "management information tree". The "association services" use "remote operation service elements" (ROSE).

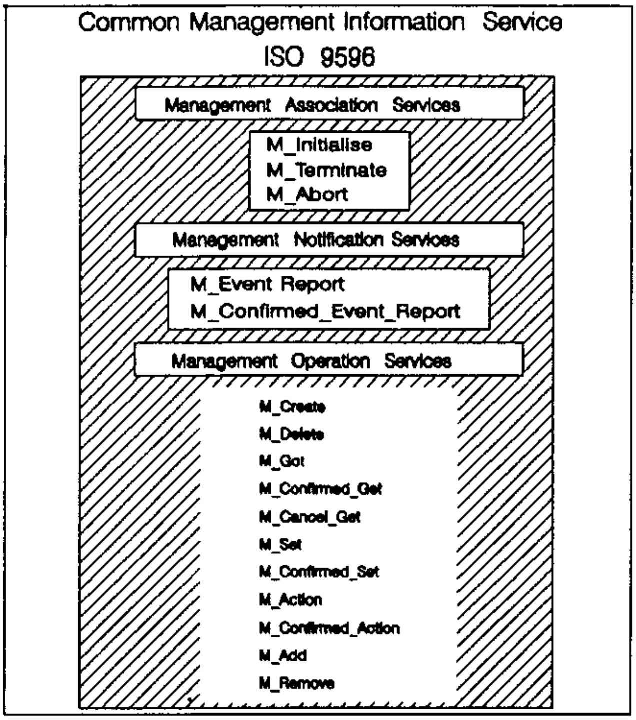

FIG 9.4.4 COMMON MANAGEMENT INFORMATION SERVICES

9.4.6 Network Management Forum

The Network Management Forum is an international consortium of telecommunication and computing companies, service providers and users with a common interest in the development and deployment of network management systems. The forum was established in 1988 and has now over 100 members. The members' goal is the definition of a common network management interface that will allow their product to interoperate or communicate with each other.

The forum exists to accelerate the development and use of international standards for network management. The forum does not create standards. It defines a common implementation profile based on existing and emerging standards.

9.5 Transmission Control Protocol/Internet Protocol (TCP/IP)

TCP/IP was developed as a standard internetwork protocol by the American Internet Activities Board(IAB) in 1985. It is used extensively in data communication networks (LANS and WANs). It has been instrumental in achieving network compatibility in multivendor systems. TCP/IP is a well developed protocol and there are available at present many TCP/IP based products. TCP/IP and OSI based protocols are not compatible.

9.5.1 Simple Network Management Protocol (SNMP)

The name "simple network management protocol" (SNMP) stands for a set of regulations established by IAB, which operates the US research and US federal communication network. Standards in force within Internet are published in what are refereed to as "Requests for Comments" (RFC). Table A3 in appendix A lists the most important of these.

SNMP derives from the TCP/IP series of protocols and was developed by Internet as a simple and quick method of monitoring performance and system defects. It has gained considerably in significance Ref.[10]. The purpose of SNMP is to provide network managers with a central point for monitoring, checking and managing their systems. It is completely disassociated from the techniques of specific manufacturers and is intended for distributed data processing applications in commercial offices and administration.

SNMP is a protocol which defines how the manager and managed agents may communicate. The SNMP manager is a program which can provide information about the network and also control the network. The agents are devices on the network. In order to communicate with the manager it is necessary for the agent to run some software. SNMP is best developed for agents such as routers, gateways, bridges etc. It is for this reason that it is widely used at present in LANs and WANS.

The relationship between SNMP and CMIP (ISO/OSI) reflects the relationship between TCP/IP and ISO/OSI. Basically one would prefer communication between heterogenous installations according to the OSI standards, but TCP/IP is installed instead, because it is compacter, simpler, cheaper and has extremely high availability.

SNMP monitors the network by accessing the units and continuously extracting data from the agents, which are gathered in the "network statistics data base" (NSD). If one of the units is no longer functioning and therefore cannot be accessed, an alarm condition (trap) occurs. There are five important events, which result in a trap: loosing a connection, restarting a connection, initialising an agent, restarting an agent and the failure of an authenticity check.

SNMP is only one part of an overall management structure, the other parts being the management information basis (MIB) and the structure of the management information (SMI) specifications (Table A3 in appendix A). The MIB is a collection of objects in the agents, which are accessible to and can be checked by the system manager.

A compromise is CMOT (CMIP over TCP/IP) which specifies an hierarchically orientated network structure with different domains. This protocol is based on ISO transport protocols and exhibits greater functionality and more flexible object definitions than SNMP, which as a consequence places higher demands on the administrative systems. CMOT provides TCP/IP networks with the functionality of CMIP.

9.6 IEEE Management

IEEE 802 was created to develop standards for communication in local area networks (Fig. 9.6.1) Sub-group 802.1 includes a working group concerned with the management of networks in LAN and MAN environments Ref [11]. This sub-group has established the following parts:

- Part B specifies services and protocols for network management tasks without resorting to a complete 7 layer stack.
- Part D of the standard concerns LAN bridges.
- Part E defines services and protocols for remote station loading in a LAN/MAN environment.
- Part F lists guidelines for defining managed objects, which are compatible with the OSI management concept.

None of these parts (Appendix A, table A4) has been given final approval to date.

The OSI management model is more general than that of 802.1. It requires OSI systems, which communicate across all 7 layers as distributed participant applications. In many cases, there are devices in a network which do not support all 7 layers (e.g. modems, bridges, repeaters) and therefore it must be possible to exchange management information on the lower layers. Network management according to 802.1 only uses the services of the lower layers and is intended for LAN/MAN management. It does, however, conform to OSI and does not exclude the use of all 7 layers of a system, which is connected to a LAN. In the long term, a large part of the IEEE standards will find its way into ISO standards. Thus the possibility of subsequently upgrading systems with network management, which were designed according to the IEEE 802.1 standard, is assured see Ref [11].

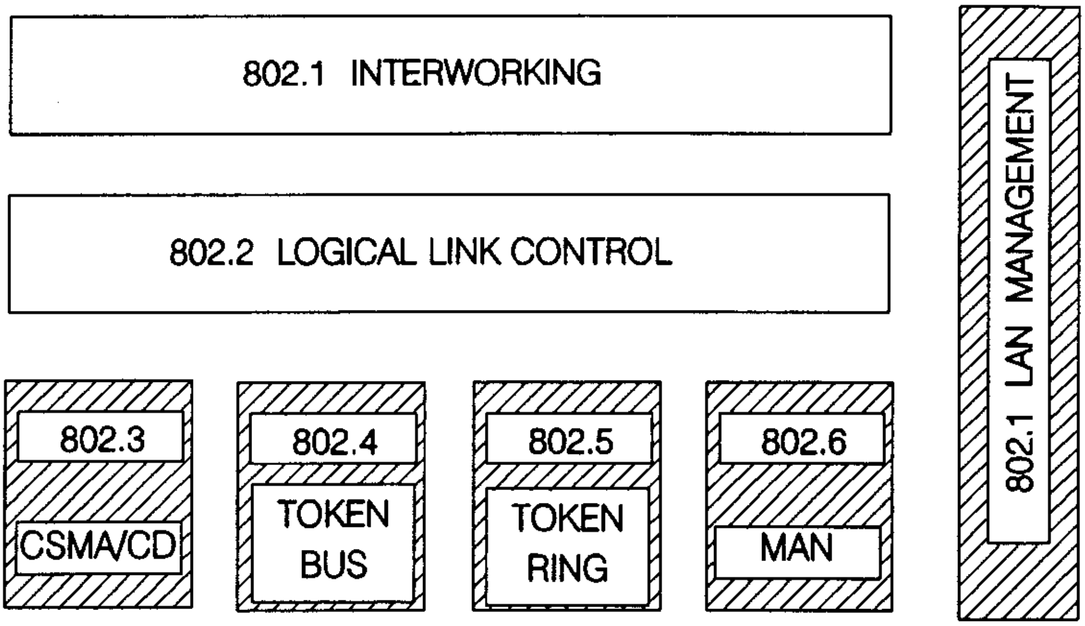

FIG 9.6.1 IEEE 802: LAN MANAGEMENT

SECTION 10 FUTURE TRENDS IN TMN

10.1 General Comment

Predicting the future of TMN is a difficult task, however if it is to be attempted, the first step is to set some limitation on what is meant by the future. The second step is to identify those factors and business needs which will determine the shape of TMN in the chosen timescale.

In regard to the timescale it is clear from the last ten years that telecommunication technology is developing at a very fast rate. This makes accurate forecasts difficult, however it has also been estimated that the time span between launch of a telecommunication product or system and its general acceptance is five to seven years. It is also clear that the level of activity in the general business environment, which is very difficult to predict, can greatly affect the development and use of new technology. Bearing these factors in mind it will not be possible to forecast trends more than five years ahead with any degree of accuracy.

Some of the factors which will influence the development and use of TMN are clearly identifiable,

- Technological developments in networks and TMN, including agreement of standards.
- Changes in the power utility industry and the type of telecommunication services required by utilities.
- Changes in the telecommunication industry.

In the following sections the effect of these factors will be examined.

10.2 The Changing Power Utility Business Environment

10.2.1 Change in the General Business Environment

The ability of a business to respond quickly to changing circumstances is one of the hallmarks of success. This is particularly important in the present highly competitive business environment and is likely to remain so for the next 5 years. There is also a much greater emphasis on quality. This emphasis on quality encompasses a consistently high grade service level to customers. An acceptable return on investment is also of great importance.

In order to achieve this high service level, quality, return on investment, flexibility and fast response a business must have an efficient Information Technology (IT) system which in turn depends on a responsive and flexible telecommunication network.

Many businesses now see their telecommunication networks as a dynamic system which is indispensable to the achievement of strategic goals.

10.2.2 Change in the Energy Market

Some of the major issues facing the power utility industry are,

- Various emission control protocols which will increase operating costs.
- Reduction of carbon dioxide emissions which may place additional costs on power utilities.
- An increasing cost associated with the responsibility on power utilities for waste management.

- In the EC a number of directives have been or will be issued which have major implications for power utilities. These directives have effects in respect of increased competition, pricing policy and transit arrangements.

Many of these issues will place additional financial burdens on power utilities. This will lead in turn to efforts to improve efficiency and return on investment in the business as a whole.

There are some areas where power utilities are expanding their business interests. These include,

- Diversification into other businesses.
- Involvement in power utility consultancy outside their own geographical area.

The involvement of utilities in consultancy and diversification of business interests will place a greater emphasis on effective telecommunication networks. It will also alter the scale and capacity of these networks and place increased responsibility on the manager of the network to achieve optimum operation levels.

In respect of size and organisation the power utility industry is in general downsizing. Organisational structures are moving toward flatter, loosely coupled, distributed peer to peer departmental systems.

All of the above factors will have a major influence on power utility Information Technology, Telecommunication Networks and TMN.

10.2.3 Deregulation of the Telecommunication Market

Privatisation of national telecommunication operators and liberalization of the telecommunication market have created many opportunities for new suppliers of telecommunication services and infrastructure. Private companies have been invited to invest in the installation, operation and maintenance of national telecommunication systems and may also now offer telecommunication services to third parties. The telecommunication market is set to continue on a path to deregulation.

The development and provision by power utilities of new telecommunication services to third parties may provide profitable investment opportunities. The types of service which have already been offered by some utilities are,

- Leased circuits/bandwidth.
- Management of facilities.
- Private mobile radio management & facilities provision.

In the case of trunk digital circuits demand for high speed communication routes between major population centres is growing rapidly. Some power utilities are in a position to provide these circuits using their own digital circuits and access routes originally obtained for power transmission and distribution circuits.
Liberalization of the telecommunication business has opened up opportunities for power utilities to supply services where they already have considerable expertise. The most obvious services which power utilities may provide are those where they have considerable experience such as management of networks, e.g. private mobile radio, cellular radio, packet switch networks and fibre networks.

If power utilities are to provide these services they will require effective TMN in order to manage these systems.

These changes in the telecommunication market have not only given power utilities the opportunity to provide service to third parties but also to lease service from third parties. Deregulation of the telecommunication business and the introduction of competition in the area of service provision has improved the service quality and delivery of circuits to a point where it may be possible for power utilities to lease substantial parts of the service they require rather than invest in telecommunication networks and other facilities.

Outsourcing, or transferring functions previously performed by internal IT or Telecommunication groups, is being considered by some companies. This is being driven by a number of factors both strategic and financial. In some cases outsourcing is seen as a means of reducing the power utility's need for costly network and management equipment and the expertise to operate it.

The type of functions which may be outsourced are,

- Voice & Data network management.
- Executive information systems.
- Telecommunication network operations.
- Network design.
- Data centre operations.

Business needs for information from many sources is increasing and this is putting increased pressure on existing networks and their management systems. Outsourcing must be considered when major investment is necessary in order to provide these services.

A number of consortia have been formed to offer management and support services to private networks such as those in power utilities. Some of these consortia are composed of major telecommunication operators and system suppliers.

10.3 The Telecommunication Services which Power Utilities will need in the Future

10.3.1 Existing Services

At present power utilities need telecommunication facilities for a variety of operational and general business reasons. These are,

- Management of the energy system.
  - Network operation and control.
  - Generation operation and control.
  - Load management.
  - Energy accounting.
  - Analysis of power system faults.
- Management of the telecontrol system.
- Power system operator communication (Voice and data).
- Business voice and data communication.
- Customer communication.

It is worth noting that in many instances the business traffic is of equal importance to the operational communication. These existing services are discussed in more detail in Section 4.1.1.

10.3.2 New Services

A number of new services will greatly affect both TMN and the structure of telecommunication networks. Some examples of these new services are outlined below.

Video Communications

Power utilities in common with other major businesses have a need for video communications facilities. The need arises both within the company and also for more effective communication with business partners and suppliers. In the case of power utilities video conferencing could be particularly useful for companies involved in consultancy work and also for communicating with suppliers of power equipment during installation and maintenance.

The requirement is that users of the system should be able to setup a conference and exchange data from an office environment and preferably desktop to desktop. Systems which offer video conferencing over LANs are now becoming available.

Integrated Services Digital Network (ISDN)

The purpose of ISDN is to provide integration of voice and data services. The ISDN user is allocated bandwidth in 64 kilobit/s increments, called B channels. A 16 kilobit/s signalling channel, called a D channel, is also provided. The basic interface is composed of a 2B+D channel and primary access is provided by a 30B+D or 23B+D channel.

The main use of ISDN may be in the provision of wide area voice and data service. This may be an option which power utilities will use with consequent effects on private telecommunication networks and TMN.

Strong growth in the provision of ISDN service is expected throughout the world in the next 3 years.

Frame Relay

Frame relay is an implementation of fast packet switching using the data link layer structure specified in CCITT Q.921/I.441. This system is suitable for narrow band ISDN and is intended for data applications. Frame relay may be a good choice for LAN interconnection because of low overheads and high data rates (up to 2 Megabit/s) at present.

Many PTTs and others are offering frame relay service at present and this market is expected to grow significantly.

Asynchronous Transfer Mode (ATM)

ATM is a packet oriented, non-acknowledging multiplex system. Information is sent in packets of fixed length called cells, Each cell consists of 48 octets of information and 5 octets of header information. ATM allows connections with any bit rate. Current standards specify transport bit rates of 155 to 622Mbits/s. The costs associated with the development, installation and operation of ATM systems are expected to be very competitive and it may form the basis of future major transmission networks. As such it may be of future interest to power utilities.

10.4 TMN - The Next Five Years

In common with Network Managers in other business environments those in power utilities have to consider very carefully their strategy over the next 5 years. The following is an attempt to describe the features which a power utility TMN will require during this period.

10.4.1 TMN - Desirable Characteristics

A comparison of existing and future characteristics of TMNs is shown in Table 10.1

CHARACTERISTICS OF NETWORK MANAGEMENT SYSTEMS	EXISTING CHARACTERISTICS	DESIRABLE FUTURE CHARACTERISTICS
Operating System	User must know the Operating System	Should be transparent to the user
Network Failures	User reported	Network Manager detected with recommended action
Network Repairs	Faults repaired after network user has been affected	Prevention of faults which affect the network user
Network Configuration	Manual	Automatic reconfiguration
Network Accounting	Accounting performed by add on systems	Detailed flexible billing
Network Performance	Limited data collection	Service quality monitoring
Network Security	Elementary security against unauthorised access	Comprehensive monitoring & reporting of all access to the TMN
Interfaces	Proprietary	Open System

Table 10.1 Comparison of Existing and Future TMN Characteristics

It is clear from this comparison that there is considerable room for development in existing TMN.

10.4.2 Configuration of Future TMN

A major issue in the design of any TMN is whether it should be centralised or decentralised. There are three main types of configuration,

- Centralised Management : This has been the standard approach to management of networks. The network is monitored from a central point and network data is stored and processed at this point. See Figure 8.6.2.

- Manager of Managers (MOM): This system enables a number of individual management systems to be managed. The subsidiary systems may be proprietary however an Open System interface to the MOM is necessary. See Figure 8.6.1.

- A Multiple Cooperative Manager : This describes a system where a number of management systems are involved in managing the network. The relationship between the manager and agent may be defined on a dynamic basis. OSI interfaces between the different network management systems and also between the managers and agents is necessary.

To date most TMN systems have been based on centralised single processor systems. These have some disadvantages such as,

- Low availability.
- Costly upgrades.
- Lack of flexibility in reporting arrangements.
- Poor response in high load periods.

Developments in,

- RISC architecture.
- Distributed and parallel processing.
- Lower cost memory / storage.
- Increased processor power.

will change existing TMN system architecture. Multi-processor bus architecture systems which are becoming available have eliminated some of the disadvantages, listed above, of the single processor system.

For power utilities it is necessary that the telecommunication network, which is used in the management of the power system must have a high availability and hence the TMN system also. A distributed configuration appears to offer considerable availability advantages to TMN systems.

Power utilities generally cover a large geographical area. This area may include a number of administrative divisions and centres. It may also be desirable to devolve limited control of a part of the telecommunication network to a number of regional control centres. This means that future TMN systems should be capable of operating over a wide area and of reporting to a number of centres.

From the above it would seem that a multiple cooperative manager may be best suited to utility needs.

10.4.3 New Facilities for TMN

10.4.3.1 Interactive Voice Response

These systems could be used in conjunction with TMN. Major features of Interactive Voice Response systems are,

- Service hours can be expanded without increasing staff
- They can operate 24 hrs /day
- No special equipment or training is required to use the system

Interactive voice response systems allows a caller to enter or retrieve information over the telephone. Their main use in TMN may be in allowing network users to enter and retrieve network information outside of normal working hours. Callers use a touch tone keypad in order to interact with the system.

In conjunction with artificial intelligence interactive voice response systems could be developed which would,

- Provide diagnosis of simple faults for system users.
- Assistance in using a function.

10.4.3.2 Speech Recognition Systems

Systems are available to allow callers to use simple commands and get a response, however the vocabulary of such systems is limited at present. Systems with larger vocabularies are being developed and should be capable of a greater variety of uses.

10.4.3.3 Fax Integration

Systems are now available which enable the caller to get a fax response to a query. These are in the form of a standard response to typical customer queries.

10.5 Use of Expert Systems

10.5.1. General

The management of telecommunication networks is a complex operation which requires skilled personnel. Expert Systems could be used,

- To reduce the work load on network operators and thus increase their effectiveness during high traffic periods or system disturbances.
- To reduce the numbers of skilled operators required.
- To help in training network operators.

In order to perform these functions expert systems should be capable of,

- Requesting and storing data from the network.
- Relating data.
- Tracking a number of incidents.
- Communicating diagnoses (including changes) to the operator in a timely and efficient way.

The areas where it is likely that expert systems will be useful are,

- Fault diagnosis and recommended corrective action.
- Network configuration (Help the operator in reconfiguring the network).

The reduction of the number of alarm signals and the presentation of the cause of faults with a proposal for corrective action could significantly improve the response of operators to fault conditions. It may be that future systems will not only propose corrective action but in fact perform the corrective action without operator intervention.

Expert systems should be integrated into existing management systems. Telecommunication network management depends on many on-line decisions being made upon a large body of constantly changing data. Traditionally, operations staff were trained to handle certain types of problems themselves. Any problems they could not handle were passed on to technical staff.

With the growing complexity and diversity of telecommunication networks, it has become increasingly difficult to either train operations staff in problem handling or hire additional technical support people. Thus, new approaches to solve the management problem are emerging. One of them involves the use of artificial intelligence (AI) techniques. Among other things, AI is a set of programming methodologies that focus on the techniques used to solve problems rather than on solution algorithms. A subfield of AI are expert systems.

10.5.2. Expert Systems

Expert systems are computer programs designed to simulate the reasoning process of human experts in narrow, specified domains of knowledge. The principal components of such systems are:

- Knowledge Base.
- Knowledge Acquisition.
- Inference Engine
- User Interface.
- Query Module.

The first one contains information from human experts in addition to facts provided by the user during interaction with the system. The knowledge acquisition is a software module that helps in the collection of knowledge for the base from the human experts (in some expert systems this module may not exist). The inference engine deduces knowledge that is not directly contained in the knowledge base turning it into an interactive system with which the user can interact. The interface formulates questions to the user and may understand answers provided by the user in a natural language (through speech recognition and synthesis). The query module explains to the user about the reasoning behind their decisions.

In designing an expert system there are three approaches:

- Rule-based (to solve clearly defined problems).
- Frame-based (to solve even those problems still undefined within a general domain of knowledge).
- Hybrid (employs both methods).

Although the potential of expert system applications in TMN is just beginning to be recognized and exploited, factors such as: increased processing power, lower storage costs, parallel processing, and the availability of development tools and techniques will be drivers for expert system and telecommunication developments due to the fact that both are computer-based technologies.

In the near future it is likely that expert systems will become significant in the following areas of TMN.

- Identifying and diagnosing network problems.
- Increasing the effectiveness of operation staff during high traffic periods or system disturbances.
- Automating network operations.
- Training operation staff.
- Automating network configuration.

10.5.3. Future Trends

Further in the future there appear to be three main lines of development in the application of expert system to TMN,

- Embedded expert systems. Systems that are embedded or integrated as a single component in a large system. Systems in which multiple "local" agents cooperate and communicate to collectively perform global tasks, as a way of achieving real-time performance. In the end, the goal is the autonomous network, in which error-free operation is provided by hardware flexibility and redundancy and intelligent diagnostic functions embedded into the network components and into the TMN system.

- Intelligent user interfaces. Through them, the network understands user needs and adjusts to their profiles, providing the user with advanced services. Expert systems will enable the interface to intercept and remedy incorrect or inefficient user actions, recover from system errors and answer a wide range of queries.

- Intelligent databases. Expert systems will be used to retrieve information from different data bases with many different, dynamic data types, that is not explicitly stored, but must be inferred from rulé-based knowledge combined with facts from one or more data structures.

Also research in knowledge acquisition, knowledge representation and machine learning will allow future expert systems to learn, thus gaining the ability to automatically accommodate changes in traffic demand and to anticipate overloads.

But the future offers both opportunities and challenges. The former are provided by developments in computer hardware, software and information systems: the cost of processing power and memory is decreasing rapidly exemplified by cheap, powerful RISC architecture workstations.

The challenges remain in building cost-effective systems in a timely manner. They must go through several complicated steps: user needs analysis, architectural design, knowledge acquisition, representation, implementation and testing. To reduce these development costs more powerful software tools are needed.

Another constraint is the development time, because the lifetime of knowledge in some fields like telecommunication, is becoming shorter it might be considered futile to develop a knowledge based system that may be outdated by the time it is finished.

Finally, it could be concluded that the use of expert systems in TMN provides both advantages and disadvantages. These include:

- Provision of higher quality services.

- Substantial increases in performance. Routine use of expert systems for network routing, system maintenance, and so on would significantly improve the performance of telecommunication networks. It would allow personnel to perform at or above the level of an expert. From the customer's standpoint, it should yield a better product or service with a higher level of reliability.

- Capture of knowledge that will be less available in the future. This is an important, though difficult to quantify, benefit. In the dynamic world of telecommunications, expertise is being lost as experienced personnel move to work on new systems or new problems or just leave the power utility. This generates potential problems in the use of older systems. An expert system can capture the expertise of a top expert while available and at a peak performance and make it available for the future.

- Expert performance available in all locations at the same high performance level 24 hours a day.

- Provision of lower cost service by productivity improvements.

- Significant increases in productivity. An expert system in Integrated TMN can bring a less experienced person to the level of an expert, allowing tasks to be performed faster and more efficiently. Even experienced personnel can be aided, as they are still not at the level of a top expert.

- Reduction of staff costs and making top performers available. With an expert system, some high-level jobs could be performed by lower grade staff. This also frees the top performers to concentrate on the more important jobs, which may be beyond the reach of the present state-of-the-art expert systems.

- Better performance with expert systems than with an expert. Expert System can combine the capabilities of the computer with the expertise of a top expert. Being a computer system, an expert system is thorough in all its analyses and will not make many errors that average maintenance personnel may make and that even the best human expert will occasionally make. Also, an expert system can perform detailed, repetitive, or laborious tasks that an expert, though capable, often might disregard if he or she feels that they have only a small chance to help solve the problem.

- Improvement in worker's general performance by having the presence of an expert review. When the expert system is used to make recommendations related to a worker's task, the worker subconsciously may be more careful in his or her work, so as not to be "caught" doing a poor job by the expert system.

- Other benefits.

  - Provides managers with greater flexibility in staffing. Since the required skill level may be reduced for certain jobs, managers, at times, can use personnel with skills in one area to work in related one, with the assistance of an expert system.

  - Expert systems can be major aid in training. They often can output explanations and justifications of their analyses; in many levels of detail. This can be a major aid in training inexperienced personnel. In addition, some expert systems have been developed specifically for training, having the expertise of a trainer as well as the application expertise.

Despite these advantages, those introducing expert systems in a TMN must be careful for the following reasons:

- As with the introduction of any automation, expert systems may create a feeling of insecurity among workers. If expert systems are not implemented carefully, it could lead to social problems in changing the way things are done owing to the deviation from "business as usual". To avoid this situation, the system and technology should be introduced gradually and carefully.

- Expert systems arė not sensitive to political situations. They could produce results which have political consequences. It may be important to employ expert systems in a subordinate role - in a decision support mode.

- Finally, there is a problem with unrealistic expectations. The area of expert systems has many people expecting too much and others expecting too little.

10.6 Customer Managed Networks

10.6.1 Customer Managed Communications

Public and private carriers in a number of countries have introduced management systems which allow the customers to manage that part of the network which they are using as if it were their own. The purpose of these systems is to allow the customer to have integrated end to end management of the services provided on the network. Integration is necessary because most networks contain proprietary elements from different suppliers and also different management systems.

SECTION 11 CONCLUSIONS

Network management is an essential tool for the successful and efficient operation of any network. Network management may be divided into centralised and local (regional) functions and systems according to the organisational responsibilities of the network operator. Careful planning is required to allow the phasing in of newly emerging technologies.

The management of telecommunication networks for power utilities is no exception since such networks require constant monitoring and control and enable telecommunication staff to carry out maintenance procedures and changes by downline loading of data to remote sites and to maintain optimum service levels.

During the past few years, it has been recognised that network management has become a vital element in the efficient operation of voice, data and image communications. Once considered an option, it is now a necessity for administering and operating both public and private networks. In common with other large organisations managing corporate networks, the situation arises where a range of network management tools sourced from multiple vendors are not compatible. In response to this need, the ISO has defined a set of Open Systems Interconnection standards for network management. The framework for managing the telecommunication networks, both public and private, is defined by CCITT (TMN specifications) and regional telecommunication standardisation organisations (e.g. ETSI in Europe and ANSI/T1 committee in the USA).

Integration of systems is paramount to ensure management of operational functions such as control, supervision and ease of maintenance, along with normal electronic mail, telephony and administrative duties. Integration is typically achieved by interconnecting specialised management systems, either peer-to-peer or to an upper level 'MOM' system, preferably using standardised interfaces. The appendices give examples of already implemented networks as an aid to planning.

For good quality telecommunication systems adequate standards are essential particularly when providing telecommunication services as an additional business venture to PTT's and one's own customers. Accordingly, standards are also fully discussed in this Report to provide advice to personnel involved in TMN systems.

SECTION 12 ACKNOWLEDGEMENTS

The members of CIGRE Working Group 35.02 would like to record their grateful thanks and appreciation to all those who have assisted in the preparation of this TMN Report. They would also like to express their appreciation to those who responded to the questionnaire on Telecommunication Network Management.

In particular, help and assistance has been freely given by the present and previous Chairmen of Study Committee 35, G. Vincent and R. Koskinen respectively.

The members of the working group would also like to acknowledge the assistance of the power utilities and telecommunications companies which are represented by working group members in the preparation of this report.

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APPENDIX A REVIEW OF STANDARDS (December 1993)

ISO Standard	CCITT Rec.	Title
7498 (IS)	X.200	Basic reference model
7498-4 (IS)	X.700	Management framework
9595 (IS)	X.710	Common management information service definition (CMIS)
9596 (IS)	X.711	Common management information protocol specification (CMIP)
10040 (IS)	X.701	Systems management overview
	X.702	Systems management tutorial
10064 (IS)		Systems management function
10164-1 (IS)	X.730	Object management function
10164-2 (IS)	X.731	State management function
10164-3 (IS)	X.732	Relationship management function
10164-4 (IS)	X.733	Alarm reporting function
10164-5 (IS)	X.734	Event report management function
10164-6 (DIS)	X.735	Log control function
10164-7 (IS)	X.736	Security alarm reporting function
10164-8 (IS)	X.740	Security audit trail function
10164-9 (DIS)	X.741	Objects and attributes for access
10164-10 (DIS)	X.742	Accounting meter function
10164-11 (DIS)	X.739	Workload monitoring function
10164-12 (DIS)	X.745	Test Management Function
10164-W (WD)	X.744	Software Management Function
10164-13 (DIS)	X.738	Measurement Summarisation Function
10164-14 (DIS)	X.737	Confidence and diagnostic testing function
10164-Z (WD)	X.743	Time management function
10165		Structure of management information
10165-1 (IS)	X.720	.Management information model
10165-2 (IS)	X.721	Definition of management information
10165-3		Cancelled
10165-4 (IS)	X.722	Guidelines for the definition of management objects

Table A1 ISO Network Management Standards with corresponding CCITT Recommendations, Series X.700 for Network Management,

IS : ISO International Standard
DIS : ISO Draft International Standard
CD : ISO Committee Draft
WD : ISO Working Document

M-SERIES	RECOMMENDATIONS
M.3010	Principles for a TMN (formerly M.30).
M.3020	TMN Interface Specification Methodology
M.3100	Generic Network Information Model
M.3180	Catalogue of TMN Management Information
M.3200	TMN Management Services: Overview
M.3300	TMN Management Capabilities presented at the F interface
M.3400	TMN Management Functions
G-SERIES	**RECOMMENDATIONS**
G. 773	Protocol suites for Q-interfaces for management of transmission systems.
G.774	SDH Management Information Model
G.784	SDH management
Q-SERIES	**RECOMMENDATIONS**
CCITT Q.811	Lower Layer Protocol Profiles for the Q3 Interface
CCITT Q.812	Upper layer Protocol Profiles for the Q3 interface

Table A2: Further CCITT Recommendations related to TMN

RFC1052	IAB recommendations for the development of the Internet network management standards
RFC1095	Common management information services and protocol on TCP/IP (CMOT)
RFC1155	Structure and identification of management for TCP/IP based internets
RFC1156	Management information base for network management of TCP/IP based internets
RFC1157	A simple network management protocol SNMP

Table A3 : IAB Standards for Network Management

802.1A	Overview and architecture
802.1B	LAN/MAN management
802.1D	MAC bridges
802.1E	System load protocol
802.1F	Guidelines of layer management standards

Table A4 : IEEE Standards for Network Management

APPENDIX B TYPICAL TMN STRUCTURES

The TMN structure shown at FIG B1, represents an integrated management structure capable of managing both physical and logical networks for different services.

It has a hierarchical structure consisting of a main system, a sub-system and network elements. The master system should be installed as an extension of the telecommunication network.

The next level is the sub system which can operate independently and consists of,

- OS
- DCN/2
- MD

The separate operation systems, with the possibility of interconnection, can provide for the following ranges:

- Transmission network.
- Switching systems.
- LAN/WAN - networks

  etc.

Some special features of the transmission management system (TMS) are,

- The DCN/2 can be a LAN when the mediation device is situated near (shorter than 500m) to the operation system
- All MD, which have a protocol transforming function from Q2' to Q3' (Q3) and reversed, have a connection to the operation system.

The lowest level are the network elements NE, in which,

- The data information (data about quality, configuration and alarming).
- The control information (necessary to build up the communication between NE and MD).

are stored.

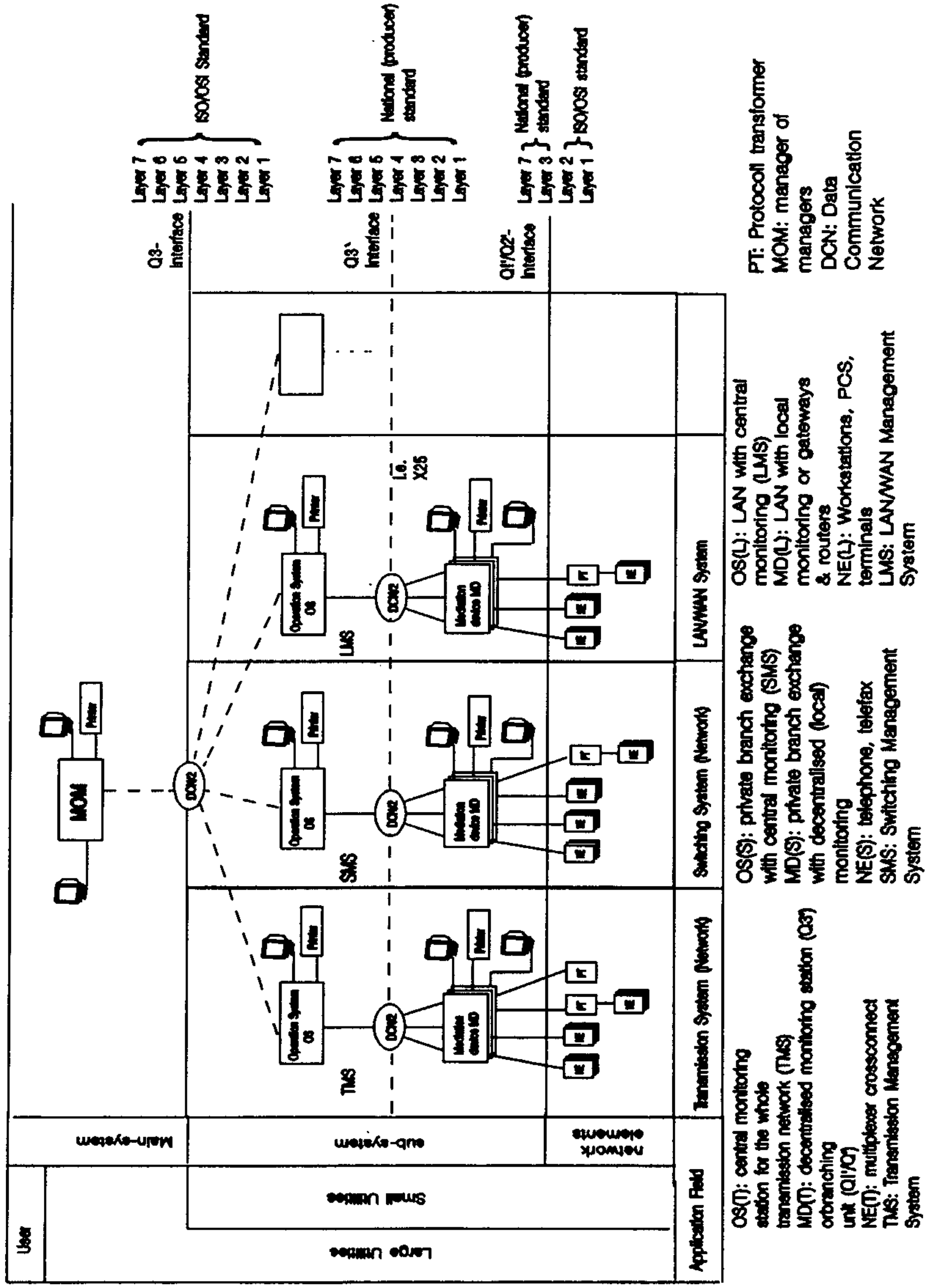

FIG. B1 Typical TMN Structures

APPENDIX C EXAMPLES OF TMN IMPLEMENTATION

Appendix C provides two examples of TMN implementation in power utilities:

C1: This paper gives a description of the characteristics required for a TMN system which will be set up in 7 EdF regions in order to manage the operational X.25 network.

C2: A description of a centralised Network Management Centre operated by Scottish Power.

Appendix C1 The Characteristics of the TMN Controlling EdF's X.25 Operational Network

Foreword An X.25 operational network to carry Telecontrol traffic will be implemented in 1993 by EdF. This will utilise an X.25 network the availability of which will depend directly on the performance and quality of the management and maintenance functions provided by the TMN.

In analyzing this system two types of TMN function may be considered,

- Those that depend on the network's management functions. These functions use hardware and software tools separate from the X.25 switches and are largely set up by centralized operators.
- Those that depend on the network's maintenance functions. These generally use software tools integrated in the switches and are set up by local operators.

These management and maintenance functions are described in the following sections.

Capacities and Limits of the Management Fields

The network is divided into seven regional subnetworks which are organized around the Regional Control Centres.

Each regional subnetwork is managed by its own TMN (the architecture of a subnetwork is shown in Fig. C1), with about 100 switches and 300/400 network elements.

The switches installed in the National Control Centre are managed by one of the seven regional TMN.

In the case of the links connecting two subnetworks, each regional TMN can check the condition of the interface. Management terminals are connected to the TMN through an administrative network separate from the X.25 operational network. This means that access is securely controlled.

Man Machine Interface

There are two kinds of Man Machine Interface (MMI) for the TMN terminals,

- Interface in mode "Menu".
- Interface with direct controls.

The operator chooses the MMI depending on requirements and skill. The menus have been designed in order to minimize the number of selections and to ensure fast operation for the TMN operator.

A help function is available at any time in order to explain to the operator the use of the keyboard and the controls.

Controls may be performed using three methods:

- Immediately.
- Batch (date and time programmed by the operator).
- Periodic.

All terminals have a colour graphic display.

Functions of the TMN

There are four modules provided for network management,

- Initialization of the TMN System.
- Control of the network.
- Management of the network.
- Configuration of the devices (X.25 switches).

Initialization of the TMN

This module has four main functions :

- Configuration of the TMN System.
- Configuration of the Network.
- Configuration of the parameters involved in the network's management.
- Access protection.

Configuration of the TMN System

Two characteristics may be considered:

- Hardware configuration.
- Software configuration.

The connection of the TMN is identical to the connection of the network elements. This means that the TMN System may be established anywhere in the X.25 network.

The Network Manager can change the version of software without modifying the configuration data files.

Configuration of the network

This function allows the operator to describe the topology of the network, that is to say :

- X.25 switches.
- NE connections.
- Internal links between switches which are either analog links (with modems) or digital links.

The function can check the coherence between the data existing in the TMN System and that of the actual network. It is possible to display colour coded network diagrams. The switches and links are displayed with names in clear text, for instance,

- Area Control Centre XYZ.
- Regional Control Centre ABC.

An element can be added or deleted with minimum modifications to other elements in the network.

Configuration of the Parameters involved in the Network Management

This function allows the operator to determine the parameters controlling the functions of network management, for instance :

- Cycle of interrogation of the devices.
- Limits of the alarms on the devices for supervisory functions.
- Definition of parameters measured for statistical functions.

Using this, functions such as supervision and statistical measures may be enabled.

Access Protection

In the case of any connection to the TMN the following parameters are recorded,

- Operator identifier, date, time, connection time, functions used.

Control of the Network

Three main functions are taken into account,

- Monitoring of the network.
- Diagnosis of failures.
- Maintenance management.

Monitoring of the Network

This function is permanently enabled in order to get real time reports on the network. Three facilities are necessary for this function,

- Detection of alarms.
- Detection of statistical - alarm measurements.
- Abnormal situations.

The alarms may be from the switches (couplers, processors, etc.), internal links or NE links. The TMN can filter and analyze alarms coming from the same incident and give the network-manager a report about the location and a description of the incident.

There are two kinds of statistical-alarm measurements :

- Measurements concerned with the quality of realtime operating network.
- Measurements that have to do with the loading of various equipments, these measurements are recorded in order to size the network correctly and are also used directly by the management module.

Measurements of the first kind give for example :

At Frame Level

- The number of circuits cut.
- The number of rejected frames.

At Packet Level

- The number of restart requests.
- The number of clear requests.
- The number of interruptions.

The detection of abnormal situations makes it possible to monitor a network element's condition, for instance,

- NE out of service.
- Looped link for test.
- Calls to unknown network elements.

Any such situation will cause an alarm.

Supervisory information is prioritised and displayed on screen. When abnormal situations occur the operator is alerted by a tone/buzzer and a change of colour of the affected element(s) .

Diagnosis of Failures

The aim is to localize and identify the failures detected by the monitoring function in order to help the maintenance function.

The network manager can test the switches and the modems, e.g.

- Traffic observation, in order to check that the network elements respect the procedure at frame and packet level.
- Measurement of significant events.
- Traffic generation.
- Remote diagnosis of links by looping the modems and generating test procedures.

The network manager can put a switch out of service.

Maintenance Management

This function is provided by a software module which records every intervention on the network in a file with the following parameters,

- Type of intervention (utility operator, supplier, etc.)
- Equipment concerned.
- Time of intervention.

These records will be used to build up a statistical picture of all interventions.

Management of the Network

Allows the network manager to:

- Ensure that the network operates properly.
- Plan for the future development of the network.
- Manage the necessary means.

The operator has at this disposal the following functions

- Availability of the network.
- Routing controls (possibility to draw the virtual circuits).
- Detection of saturation.

In using the information provided and stored by the module "monitoring of the network", the collected measurements are,

For the switches :

- The total number of active network elements.
- The total number of active logical gates.
- The number of calls.
- The CPU load.
- The total traffic.

For the links :

- In service / out of service.
- The number of logical channels engaged.
- The statistics at the frame level.
- The statistics at the packet level.

Configuration of the Devices

Allows the operator to configure the switches (remote configuration) from the TMN, or prepare a configuration which is afterwards remotely loaded.

Maintenance of the Network

In operating the X.25 network, two kinds of operators may be distinguished:

- Network manager who has access to all the functions, including those allowing,

  Configuration of the TMN system.

  Authorization of other operators to connect to the TMN.

- Maintenance operators, who have access only to the supervision and maintenance functions for the X.25 switches (they cannot use the other functions of the TMN).

The limitations of access could be functional (limitation of functions), geographical or temporal.

To locally repair and maintain the X.25 switches, the maintenance operators may use the following functions,

- Initialization of TMN.
- Network management.
- Configuration of equipment.

without having the authority to change any parameters.

- Implement local monitoring functions related to the switch to be repaired. All other functions are not allowed.

The MMI for maintenance function may not be as sophisticated as that used for management functions.

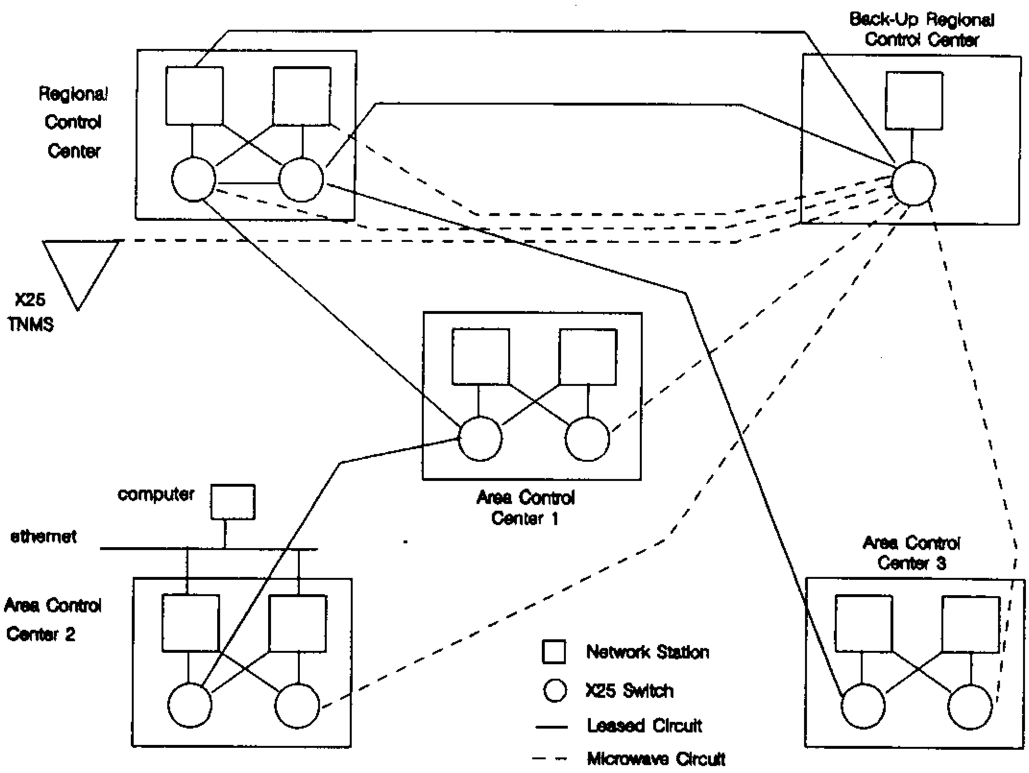

FIG. C1 Regional Substructure

Appendix C2 A U.K. TELECOMMUNICATION MANAGEMENT NETWORK

INTRODUCTION

Scottish Power has been implementing a strategy of integrated telecommunication networks for the past 10 years which in general uses digital technology to support voice and data for all locations within the company.

During the design and planning of the network it was recognised that there was a need for a network management system to co-ordinate the running of the network and to provide the information necessary for efficient and effective operation and for planning the growth of the network.

The concept is based on a centralised network management centre to provide overall co-ordination of the integrated system.

The network management and overview systems have been located in a purpose-built room which has been specifically designed to offer the operators a pleasant environment and guaranteed system availability.

Lighting, air conditioning and sound absorbency characteristics are factors which required careful consideration to minimise operator fatigue.

Power supplied to the network management centre are backed up by a UPS and diesel generator to maintain continuity of supply. This is considered particularly important not just to avoid the loss of service of systems but to prevent disorderly shut-down of computers.

RANGE OF SERVICES PROVIDED

Network Control
Network Configuration
Network Status Alarms
Network Traffic/Analysis
Fault Management

Automatic and time tagging of system fault
Automatic escalation of fault time levels
Automatic fault clearance time/date

Equipment Records
Cable Management
Call Accounting
Network Loss Plan
Directory Services
Manual Input of Other Faults
Fault History

SYSTEMS INSTALLED AND COMMISSIONED

The undernoted systems are initially provided on a stand-alone basis, with displays based on colour graphic terminals.

- Packet Switch Network Management System
- Digital Transmission Network Management System
- Telephone Networks Network Management System
- Telecontrol Network Management System
- Mainframe Access and Cost Management System
- Private Mobile Radio Network Management System
- Other Data Bases Network Management System

OPERATIONAL PROCEDURES

The Network Management Centre is staffed during normal office hours with four Network Operator personnel and a supervisory engineer.

During normal office hours system occurrences and user reported faults are brought to the attention of the Network Management Centre. Outside such hours system occurrences are reported to the National Control Centre and a Telecommunication Engineer is advised accordingly. A Personal Computer (PC) is used by the engineer on call to access the Network Management Centre via telephone call from home to allow the engineer to directly access the systems at the Network Management Centre via dedicated security hardware. The security equipment demands that users attempting to log in to the system provide not only a password but also a Personal Identity Number generated by a small electronic card which changes every minute according to an algorithm unique to that user.

COMMUNICATIONS

The Network Management Centre systems connect to other network management computers by thin ethernet LAN, direct serial connection of X.25 link (Figure C2). The LAN is extended outside the Network Management Centre to allow connection of other terminals used by design and management staff.

THE OVERLAY CONCEPT

An overlay management system for integrating multi vendor network management systems is the preferred solution within ScottishPower. ISO has done a considerable amount of work in communications management and the basic OSI management structure has been adopted in principle thereby ensuring compatibility of standards. The overlay systems will draw together the interfaces of a number of network management systems and integrate them into a single display, thereby creating a standard operator interface and eliminating the number of different physical management terminals in the Network Management Centre.

The advantages derived is that alarm information, gathered from each management sub system can be rationalised to annunciate and display only the important or higher level alarms relevant to a fault condition whilst storing and suppressing lower level alarms generated along with higher level alarms. This prevents the operations from being swamped with alarms of no consequence and enables the fault diagnosis to be carried out effectively.

Colour graphics are used to provide a multi-level view of the network and its status. The operator will select the level to be observed starting with a full overview of the network and move down through the levels displaying greater detail for the operator.

The overview system hardware is based on a multiprocessor computer which is optimised for use as a fast, high capacity file server. Disk and memory have a capacity of 1.6GBytes and 256Mbytes respectively. To enhance system reliability the disks can be configured to provide disk mirroring or other measures which make the system resilient to individual disk failure.

The software operating system is Unix with extensions to allow running of standard MS-DOS applications.

Applications include the following:-

- Emulators for standard and proprietary terminals
- Telecontrol RTU emulation
- Alarm management facilities

- CAD facilities
- Multi-user database

A substantial proportion of the applications software has been specially written or adapted from existing applications by ScottishPower and will be supported by this utility.

The long-term objective for the Overview System is that it will conform to CCITT M-Series recommendations. Current generations of Network Management system are designed to proprietary "standards " and therefore require the interface to the Overview System to be individually tailored.

CONCLUSION

Centralised Network Management has proved essential for the successful and efficient operation of the large diverse networks within the Company.

Considerable advantages are gained by providing individual Management Systems for each network. Firstly software has been developed to meet the specific network requirements, and secondly system down time or software amendments affect only specific network, leaving other systems untouched.

A major disadvantage of a number of individual management system in the Network Management Centre is the different operator machine interfaces. The non standard terminal procedures tend to be confusing for network management personnel and consequently could cause loss of service.

The Man Machine Interface (MMI) difficulties encountered operating the individual management systems will be overcome by the introduction and development of an overview system.

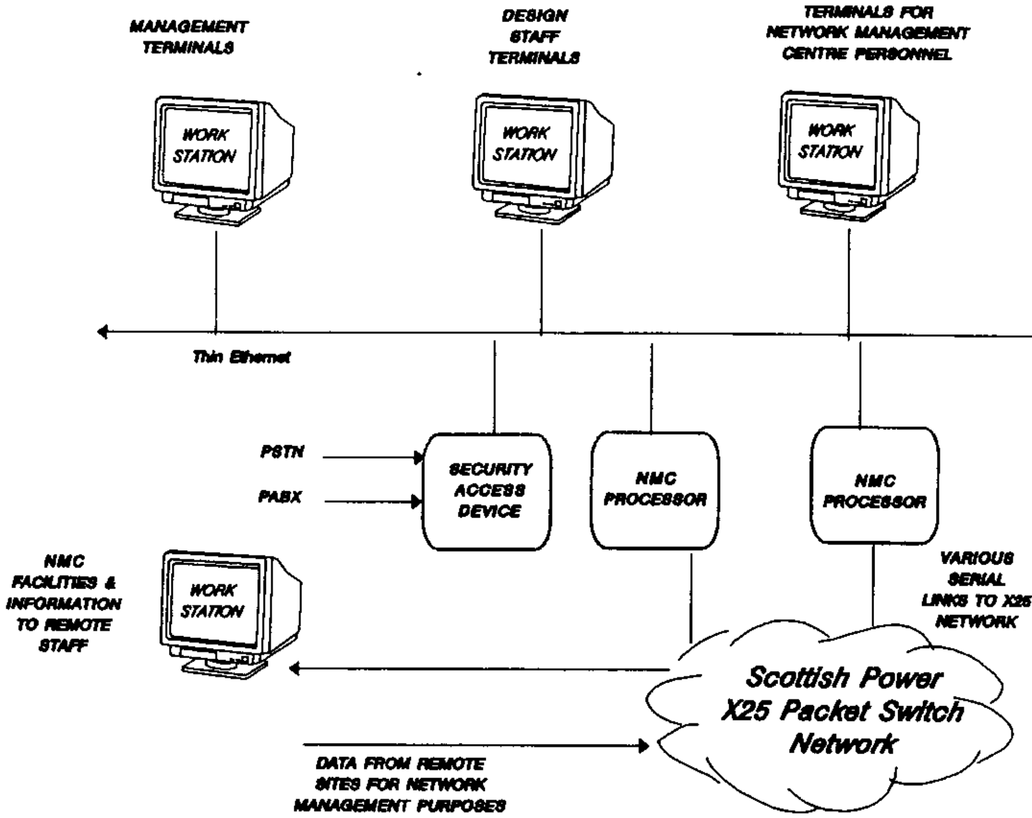

FIG. C2 NETWORK MANAGEMENT SYSTEM

APPENDIX D LIST OF WORKING GROUP MEMBERS

G1 LIST OF WG02 MEMBERS

P. Somervuo	Chairman WG02	Finland *
A.D. Bartlett	Secretary WG02	United Kingdom *
G. Vincent	Chairman SC 35	Australia *
E.K. Salo		Finland *
T. Greene		Ireland *
S.A.V. Andersson		Sweden
E. Andersen		Denmark *
J. Tervo		Finland
J.P. Bourbigot		France *
F. Gonzalo		Spain *
O.H. Nordgard		Norway *
J.P. Pittion		France
J.A.N. Aguiar		Portugal *
K. Morf		Switzerland *
H. Wissen		Sweden *
B. Toet		Netherlands
Y. Loussouarn		France
G. Endlich		Germany *
J. M. de la Pena		Spain
J. Melin		Sweden

G2 CORRESPONDING MEMBERS

R. Koskinen	Chairman SC35 (Past)	Finland
G. Carlton		United Kingdom *
E. Pace		Italy *
A. Pollard		South Africa
T. Saxton		USA
M. Ozaki		Japan

* Contributor to TMN Report

APPENDIX E ABBREVIATIONS

ACSE	Association Control Service Element
AI	Artificial Intelligence
ANSI	American National Standards Institute
ATM	Asynchronous Transfer Mode
CAD	Computer Aided Design
CCITT	Comite Consultatif International Telegraphique et Telephonique (International Telegraph and Telephone Consultative Committee). Replaced by ITU-TS in March 1993.
CEPT	Conference Europeenne des Administrations des Postes et des Telecommunications
CMIP	Common Management Information Protocol
CMIS	Common Management Information Service
CMOT	Common Management Information Services On TCP/IP
COS	Corporation For Open Systems
CSMA/CD	Carrier Sense Multiple Access with Collision Detect
DBMS	Data Base Management System
DCF	Data Communication Functions
DCN	Data Communication Network
DIS	Draft International Standard
DP	Draft Proposal
ECMA	European Computer Manufacturers Association
EMA	Enterprise Management Architecture
EMS	Energy Management System
ETSI	European Telecommunications Standardisation Institute
FCAPS	Faults, Configuration, Accounting, Performance and Security
FDDI	Fibre Distributed Data Interface
FTAM	File Transfer, Access and Management
IAB	Internet Activities Board
IEC	International Electrotechnical Commission
IEEE	Institute of Electronic and Electrical Engineers
IS	Information System
IS	International Standard
ISO	International Organisation for Standardisation
IT	Information Technology
ITU-TS	International Telecommunication Union Telecommunications Standardisation Sector
LAN	Local Area Network
LME	Layer Management Entity
MAN	Metropolitan Area Network
MD	Mediation Device
MF	Mediation Functions
MIB	Management Information Base
MIT	Management Information Tree
MMI	Man/Machine Interface
MOM	Manager Of Managers
MS	Master Station
MTBF	Mean Time Between Failure
MTN	Managed Transmission Network
MTTR	Mean Time To Repair
NE	Network Element
NEF	Network Element Functions
ONP	Open Network Provision
OOD	Object Oriented Design
OS	Operations System
OSF	Open Systems Foundation
OSF	Operation Systems Function
OSI	Open Systems Interconnection
PABX	Private Automatic Branch Exchange
PAX	Private Automatic Exchange
PDH	Plesiochronous Digital Hierarchy
PE	Protocol Entity
PLC	Power Line Carrier

PMR	Private Mobile Radio
PTT	Post, Telephone and Telegraph
QA	Q Adaptor
QAF	Q Adaptor Functions
QOS	Quality Of Service
RFC	Request For Comments
RISC	Reduced Instruction Set Computers
ROSE	Remote Operation Service Element
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SDH	Synchronous Digital Hierarchy
SMAE	Systems Management Application Entity
SMAP	Systems Management Application Process
SMFA	System Management Functional Areas
SMI	Systems Management Interface
SNMP	Simple Network Management Protocol
SQL	Structured Query Language
TCP/IP	Transmission Control Protocol/Internet Protocol
TDM	Time Division Multiplexing
TMN	Telecommunication Management Network
UNMA	Unified Network Management Architecture
UPS	Uninterruptible Power Supply
WAN	Wide Area Network
WD	Working Document
WS	Workstation
WSF	Workstation Functions

Publié par le CIGRÉ
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