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RENEWAL OF EXISTING TELECONTROL SYSTEMS

Working Group 01

of

Study Committee 35

(Communication and Telecontrol)

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1 INTRODUCTION

The utilisation of digital computers in electric power control systems is now widespread around the world. They have been in use since the late 1960's and in most cases the initial hardware and/or software problems were faced satisfactorily.

Despite the success of the initial operating period, several factors intervene over the years to render the control systems obsolescent.

The hardware is certainly one of the main reasons for the telecontrol system (SCADA, EMS) obsolescence; other obsolescence factors can be the higher than expected increase of the controlled network, lower than expected resources or performances of the system, the difficulties in the software maintenance, the modified operating environment, and so on.

From the user point of view the obsolescence can be defined as the situation in which the user requirements can no longer be satisfied or the hardware and software maintenance no longer can be economically justified.

This report is a collection of considerations and comments on telecontrol systems obsolescence. It should be useful in determining when a detailed investigation of obsolescence is needed and how to proceed in that situation. However since the parameters involved in the problem are so varied, it is impossible to define precise and absolute rules. Section 2 of the report deals with the main problems occurring in the telecontrol systems which can be considered as alarm-bells indicating the need for the replacement of the whole telecontrol system, or part of it.

The hardware, software and operation problems of the most significant components of a telecontrol system, that is the control centre, communication network and Remote Terminal Unit (RTU), are taken into account.

Section 3 describes a possible methodology for selecting the best solutions for renewal of the control systems on the basis of existing limitations and future telecontrol system requirements.

Section 4 details a changeover strategy suitable for minimising the total changeover time and the troubles for the operators during the changeover.

2 EXISTING PROBLEMS IN TELECONTROL SYSTEMS

2.1 Hardware

2.1.1 Obsolescence of the control centre and/or RTU

With the fast moving state of the art in hardware design, the hardware manufacturers are forced to produce new products as soon as the development costs of the existing products have been covered. This implies the production of new equipment on average every 4 to 5 years.

The old products are normally maintained by the manufacturers for a further 6 to 8 years.

The life cycle of a control centre equipment is typically 10 to 13 years.

The total time frame is on the other hand consistent with the life cycle of the component themselves (silicon, insulation, plastic, etc.).

Since the hardware to be used in a control centre is established at the telecontrol system design phase, that is at least 2 or 3 years before the telecontrol system becomes operative, there is a high risk of getting into hardware obsolescence before reaching the desired 10 to 12 years of telecontrol system operating life. Strictly related to the hardware obsolescence is normally the continuous increase of the maintenance costs up to unacceptable levels. An economic balance should therefore be established periodically to compare the initial purchasing costs and the maintenance of old and new "equivalent" equipment. The result could be that it is convenient to replace old equipment with new even though manufacturers guarantee maintenance support.

Problems due to the utilisation of old and out of market equipment may also come by user personnel having knowledge shortage or low familiarity with the equipment.

The hardware problems listed above are of course more common for the equipment (normally more complex) installed at the control centre level rather than at the RTU level. The life cycle for RTUs is typically 15 to 20 years.

2.1.2 Inadequacy of the control centre and/or RTU

At the design period of a telecontrol system it is necessary to foresee the controlled power system expansion (e.g. increase of substations or of acquired data) over the life of the system, as well as all the possible new functions to be integrated into the system in future.

Even though the designers dedicate maximum attention to the problem, the risk of an inadequate system design is not negligible.

As far as the hardware is concerned, the design mistakes are normally cured by increasing the equipment but the physical extension of the hardware may sometimes be impossible due to unavailability of the same type of equipment and therefore incompatibility with that originally installed.

In other cases the same type of equipment may be still on the market but unfortunately the system has already reached the maximum equipment expandability.

A periodic check should therefore be performed in order to verify the eventual reaching of the maximum levels. The maximum levels can be defined as the upper limits at which the system is still capable of performing all its required functions with a sufficient margin existing to allow adequate time for an appropriate investigation of alternatives. The maximum levels apply to hardware, software and operating environment.

In the following an attempt is made to define some reference figures for the hardware maximum levels.

1) Main memory

Main memory is normally allocated as either Resident and dedicated for one specific user or as Overlay where several users can share the memory resource. A utilisation of main memory of 85% for Resident and 90% for Overlay areas should be considered the maximum limit.

2) Bulk memory

The maximum utilisation of bulk memory must allow a reserve area equivalent to at least twice the system main memory size.

3) Peripheral I/O channel capacity

The capacity of the computer system I/O channels (serial and parallel) can limit data transfers to peripheral devices. The maximum design limit for the I/O channel utilisation should be 90% of the total capacity in emergency loading condition.

4) RTU

For the RTUs reaching the maximum equipment expandability can in most cases be overcome by installing an additional RTU.

2.1.3 Lower than required performances of the control centre

The real time telecontrol systems for electrical networks require very stringent performances in terms of CPU time, availability and response times.

The user has to define the relevant figures at the requirements definition time with reference to the peak levels of activity occurring during emergency electrical conditions. Particular attention should be paid by the user during the system acceptance tests in order to verify that the required performances are met fully in every respect.

We can however be sure that the software functions, the controlled network and the number of people working on the computer system will grow during the system life so that a periodic check of the performance figures should be performed in order to verify that the actual values are still satisfactory.

In the following an attempt is made to define some reference figures for the maximum performance levels (the definition of the maximum level is given in section 2.1.2).

1) CPU Time

The telecontrol systems are subject to peak levels of activity during power system emergency conditions. To ensure adequate reserves during critical circumstances a CPU utilisation time of 65% during normal operation and 85 - 90% in emergency and peak conditions should be considered as the maximum limit.

A new application function adding more than 5% to the total CPU time should be considered as a major function and re-evaluation of computer system loading should be made.

2) Availability

For redundant systems the availability target figure should be 99.8% or better for the on line operating functions which is equivalent to at most 18 hours of unavailable time per year. For non-redundant systems, the availability target figure should be 99.0% or better for the on line operating functions, which is equivalent to at most 88 hours of unavailable time per year.

Also the frequency of automatic system restarts or automatic failovers or loss of component subsystems which do not directly affect system availability should be monitored and initiate an obsolescence evaluation when they exceed more than 15-20 occurrences per month.

3) Response times

For the operator the most critical response times are:
- the alarm (or change of status) visualisation time, i.e. the time from the alarm entering the computer system to the alarm display on the Visual Display Unit (VDU) screen;
- the VDU display callup time, i.e. the time from the activation by the operator of a request for a specific display until that display is on the VDU screen complete with all associated system information.

The maximum limit to the above response times should be not more than twice the original response times.

2.2 SOFTWARE

2.2.1 Maintenance problems

The software used in the telecontrol systems usually has deficiencies which become quite apparent after some years of the system's useful life when the need for inserting new application functions or larger sets of data occurs.

In the first period of the system life there are no big problems with software maintenance which consists mainly of removing hidden bugs undiscovered during the system acceptance tests. Also the supplier personnel who have written the programs are normally still available.

After a period of time using the system the user wishes to make changes and/or improvements.

At that time the user should have the ability to modify existing programs or to create new ones.

But the user may unfortunately discover that it is impossible to proceed to the software maintenance because during the system commitment and acceptance no particular care has been taken to verify that the following situations do not occur:-

- the programs used for the telecontrol system have been written in a language unique to the relevant computer or to the system supplier and it may not be familiar to or understandable by the user personnel;
- there is shortage of software tools (assembler, compiler, test aids, utility programs, etc.) for developing new programs;
- the operating system used in the computer is unable to handle new input/output channels or new memory necessary for running new programs;
- there is a low quality of program documentation and therefore poor program readability;
- the programs are not constructed and the software modules are closely interlinked; in this case a change in one module can cause unexpected faulty reactions in other modules.

If unfortunately one or more of the above conditions takes place it is practically impossible to maintain the telecontrol system. In this case we can say that the system is close to obsolescence.

2.2.2 <u>Database inadequacy</u>

The size of the controlled electrical network will certainly increase during the control system life.

Normally such increases are taken into account at the system design time, but not infrequently the network changes are more substantial than expected and the database is not sized to accommodate larger sets of data nor can it be expanded to include larger sets of data. It is therefore important at the initial design phase to ensure that the database could be extended readily at a later date.

Other problems can arise as a consequence of a database structure that is not flexible making it very difficult or impossible to define new data tables for new application programs. Sometimes there is a need for the user to understand the database addressing mechanism and its storage, also the user may have to interpret the software that drives the database before it can be used to bring data into a new program.

The electrical network by its nature changes frequently, so that periodically there is the requirement to update the database describing the controlled network. The database updating procedure must therefore be simple and short. This is especially the case for the installation and test phases of the new database in order to reduce to a minimum the changeover time from the old to the new database. During the system design the characteristics of the database and its maintainability are to be considered carefully because they can become an important reason for the telecontrol system obsolescence.

2.3 DATA COMMUNICATION SYSTEM

2.3.1 Limitations of the data transmission network

The data communication system can be divided into two different networks.

Firstly there is the data communication network between the control centre and the RTUs. This network consists mostly of one or two front end processors, single or duplicated transmission links and RTUs. The network can be star-shaped, meshed or a combination of both. One of the limitations of this network can be availability which is lower than expected. The reason for this can be the low availability of the telecommunication links or can be caused by the structure of the network (single front end, single telecommunication link, star-shaped network). Another limitation can be the transmission speed. This can influence the performance of the control centre especially during large disturbances. Also the utilisation of a non meshed network means a low configurability of the data communication network.

The second data communication network is the network between control centres. The lay-out of this network is strongly dependent on the organisation of the power utilities. One can distinguish between a large power utility with a hierarchical telecontrol system based on control centres at different levels and a set of independent utilities each equipped with its own control centre.

The transmission links between control centres are normally duplicated and sometimes triplicated; to obtain a satisfactory availability two links are generally provided with path diversity.

On the data communication network between control centres one main limitation, due to the growing demand for information exchange, can be the speed of the data link. Poor quality of the telecommunication links can give problems especially when operating at high-speed.

The front end processors, the RTUs and the modems are not normally a bottle-neck in expanding the data transmission network. For the RTUs if the number of inputs increases extra RTUs can be installed in the system by putting more RTUs in a loop.

The modems in the connection from the front end processor to the RTUs are either according to a CCITT-specification or dedicated to a system. CCITT-modems are readily available because there is a huge market. For dedicated modems the risk exists that they are not readily available on the market or they are very expensive.

2.3.2 Communication protocol

1) Control centre to RTUs

The communication protocol between the front end computers and the RTUs is generally not standardised. Therefore it can give problems introducing a new type of RTU. The introduction of a new type of RTU may be necessary because the supplier has interrupted the production of the old one or the old one has become too expensive. It can therefore require the installation also of a protocol converter in the front end processor and sometimes full emulation of existing RTUs may be necessary.

2) Control centre to control centre

In control centre to control centre the communication protocol may be non-standard or dedicated to one supplier. The installation of a new control centre or a new computer type in a control centre may therefore be difficult. Modification of the existing protocol may not be easy. Besides the communication protocol may not be well enough protected against communication errors.

2.3.3 RTU functional limitations

In the early generation of computer controlled telecontrol systems the computers in the control centre contained most of the functionality and intelligence. The RTU, however, was a rather simple computer controlled device. This set-up was justified for economical reasons. It is therefore almost impossible to implement new functions in existing RTUs. Some requirements for new functions may be for example the introduction of remote diagnostics, the introduction of more intelligent station functions or the connection of the same RTU to different control centres.

Normally the hardware lay-out of the RTUs is so designed that without wiring modification the I/O capacity can be easily expanded. The database capacity of the RTU is in accordance with the maximum hardware capacity or can easily be expanded. In the case of an RTU which has reached its maximum capacity an additional one has to be installed.

2.4 SYSTEM OPERATION

2.4.1 Changes of the operating requirements

At the time of setting up a telecontrol system, the identification and distribution of the operative functions among the control centres at the different levels is carried out essentially on the basis of the duties and responsibilities assigned to each centre. During the life of the system a new operative environment may occur for different reasons, e.g.:

- a reassignment of the responsibilities to the various hierarchical levels of the system due to changes of the organisational structure of the power utility.
- the installation in the electrical station of equipment providing new function (e.g. oscilloperturbographs, chronological event records);
- the need of activating the data exchange with the control centre of other power utilities;
- the need to increase the number of the operators and therefore of the consoles at the control centres;
- the need to improve the system operativity by introducing VDUs with higher resolution or advanced full graphics features like pan and zoom;
- the need to present to the operators only syntheses information during electrical disturbances thus avoiding in those circumstances the operator being flooded with an avalanche of alarms making it practically impossible to realise quickly the origin and the evolution of the occurred incident;

- the need for transferring data to and from other computer systems such as the corporate data processing department or engineering department computers.

The existing telecontrol system may not be able to handle the above new operative environment due to hardware and/or software deficiencies.

2.4.2 Limitations of the support facilities

An indirect reason for the obsolescence of the control centre may be due to limitation of the support facilities. Examples of these limitations are:
- too high power consumption of the installed equipment;
- insufficient air conditioning capacity;
- achievement of the Uninterruptible Power Supply (UPS) maximum capacity;
- low reliability of the UPS with frequent shut down of the computer system;
- low protection against electromagnetic interferences;
- insufficient room for the increase of existing hardware;
- need for separate rooms to provide fire security;
- need for greater physical security of the control centre.

None of the above problems may be considered as a cause of the telecontrol system obsolescence, since it is normally possible to operate directly on the involved service (UPS, air conditioning, electromagnetic protection) and eliminate the occurred limitation. Only if there are limitation in the hardware and/or software and/or data communication and/or system operation (see previous paragraphs), the occurrence of problems for the support facilities may represent and additional reason for diagnosing the obsolescence of the telecontrol system.

3 METHODOLOGY FOR SELECTING THE SOLUTION

3.1 Introduction

Renewing an existing telecontrol system must deal with two main subjects: the design of the new system and the migration from the existing system to the new one.

Firstly that means every item for the design of a complete system has to be carried out and secondly each normal development phase of this new telecontrol system has to be considered from the changeover point of view: requirements definition, identification and selection of the solution brings different advantages:
- all the advantages of the new system;
- the possibility of integrating part of the old system and then carrying out a progressive implementation of the new one;
- all the benefits of past experience, which allow the avoidance of previous difficulties.

However, some drawbacks also have to be emphasised:
- no interruption of the operational service is allowed;
- the renewal of the existing system is very often the occasion for the users to demand many new (and difficult) requirements;
- the changeover phase requires the development of specific interfaces (hardware and/or software);
- the changeover phase entails more work for the support and maintenance staff;
- on the financial point of view, the existing system is not always totally redeemed so that it is often difficult to justify the best technical solution for the new one.

3.2 Requirements definition

3.2.1 General methodology

The requirements definition is the first and perhaps the most important phase for the renewal of a system. An error at this step may have serious operational schedule and financial consequences. The requirements definition has to answer two main questions:

. what are the functional needs at the present time, and in the short and long term?

. what are the reasons for renewing the existing system?

Consequently the method for the requirements definition combines two analyses: future needs investigation and examination of the existing system limitations.

Normally the needs investigation is in the user's field but users very often express their demands in terms of solution and refer to the existing system, so that the designer has to deal with both preoccupations. Therefore the best way is to begin with the examination of the existing limitations which gives a good understanding for the continuation.

This general method of investigation, which goes from the designer's point of view to the user's one, is necessarily recursive and the final comparison introduces an important parameter, the time, as shown in figure 1.

The diagram is of course theoretic, but it shows the difficulty in choosing the optimal implementation time T and function level L for the new system.

The optimal function level L will depend on the ability of the telecontrol system to accept new functions and to follow the development of the electrical network.

The optimal implementation time T depends on the limits of the existing system; the function limit time t1 which depends on the enhancing ability of the existing system and the technical change time t2 (t2 is the complex result of different criteria, such as technical obsolescence, maintenance cost and difficulty and system availability); t2 may be shorter than t1 but when the opposite occurs (see fig.1), the renewal of the system becomes a financial anticipation and has to deal with this problem, as mentioned in the introduction.

A telecontrol system is complex and distributed, each part of which has specific problems, so that all that has been said for the whole system is true for the RTUs, for the different control centres and for the communications network itself. Before beginning the requirements definition it is very important to identify what parts of the system are permitted to be modified or not.

Finally, in addition to the first two main questions, the requirements definition has to answer two other questions:

- what parts of the existing system have to be renewed?

- at what time the new system has to be available?

3.2.2 Existing telecontrol system limitations

Section 2 deals with the description of every kind of problems that may be found in telecontrol systems, and it is not the aim of this paragraph to describe them.

Fortunately an existing system does not always have to face each problem but it is essential to identify, as soon as possible, the future possible difficulties and to classify them.

Such a good classification may follow the same functional structure as the system itself and for instance be scheduled like this:
- data processing subsystem (real time systems within the control centres)
- data transmission subsystem
- management subsystem (database generation, communication network administration centre, failures and faults real time supervision, installation testing, follow-up function).

For each subsystem, potential problems have to be classified according to the following manner:
- . operational limitation
- . functional shortage
- . user dissatisfaction
- . unsatisfactory availability
- . maintenance difficulty and cost,

with special mention of the basis of limitation: hardware and/or software.

The type of solution to each problem depends on many factors, especially on the flexibility of the existing system. For example, many operational problems may be solved by adding new memory, often sufficient to handle increases of the electrical network. The decision to renew a part or the whole of a telecontrol system is mostly a conflict between different partial limitations and their costs. In this case, it is generally possible to forecast the renewal and to make it more progressive, provided that one does not delay too long.

Another reason for the renewal may be the impossibility to deal with one limitation. For example, as mentioned in Section 2, even when it is possible to add new memory, the increase of the electrical network becomes an obstacle when the computer system reaches the maximum database size. In this case, a different solution is required.

As has been said, the careful examination of the existing limitations gives the means to establish priorities for the renewal and prepares the function requirement investigation, due to a good understanding of the different problems.

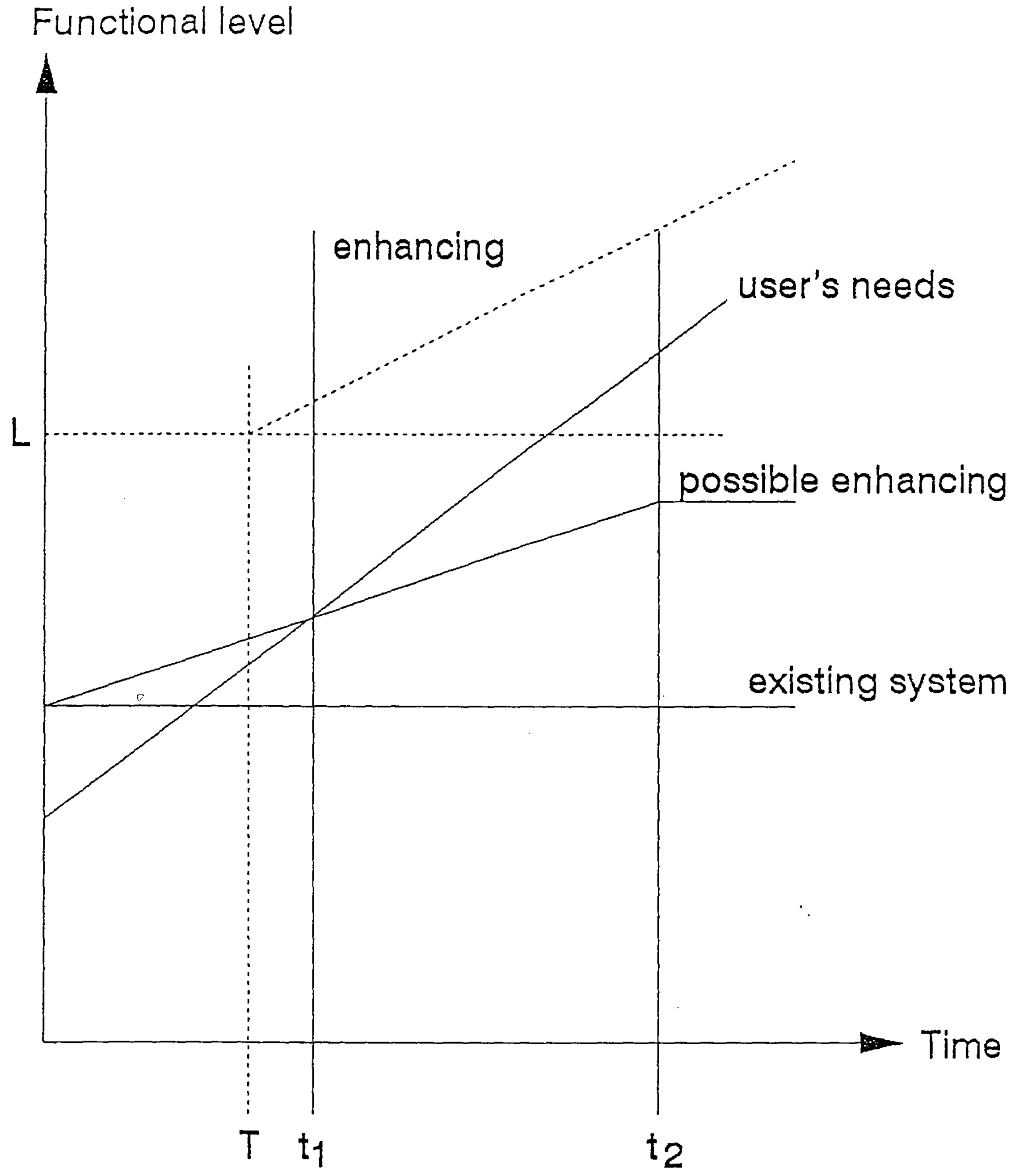


Figure 1

L = optimal functional level for the new system
T = optimal implementation time for the new system
t_1 = functional limit time
t_2 = technical change time

3.2.3 Actual and future requirements

It is fundamental to distinguish two separate levels for the requirements definition, according to:

- the characteristics of the electrical network and the way to control it (operation definition)
- the design of the telecontrol system and of its different subsystems (telecontrol system definition).

Operation definition

The aim of this report is not to explain how to deal with the operation definition but it is not reasonable to begin the design of a telecontrol system without a clear knowledge of the whole operational structure for which it is made. That means for the short term as well as the long term:

- the size and the development plan of the electrical network to be controlled
- The different levels of the operational structure and the general function each level is in charge of: network monitoring and/or remote control (may be different according to the voltage), load-frequency and voltage regulation, etc...
- the general characteristics of each function:
  . human operation or automatism,
  . required availability and take-over possibilities,
  . required information and their characteristics (digital or analog, cyclic or not, synchronised or not, etc...)

Everything in this definition depends directly on the characteristics of the electrical network. It is clear that the size of the network influences the dimension parameters of the telecontrol system and a good plan allows the correct requirement. However it is important to notice that some complex power system problems, such as the network stability, may have heavy and unforeseeable consequences on the telecontrol system. For example it may be decided after a major incident to centralise in a control centre different local automatisms. Only a great flexibility of the telecontrol system allows such a new demand being incorporated in a short time.

Telecontrol system definition

As has been said, the telecontrol system definition directly depends on the operation definition and its final objectives are the detailed requirements of each identified subsystem:
- data processing subsystem
- data transmission subsystem
- management subsystem.

First, the requirements definition of the control centres real time system will give with more detail the different characteristics for each function and the consequences for the final definition of the RTUs and the other subsystems.

At this time in the definition, it is important to be sure of the functional requirements and different methods are available: comparison with the limits of the existing system, computerised simulation (mainly for the automatic models), interview with the users (mainly for man-machine interface), etc... These validations are still theoretic and will have to be confirmed after the following phases of design and development especially before the final selection of the solution.

Accordingly for the data communication network the following requirements have to be described:

- different type and formats of information to be transmitted,
- for each site the amount of information of every type which may have to be sent or received,
- the rules for data routing and distribution,
- the transmission times (and cycle time for cyclic information), with accepted tolerances,
- the requirement or not of synchronisation,
- the relative priority of the different types of information.

These requirements are direct consequences of the requirements of the data processing subsystem itself and may have been validated by the same computerised simulation.

Finally it is fundamental not to forget what was called before the management subsystem on the quality of which depends the global quality of the whole telecontrol system. This particular subsystem has to be considered as a complete system with its own users and operational structure. These are the people who are in charge of the real time supervision of the telecontrol system, of its maintenance, data generation and follow-up. Similar questions as for the telecontrol system have to be answered: required functions, location of these functions and data having to be exchanged between the different locations.

There is of course a close connection between the telecontrol system and its management subsystem. A major question is to decide what part of the management subsystem has to be supported by the telecontrol system itself and what part has to be completely independent. For example, with regard to the down-loading function, is it allowed to exchange the data files through the operational data network or not? Such an alternative has a large influence on the final requirements. It is the same with the ability to use the services of an existing public data communication network or not.

The combined examination of the existing system limitation and of the actual and future functional requirements will make possible the definition of a general renewal plan with indication of each part to renew, the required date to renew it and the corresponding functional requirements.

The renewal plan may involve only the control centres or, more generally, also the RTUs and the data transmission network. The next paragraph deals with possible solutions for upgrading or replacing an existing telecontrol system with particular reference to the control centres.

3.3 Identification of possible solutions

3.3.1 Control centres

There are many different options for replacing or upgrading a control centre that can no longer serve the needs of the Operations Division. Serious consideration should be given to the possibility of an upgrade as it may be more economical than the complete replacement. It is essential, however, to compare the long-term costs and benefits of all the options considered and not just the short-term gains.

Some of the options are:

1 Add additional VDUs and/or peripherals.
2 Change VDUs and/or peripherals for higher capacity systems.
3 Add additional equipment for RTU communications.
4 Change equipment for RTU communications for higher capacity systems.
5 Add additional equipment for computer to computer communications.
6 Change equipment for computer to computer communications for higher capacity systems.
7 Add additional front end processors.
8 Change front end processors for new higher capacity front end processors.
9 Add new main computers.

10 Change main computers for higher capacity main computers with the same operating system as the old.
11 Change main computers for higher capacity main computers with different operating system,
12 Use combinations of the above.
13 Replace all the control centre elements, placing the new equipment in a new building.
14 Replace all the control centre elements, placing the new equipment in a new building.

Simplified diagrams showing typical configurations and possible upgrade paths are shown in Figures 2 to 7. The upgrade paths are in dotted lines. For simplicity peripheral devices, redundant paths and failover paths are not shown.

The choices available are dependent somewhat on:

1 The configuration of the present system.
2 The computer vendor support.
3 The possibility of the existing computer being replaced by a new and/or faster one using an operating system that is compatible with the old one.
4 The possibility of the addition of a new element or the change of a few elements to a relatively new system will allow the control centre to meet the new requirements.
5 The ability of the computers to operate in a network and in a failover configuration control system.
6 The possibility to reuse a significant amount of software. In virtually every case, when a computer can be replaced by a faster one with an identical operating system, it will turn out to give the shortest schedule and be the most economical. This is shown in Figures 2 and 4 to 7.

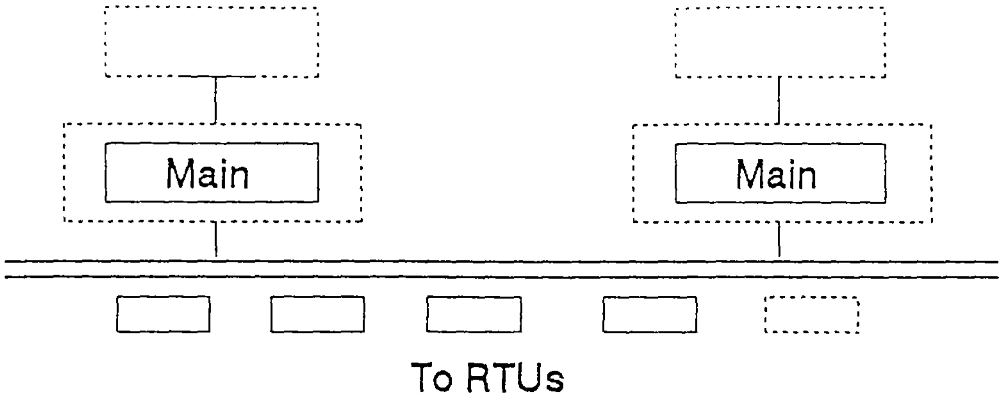


Figure 2

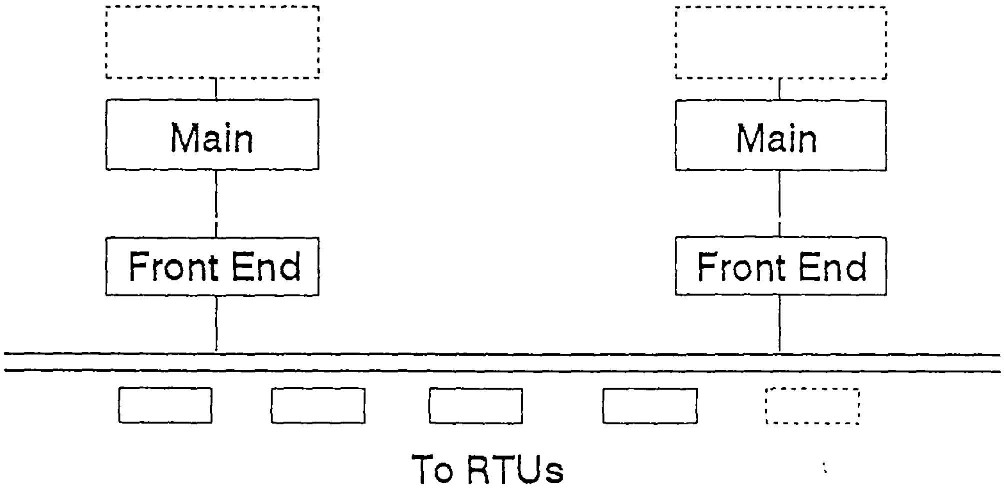


Figure 3

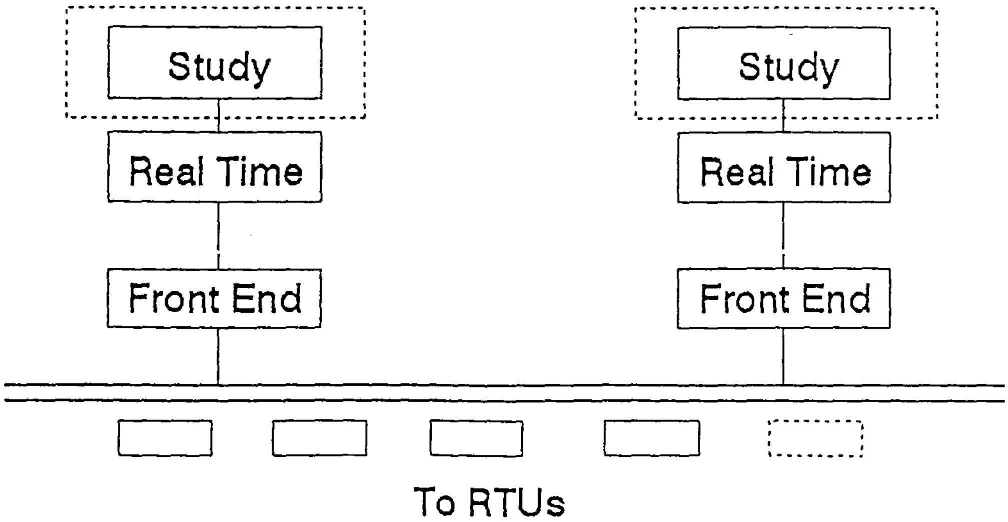
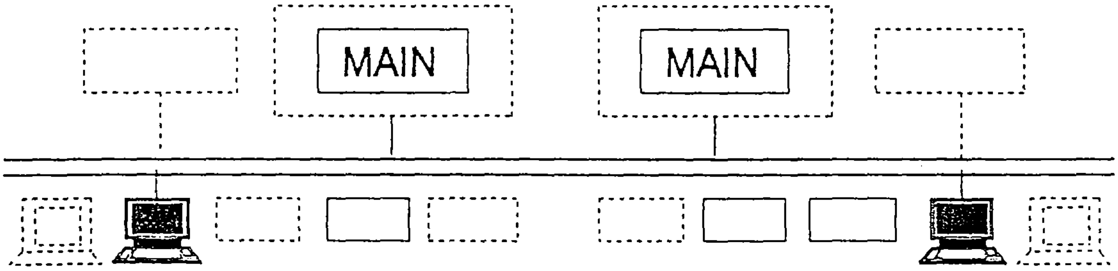
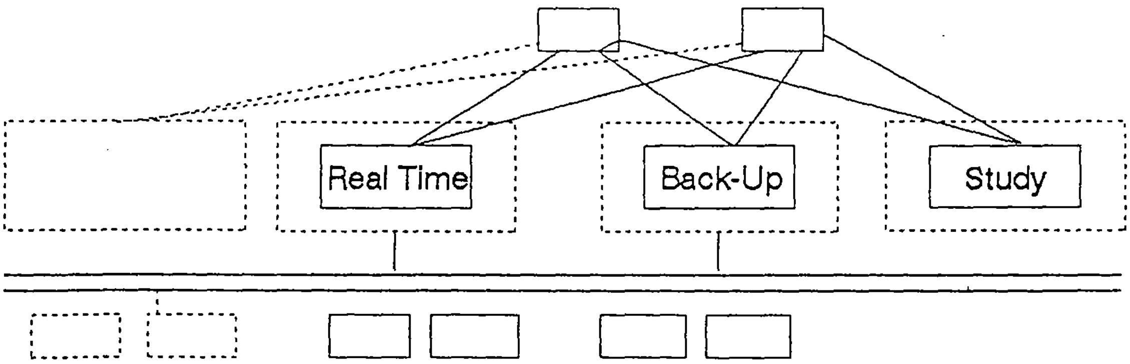


Figure 4



To RTUs
Figure 5



To RTUs
Figure 6

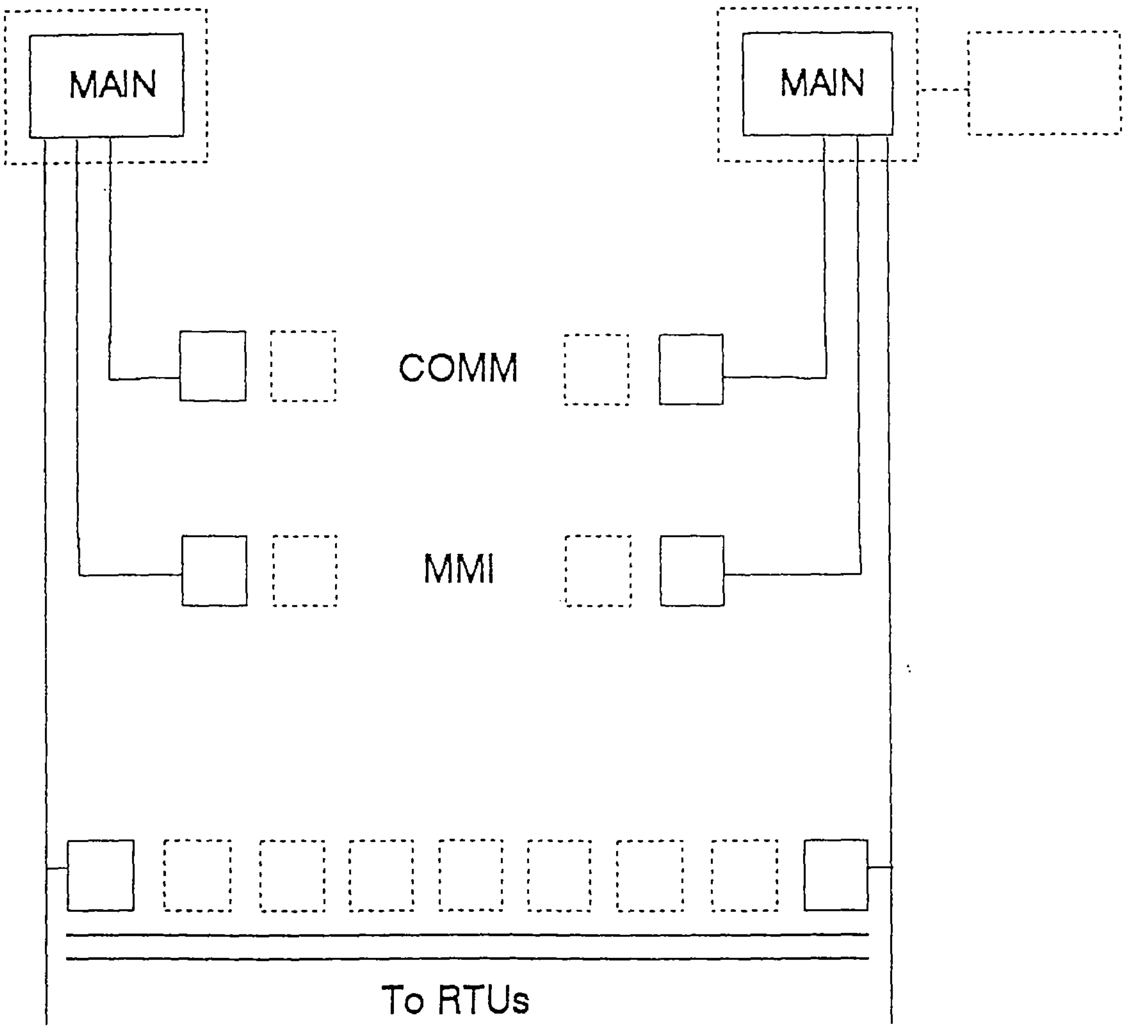


Figure 7

In some cases, very large Energy Management Systems (EMS) have been successfully upgraded in one weekend to provide increased computer power for advanced network and security applications.

In other cases, as shown in Figures 2 and 3, it may be possible to make a dual configuration into a quad or a quad into a six unit system to increase the computational power of the system. This is accomplished easiest if the computers are all of the same manufacturer and the same type. It is also possible to have new computational power by adding computers of different manufacturers or operating system by connecting them together at the communication interface level. Usually with this latter method functions are separated by computer type. For example this could mean all real time in one system and study programs in another or all real time and network function in one system and scheduling function in another. The advantage of this system is that it can significantly prolong the life of a relatively new system that is now too small. The disadvantage is that there may be a need to set up and maintain two databases and perhaps two Man-Machine Interface (MMI) systems.

Faster computers, additional computers or additional microprocessors can be added on a Local Area Network or channel basis as in Figures 5 to 7. This can be a fairly simple and cost effective upgrade if the computers are of the same manufacturer and the same operating system or if the interfaces to the Local Area Network are standard. It may be more complicated if the configuration control functions need to be changed or the interfaces are dedicated.

The cost of replacing an entire control centre with all hardware and software can be very high. Since hardware generally represents a low percentage of the cost of a control centre (typically 30%), significant money can be saved and operational risk can be avoided if the software can be reused. Important savings can be made and risks avoided even if new hardware is required because of the need to move to a new location.

Substantial savings can be realized if one of the upgrade methods discussed above can be used and found to meet the operational needs of the utility.

An upgrade path allows the telecontrol system to meet continually the emerging operating needs of a utility. The smoother the upgrade path, the less disturbance there is to operations when the upgrade must be made. The time to plan for the upgrade of a telecontrol system is before it is even ordered.

3.2.3 RTUs

There are several different options for upgrading or replacing the RTUs when the existing RTUs are not able to meet the increased requirements for the telecontrol system.

Some of the options are:

1. Install additional RTUs in the controlled stations.
2. Change existing RTUs for higher capacity RTUs.
3. Install new RTUs in large stations and reinstall the existing RTUs in smaller and/or less critical stations.
4. Combine separate station functions, like:
   - the telemeasurement and telesignals acquisition;
   - the local control;
   - the protection intervention;
   - the chronological event recording;
   - the oscilloperturbograph;
   - the automatic sequences;
   - the data transmission to one or more control centre;

   into one integrated RTU system;

   If a new RTU is necessary the following requirements are to be considered carefully:
   - high precision and stability in the data acquisition;
   - processing capacity of the acquired data;
   - standard interfaces with the data transmission network;
   - standard communication protocol with the control centres;
   - expandability in the amount and type of the acquired data.

3.3.3 Data transmission network

Some options for upgrading and replacing the data transmission network of the telecontrol system can be identified, like:
1. Increase the speed of the links.
2. Add new transmission links in parallel to the existing ones.
3. Change the existing links for ones with higher availability, reliability and capability.
4. Adopt a different data transmission architecture based for example on a packet switching network having an automatic routing of the data through the switching nodes and an automatic recovery of failed trunks.
5. Use a more efficient protocol.
6. Adopt a standard protocol.

4 CHANGEOVER PHASE

4.1 Objectives

The operation of a power system should be affected as little as possible by the replacement of the existing telecontrol system with a new one. The changeover is often under estimated and the relevant problems are realised by most users when the installation of the new system is in progress.

It depends on the extent of the replacement or method used but the transition phase can require from a few weeks to some years.

Electric companies now rely heavily on the telecontrol systems to manage the electrical network efficiently and safely, so that any disturbance to the system operation, even though the above disturbance is directed to supply the operators with a more effective and powerful telecontrol system, is considered normally with trouble and intolerance.

It is therefore essential to define in advance and very carefully the strategy to follow for facing the changeover phase in the best way.

The main objectives to pursue during the changeover phase are:

- to keep the existing system operational during transition;
- to minimise the total changeover time;
- to minimise the troubles for the operators.

The attainment or not of the above objectives depends strongly on several factors such as:-

- the new equipment will be installed at a new location with new support facilities (e.g. air conditioning, power supply) or integrated in the existing control centre building;
- the data transmission subsystem will be new or the existing one and therefore there will be a time where some of the data presently scanned may not be available to the operator or may only be scanned by one of the systems;
- the man-machine procedures (e.g. types of displays, operative sequences, characteristics of the alarms) will be unchanged with the new system or the operators will have to learn and get accustomed to a different operational environment;
- the new functions will interfere with the old ones or not.

4.2 Commissioning Strategy and Implementation Plan

A commissioning strategy should be developed to guide the implementation plan. The strategy should identify all the main activities and stages of the changeover. The best sequence for these activities should be addressed.

In addition the strategy should identify all of the people involved in the changeover eg. maintenance personnel, operators, system engineers, etc., their roles and their needs, including training. The strategy should also define the allowable impact the implementation plan may have on existing operation eg. minimum performance standards, time of day or week when degradations are best managed, which functions are the most critical and, if any, which functions require a temporary set up of emergency facilities. A monitoring plan should be established which will allow periodic verification of progress and conformity with the objectives of the changeover.

The detailed implementation plan will naturally vary depending on the configuration of the system, its data acquisition network and the extent to which the replacement is to be performed.

During the changeover it is also essential to verify periodically and incrementally if the new or updated system demonstrates its ability to perform the required new functionality and achieves the required reliability and availability.

In the next paragraph some changeover procedures are described.

4.3 Changeover Procedures

4.3.1 In case of system upgrades almost certainly there is a dependence on the equipment supplier for expertise and specialised knowledge of proprietary equipment and systems. Plans for system upgrades should therefore be drawn up in conjunction with the system supplier.

The simplest upgrade procedure is to replace an existing computer with a faster one with the same operating system. Usually, the computer is placed in the back-up mode, the existing software is loaded, tested and the on-line computer is put in the back-up mode causing the new computer to assume the on-line functions. The original on-line computer is maintained in the back-up mode so it can be brought back to the on-line position should there be a problem with the new computer. Typically, the procedure is done on a weekend and then if the new computer is stable, the remaining original computer is changed out the following weekend.

If the upgrade path is to make a dual system into a quad, a quad into a six computer system or one of a different manufacturer or operating system, the changeover is a little more complex. It should still be made on a step-by-step procedure, retaining a known working half as back-up to the new system as mentioned above. Systems should be thoroughly checked out before being placed in the on-line mode.

If additional microprocessors for RTUs, MMI and data communications can be added to upgrade the system, it is important to test the system in the off-line mode, then transfer to the on-line mode, but always save the software for the original configuration so the system can be returned to the original configuration should the new ssytem not operate properly.

New disk drives, tape drives, printers and other peripherals can be added in the same manner.

4.3.2 Replacement

The new telecontrol system should be installed, tested and operated in parallel with the existing telecontrol system.

The new system can be checked out first in the factory with the Factory Acceptance Test (FAT), set up in the new control centre and then retested to verify the FAT once the system is in the field.

If there are new RTUs, these can be installed, connected to the new system and tested and remain with the new system to help test the real time system, the MMI, the database and the network models. This is shown in Figure 8.

Typically most of the existing RTUs will need to be reconnected to the new system but must remain in service on the old system until the new system is in service. These existing RTUs must be tested to confirm that they operate with the new system. The RTUs can be cutover one at a time or one circuit at a time to verify the new system and its database. Once verified, they can be cut back to the old system to keep it operating while another set of RTUs are transferred to the new system for verification.

Once all of the new and existing RTUs and other equipment to be reused from the old ssytem have been tested in the new system, verified and all other system modules are checked out, the changeover to the new telecontrol system can be made.

Both centres can be staffed and equipment and communication channels moved from the old system to the new but retaining the option to return to the old, where possible, should the need arise. Once operational stability has been reached, the old centre can be deactivated and communication channels premanently connected to the new centre and disconnected from the old.

If the new control centre equipment is to be placed in the existing control centre building it is helpful to be able to have a separate location for the new equipment so the systems can be operated in parallel with the least possible disturbance to either system. When this is the case it is sometimes necessary to reuse existing equipment such as the mimic board, strip chart recorders and other local equipment.

The changeover in this case is much the same as described above for a new centre in a new building. It is complicated somewhat by the need to test existing equipment with the new system and yet keep it working with the old system until cutover time. It can be managed by testing this equipment in much the same manner as when existing RTUs are to be used with the new system.

Some manufacturers make RTUs that can communicate with two or more master stations asynchronously and on different protocols. If some of the substations will have their existing RTUs replaced with new RTUs and connected back to the old telecontrol with the protocol of the old telecontrol system, then when the new telecontrol system arrives for field testing the new RTU can be connected to the new telecontrol system, in addition to the old, and with either the old or new protocol. It can now be addressed by either telecontrol system, asynchronously, and can respond to the needs for testing the new system, its database, MMI and network models as well as responding to the ongoing operational needs of the old system. This is shown in Figure 8 by having both lines shown as solid and permanently connected to both systems.

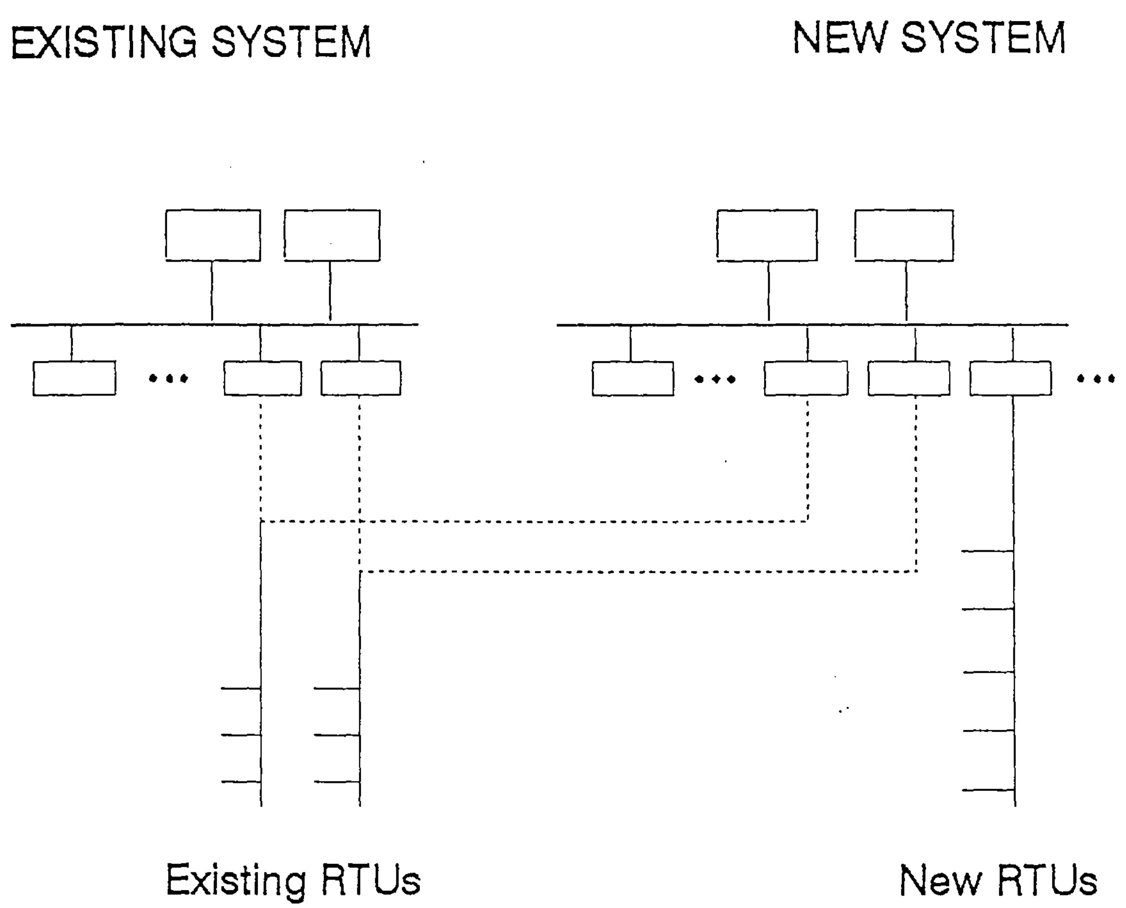


Figure 8 Changeover

5 CONCLUSION

The need for upgrading or replacing a real time telecontrol system is caused by systems that no longer meet the functional needs of the operating division. This is usually due to maintenance and performance problems related to the fact that the system is technically and commercially out-of-date.

Therefore it is very important that the renewal of a telecontrol system takes into account the requirements of flexibility, expandability and maintainability.

A telecontrol system may be divided into three subsystems:

1 RTUs (stations).
2 Data transmission network.
3 Control centres.

The key to the flexibility of a telecontrol system lies in defining industry standard interfaces among the subsystem so that each subsystem can be managed without big conditioning from other subsystems.

The data exchange among the users of the telecontrol system should occur on the basis of industry standard formats and protocols, independent from the physical structure of the data transmission network.

The transmission network should have a general architecture providing data links not only between RTUs and control centres but also between control centres or between RTUs located in different stations. On this assumption for example the transfer, the removal or the addition of a control centre should not create particular problems but it should just cause a software reconfiguration of the involved components.

For the control centres the main problem is the right identification of the hardware and software environment to adopt also taking into account the management subsystem. The selection of non industry standards technologies and tools may lead to maintenance and upgrading problems in a few years.

It is therefore fundamental to select a family of computers with a large market, a proven reliability and of strategic importance for the manufacturer's development plans.

As far as the software is concerned a standard operating system, standardised interfaces for the database, application software, man-machine and communication subsystem should be adopted; that will greatly reduce the upgrading problems for the future.

In addition to the hardware and software environment identification, the main design aspect of the control centre is the architecture, which must guarantee high reliability and availability. Considerations should be given to architectures such as computer cluster, local area network or other distributed processing architectures. The adoption of the above criteria will greatly reduce the upgrading problems of the telecontrol systems in the future.

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