MMI, SCADA AND ALARM PHILOSOPHY FOR DISTURBED STATE OPERATING CONDITIONS IN AN ELECTRICAL UTILITY

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A project report submitted to the Faculty of Engineering, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Science in Engineering.

Johannesburg 1995

Declaration

I declare that this report is my own, unaided work.

It is being submitted, in fulfilment of the requirements for the Degree of Master of Science in Engineering at the University of the Witwatersrand, Johannesburg.

It has not been submitted before for any degree or examination at any other University.

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5th day of July 1995

Abstract

Advances in digital computing technology make it possible to improve the design of the Man Machine Interface (MMI), SCADA and ALARM modules used in electrical utility control centres, to overcome the problem of control staff data overloading. A possible solution is proposed, based on an explicit representation of a disturbed power system state in addition to quiescent conditions.

The structure of modern SCADA installations is analysed in terms of the computing power of full graphic workstations, the quantities of element data delivered to the control room and the capabilities of intelligent remote terminal units. This analysis indicates that existing designs for the presentation of SCADA data need to change to solve the data overloading problem.

The proposed philosophy moves the focus of attention from the element level up to the device level by grouping and dividing all elements into categories at the RTU and linking them to their parent device. Control staff are notified graphically on the one-line displays, next to the device in question, of the existence of abnormal elements by category. The element state details for the device are only displayed on demand, resulting in a 95% reduction of alarm text messages.

Suggestions are made as to the software functions needed at the RTU and the workstation to assist with the display of system data. Lastly recommendations are offered to reduce maintenance by standardising and pre-ordering device element data.

Acknowledgements

I would like to thank the members of ESKOM's National Control for their help and support in preparing this document, in particular Mr. Len Harvey, Mr. Robert Gubbins, Mr. Emile Venter, the National Control Manager, Mr. Charles Geldard, the System Operations Manager, Mr. Juan La Grange for permission to publish this document. I would like to express my appreciation to Anthony Blake and Wally Webb for their time and suggestions while proof reading this document.

I would also like to thank Professor Ian M. MacLeod who acted as supervisor, for his assistance and enthusiasm in preparing this report.

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1. INTRODUCTION

1.1 Overview

This chapter introduces the problem of data and alarm message overloading experienced by staff in electrical utility control centres and examines the factors that make it a serious problem that requires an immediate solution. It also provides a pictorial map of the entire project report.

1.2 Problem Background

The Supervisory Control and Data Acquisition systems (SCADA) used to monitor Electrical Power Networks are designed to provide the control staff with up to date information on the current state of the power network as rapidly as possible. This is to ensure that problems detected in the power network are corrected as fast as possible to prevent further degradation of the power supply to consumers.

Currently, control staff are notified of network problems via text messages, generally referred to as alarms or alarm messages, sent to them by the "alarm system" software.

1.3 Alarm Messages

Alarm messages indicate that a power system element has changed state or has crossed a limit boundary. They are generated by the Host computer following the detection of the change by the SCADA system. The text for the alarm message is inherent in the definition of the element in the Host data base. Non-intelligent Remote Terminal Units (RTUs) are responsible for the collection and delivery of the current element states following a request for data from the host. Therefore the RTU is ultimately responsible for the generation of the alarm messages.

Each message seen by the control staff is actually very primitive. The current design of SCADA and ALARM software applications only allows for messages that refer to a single element at the RTU.

An alarm message is normally made up of 6 basic fields as can be seen in Table 1 e.g.

1. Time at which the event occurred
2. Priority of the message from 1 to 6 with 1 high
3. Station initiating the alarm
4. Name of the device or element to which the message belongs
5. Element ID in alarm if the device has more than one element
6. Alarm state, Low, High, Normal or Alarm. For analogue alarms the message also includes the value and limit boundary crossed.

1	2	3	4	5	6			
15:23:29	*5	MERSEY	1/275B	KV	280	278	LOW
15:31:23	*6	AVON	STANG1_GROUP1				ALARM
15:31:25	*6	UMFOLOZI	NORRX1_GROUP1				NORMAL
15:31:31	*5	MERSEY	CORPR1	MVA	71		NORMAL

Table 1 Typical format of alarm messages

1.4 SCADA and MMI Design

A quiescent system is one in which the alarm rate, is roughly, less than 10 alarm messages per minute. These alarm messages, each of which has to be read, understood, acknowledged and then deleted, are routinely handled by the control staff.

Little or no effective provision is made for dealing with excessive alarm data, nor with its presentation during a power system disturbance. It is during disturbances that the control staff suffer from data overloading in its extreme form.

1.5 Data Overloading Definition

Data overloading is a situation that occurs when the number of alarm messages arriving at operator workstations exceeds the ability of the control staff to use, process or react to them.

During a disturbance, the control staff tend to ignore most of the alarm messages, since 99% of these messages represent the effect of a primary cause and not a definition of the problem. Appendix 1 cont`s a sample listing from a disturbance on the ESKOM network. By observation it can be seen that the primary event was a fault at the Tutuka power station at 15h23:27, the cause was unknown. The effects of the fault are the subsequent 430 odd alarms as seen by the control staff, who have to determine the cause of the problem from the multiplicity of the effects.

Associated with the sudden surge of alarm data, is a corresponding demand for explanations as to what has gone wrong, both from staff and management. To add to the confusion, some messages flash and have audible tones associated with them.

Between 25 to 30 alarm messages can be viewed at any one time, usually chronologically with the newest message at the top. Control staff page or scroll through the listing using a mouse or key strokes to review the messages. When a new message is added to the top of the list, the display is re-output starting at the top. This makes it almost impossible to read each message or do anything until the messages actually stop arriving. An alternative is to pause the screen output or generate a hard copy of the messages in the window. During a disturbance this can be difficult to do or dangerous as the control staff need to see what else is going wrong.

The structure and format of the messages are designed for a quiescent power system state and not for a disturbance conditions. This can be seen by examining Appendix 1, each of the messages refers to a single fact or state change. Many messages refer to similar things at the same substation at the same time, such as the frequency indications from Lethabo power station. No provision is made to compensate for conditions that are already known by the control staff , nor things that will always take place under given conditions such as the voltage of a unit dropping to zero if the generator breaker is opened. In general the design of the alarm messages, their structure and content is based on each device reporting its own state changes with no regard to what is happening around it. There is no method yet, of combining messages at the source to reduce the number of messages sent to the control staff. The post disturbance evaluation techniques are manual, laborious and it is very difficult to determine what actually happened without accurate time stamped data.

All messages have to be acknowledged individually or by page before they can be deleted. Audible alarms have to be acknowledged each time they are triggered. Added to this, is the pressure to perform and make the correct decision as fast as possible so as to arrest further degradation of the electrical network.

Currently, the only concession made for disturbance conditions is the size of alarm message buffers. These buffers are usually big enough to handle the maximum number of potential alarm messages expected during a disturbance peric

1.6 Control Staff Disturbance Activity.

Initial activity focuses on establishing the extent of the disturbance and the potential knock-on effects. Control staff monitor the system disturbance behaviour initially from alarm messages and secondly by watching the system frequency meter, which graphically and digitally indicates that the system is suffering from a disturbance.

Once control staff have a mental picture of the power system following a disturbance, the generation of additional alarm messages is highly annoying. Control staff know they have a problem and the repetition of existing messages is unnecessary.

Control staff have two major issues to deal with during a disturbance;
a) Understanding the nature of the disturbance and its potential consequences
b) Correcting the problem as fast as possible.

Their priorities are :
- Find out how secure the remainder of the network is and carry out any necessary switching.
- Determine the generation needed to restore the frequency to its normal state.
- Find out how it will take to repair the fault and restore the supply to normal.
- Request the powers stations to increase or decrease generation if necessary.
- Request regions to shed load if necessary.

In effect the job of the control staff resembles the assembly of a jigsaw puzzle from an overabundance of pieces, not all of which are relevant to the puzzle at hand, but include some pieces that belong to a different puzzle that must be assembled and understood simultaneously.

The speed with which the puzzle is put together determines the speed of solution. In this analogy the jigsaw pieces have to be extracted from the alarm message texts and the displays.

In the process of solving the problem, large quantities of alarm text and display data have to be processed and discarded in order to understand the basic problem and then correct the fault. During serious disturbances, additional help is often required from field staff to obtain confirmation of the assumptions made from the reported effects.

It should be remembered that the format and structure of an alarm message is based on a quiescent power system state not a disturbed one, and as such only simple state change messages are ever allowed for. There has been no acknowledgement of the need, for the control staff to have a different alarm message format or structure, to cater for a disturbed power system state.

1.7 Importance Of The Research

The consequence of a disturbance is usually the loss of supply to consumers, by reducing the time required to restore supply, the utility reduces the loss of income, prestige and decreases the irritation to its customers.

By providing the control staff with the ability to rapidly obtain a clear picture of the fault and its effects, the power system can be restored sooner. The savings to the utility are extremely valuable and can be measured in millions of Rand.

On page 18 of the Dec. 1994 EPRI journal [18] the comment is made "...researchers at the University of Washington concluded that the problem in power system applications is no longer computation time - it is comprehension time."

1.8 Solution Options

A pre-requisite for the solution to the problem of control staff data overloading, is the realisation that the existing data presentation and delivery philosophy are no longer adequate for the control of large electric power systems. This is particularly relevant in the light of the additional data demands on the SCADA system, from both inside and outside the control room.

There appear to be two possible solution options:
- The use of expert systems to process alarm messages sent to the control staff and to produce diagnostic messages to explain the network behaviour.

- The introduction of a new Man Machine Interface and data acquisition philosophy making use of Full graphic workstations.

The use of Expert Systems has been tried on a number of occasions but does not seem to be widely accepted or implemented, [see 9, 10, 12, 15]. Expert systems running in parallel to the existing alarm system, provide control staff with a list of potential explanations or possible diagnostics of the problem, but not the exact cause. The control staff still have to wade through the incoming mass of messages in order to validate the ES output [9]. Expert systems are also very expensive to build and maintain particularly for a dynamic system such as an Electrical Utility.

Fundamentally the solution to the data overload problem lies in understanding and changing the way alarm information is acquired, delivered and presented to the control staff. It is important to recognise the needs of the control staff under different operating conditions and to support their requirements by using a full graphics man machine interface to the fullest extent before expert systems are installed.

Expert systems have a large part to play in the monitoring and control of power systems, but their integration has to be reconsidered in terms of available input data, computer power and communications facilities, as well as the value of potential output that can be provided.

1.9 Solution Objective

The objective of the solution proposed in this report, is to reduce the time it takes the control staff to understand a problem on the power system and increase speed of fault correction without forcing the control staff to process unnecessary and unwanted data, or delaying the delivery of crucial data.

1.10 Pictorial map of the project report

Figure 1-1 illustrates the different stages involved in the development of the new alarm philosophy to improve visualisation of the power system state by control staff where each block represents one or more sections in the project report.

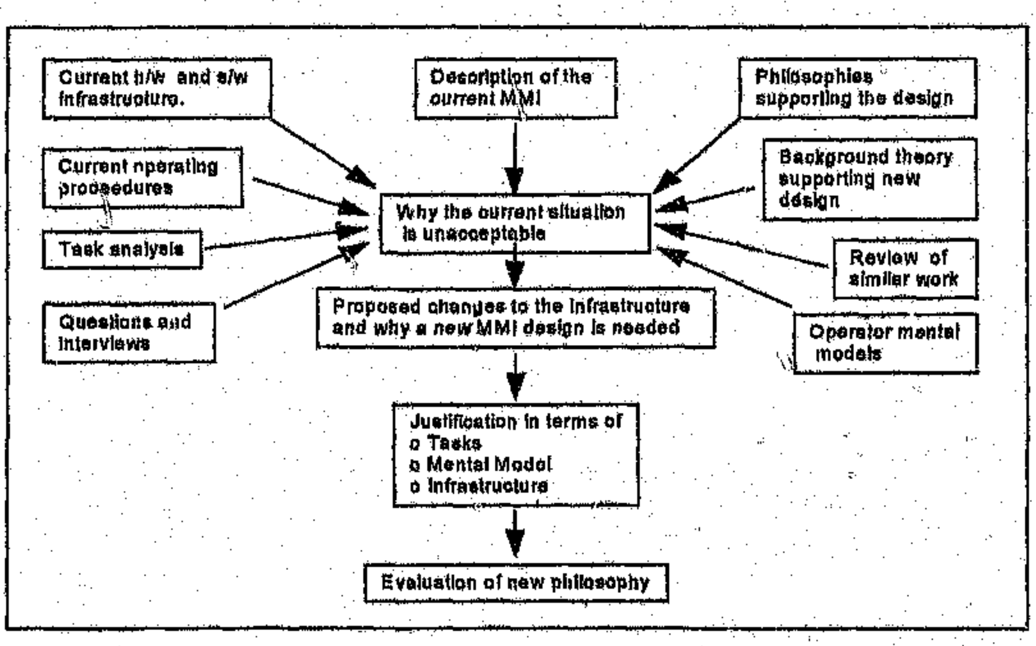

Figure 1-1 Pictorial map of the project report

1.11 Overview of the project report

Chapter 1 is an introduction to the problem of data overloading.

Chapter 2 discusses the background and reviews all the factors affecting the data overloading problem.

Chapter 3 covers the task analysis and control staff requirements used to design the new MMI.

Chapter 4 is an analysis of the associated literature relating to data overloading and existing solutions.

Chapter 5 analyses the existing data processing philosophy and control room activity, in order to identify the problems and needs of ESKOM's National Control staff.

Chapter 6 proposes a possible solution to the data overload problem and defines the basic requirements needed to implement it. The three areas are a) Host data base structure, b) Man Machine Interface and c) Remote Terminal changes.

Chapter 7 explains how the changes defined in chapter 6 can be implemented in the Man Machine Interface and how the control staff use the new MMI facilities.

Chapter 8 discusses how the "secretary mode" functions referred to in chapter 6 are used to control displayed data and the how the ERTU supplements conventional telemetered data.

Chapter 9 examines the ongoing changes taking place in SCADA systems and the consequences if nothing is done to change the existing methods of displaying large quantities of telemetered data.

Chapter 10 is the concluding chapter and evaluates the proposed solution in terms of the initial problem definition. The costs of implementing the proposed solution are examined along with an implementation plan. This chapter also includes a critical review of the project report.

There are seven appendices:

1 Examples of an ESKOM disturbance log.
2 A copy of the 1994 ESKOM Telecontrol Standard used to wire up Remote Terminal Units.
3 Task analysis of ESKOM's National Control Staff.
4 Man Machine Interface functionality comments and requirements.
5 Phase 3 protection element data for a Static Voltage Compensator
6 Glossary.
7 References.

1.12 Summary

This chapter defined data over loading and reviewed the actions of control staff during a disturbance in the power system. Of the two possible options examined, the Expert System one was rejected since it was unable to solve the basic problem of data overloading. Lastly there is a pictorial map of project report.

2. BACKGROUND

2.1 Introduction

This section discusses the relevant stages that make up the path taken by the raw data as it travels from the plant in a substation to its final output on the displays in the control room.

Figure 1-1 shows the major stages making up the data path from the monitored plant to the control room. The substation RTU sends the data via microwave radio to the control centre where the front end hardware combines all the radio signals stores them in the host data base. The MMI software uses the plant data to update the displays used by the control staff at the workstations to monitor the plant state, within two seconds of the elements being scanned by the RTU.

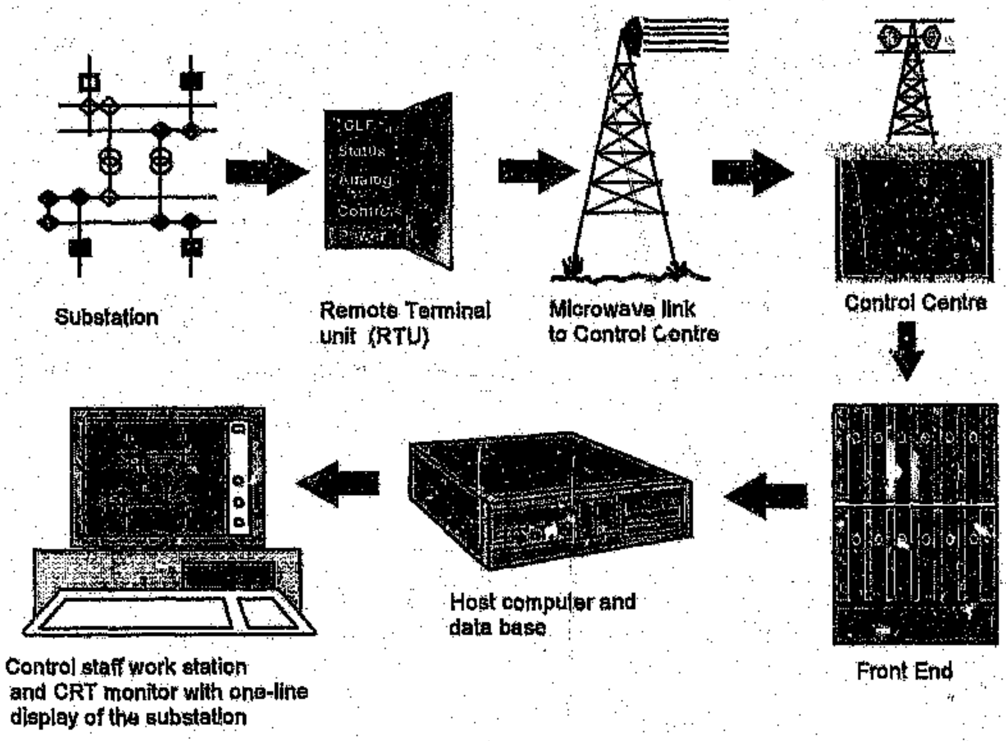

Figure 2-1 Pictorial view of the data path from the RTU to the control room

2.2 Telemetered Data

The transfer of information between the RTU and the control staff involves a number of transformations.

Initially the data is no more than signals in the substation. In the process of telemetering or moving data to the control centre and ultimately presenting it to the control staff, the following changes take place:

1. Basic signals are supplied to the RTU from the substation switching yard.
2. These signals in the RTU are telemetered to the Control Centre were they are stored in the Host data base.
3. The Host converts the data into information by adding text and presenting the information to the control staff either as an alarm message or as changes on the displays.

4. As the control staff interpret the messages or the changes on the displays the information becomes knowledge of the current power system state.

It is this knowledge that is used to understand the behaviour of the power system and to control it. Understanding the exact nature of the different stages in the data path and matching the mental images the control staff have of the power system, with the plant data, will reduce the time needed to make decisions as to how to correct problems in the power system.

2.3 Plant structure

In general terms, the electrical equipment at a substation is referred to by different names depending upon the level of detail under discussion. These different levels as indicated in Figure 2-2 have definite divisions, and fit neatly into a pyramid structure as follows:

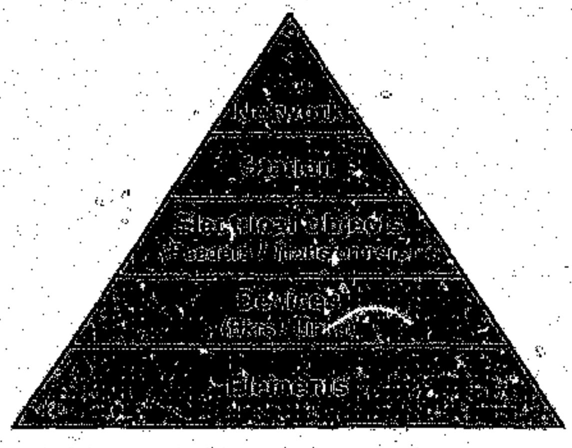

Figure 2-2 Electrical network structure

- At the lowest level are the individual data **elements** such as single or double bit status points, analogs, controllable points, tap positions, etc.
- When the elements are grouped together they form **devices** such as breakers and links.
- When the devices are grouped together they form **electrical objects** such as feeders, busbars, reactors, capacitors and transformers, etc.
- Grouping objects together creates the **substation** or power station.
- Grouping the substations together forms the electrical **network.**

2.4 Mental Models

Discussions with the control and the distribution staff involved with the physical plant at the substations and power stations revealed that they support and use the pyramid structure shown in Figure 2-2. They confirm that it is a correct interpretation of the concept model used in discussions of power system problems among themselves.

Observing the working behaviour of the control staff, they constantly traverse the different levels of the pyramid. The structure of the alarm messages match the lower four levels of the pyramid. However the electrical object name is not implicitly defined but can be determined from the device name. For example, in the alarm message below, the station is HYDRA, the electrical object is TR_2 or transformer 2, the device is the 400KV MAL_2 or the number 2 motor operated link on the 400kV busbar and the element state indicates that it is now closed.

```
15:24:31 HYDRA        TR_2_400_MAL2                CLOSE
```

Once the device and element details are sorted out, in this case the link has been closed, the focus then moves upwards again to object level, i.e. the transformer, where the next decision is made. This can be verified by listing to the communications between the distribution field staff and the control staff. The focus of attention is initially directed to a given problem area by referring to the network and station, followed by the electrical object under review followed by the device and elements with the problem.

It should be remembered that only the element data at the lowest level of the pyramid is physically connected or wired into the Remote Terminal Units.

The rest of the data in the other levels in Figure 2-2 is purely abstract and is assembled manually, based on the element states from the element level.

2.5 Remote Terminal Unit (RTU)

The RTU has two primary functions:

1. Receives scan requests and supervisory commands from the host
2. Transmits the requested scanned element data back to the host

Normally, each element in the station has its own unique location in the RTU. However, due to hardware and communication restrictions, not all the element states can be connected individually to the RTU. The restrictions force a large number of elements to be gathered into separate groups. If one element in a group is abnormal, then the whole group is considered to be abnormal. Control staff have to call out distribution staff to visit the site and determine which one of the elements caused the group to be abnormal which increases the time it takes before the problem can be solved.

The first generation of RTUs installed at the substations and power stations were used purely to forward the plant data values to the host computer system. These older RTUs are considered primitive in comparison with the current generation. New RTUs are being delivered with enhanced facilities and are called Enhanced RTUs, or simply ERTUs.

2.6 Enhanced Remote Terminal Unit

In practice the ERTU is a centralised, stand alone data capture unit that can act independently of any host computer system. It has its own onboard computer and data base which allows it to act as host device to a number of smaller RTUs or bay processors which are in turn connected directly to the plant.

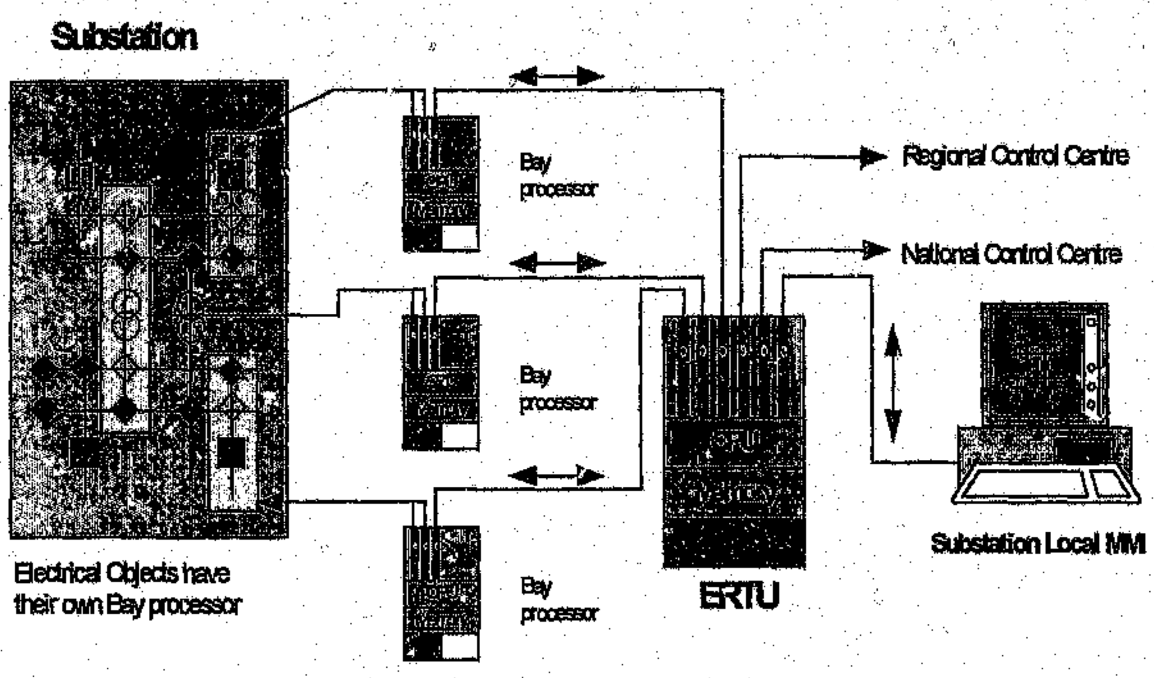

Figure 2-3 Substation and ERTU interfacing structure

An ERTU is designed not only to act as the interface between the control staff and the plant but also to provide general interfacing facilities to the plant as a whole and the substation control room, as indicated in Figure 2-3. The need to have multiple host users connecting their own wiring to the plant is replaced by a single I/O point to the entire substation via the ERTU.

The users of the ERTU are:

- Local substation control room MMI computer
- Local bay RTUs or PLCs controlling a single feeder or transformer panel
- Additional host SCADA systems supporting regional control centres
- National control SCADA system
- Local maintenance activity to the bay processors or ERTU data base and software facilities.

The design of the new ERTUs provides major advantages over the older CONITEL RTUs, e.g.

- Ability to access a far larger number of element data points at the substation.
- Provide millisecond resolution sequence of event logging on all status points.
- Perform software functions on multiple inputs.
- Communicate with multiple hosts and slave RTUs.
- Provide pre-processing of data prior to sending the results to the host.
- Removal of grouped data points.

Since the ERTU facilities cannot be supported by the existing CONITEL protocol used by the older RTUs, a new protocol called ESTEL has been developed to support the ERTU functions.

2.7 ESTEL Protocol

Since 1988, ESKOM has been developing its own standard communications protocol called ESTEL [19]. This pr[illegible] is based on the Open Systems Interconnect Refere[illegible] Model (OSI-RM). ESKOM [illegible]loped ESTEL to avoid being locked into proprietary vendor communication hardware and software.

ESTEL is designed to solve many of the problems encountered with the various vendor-specific communications protocols. ESTEL was also developed to meet ESKOM's future protocol needs for the huge variety of data demanded by the various host computers and to be compatible with international telecommunication standards.

2.8 Host Computer System

The existing computer system consists of up-to-date modern VAX hardware connected via DECnet using two Ethernet backbones as indicated in Figure 2-4.

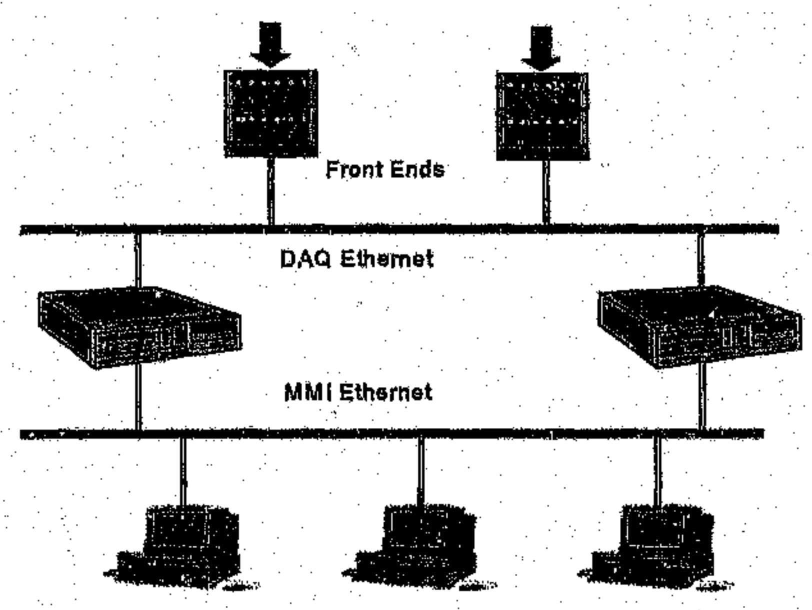

Figure 2-4 Host hardware configuration

Two separate Ethernet circuits are used to reduce the risk of single-point-failure. As indicated, each Ethernet backbone is used for different purposes.

The primary data acquisition software modules, i.e. SCADA, Alarm and the Man Machine Interface software are all relatively old and are based on a 1986 release of the original vendors product. They have since been modified to communicate with the ERTUs using the ESTEL protocol. The SCADA system was initially customised to communicate with the existing Leeds and Northrop RTUs using CONITEL protocol developed by L&N and commissioned for ESKOM in 1976.

2.9 Data Base

As indicated in Figure 2-4, the host computers receive the telemetered data from the RTUs and store it in internal data bases. The data is then extracted by the MMI software when required and displayed graphically on workstation video display units for use by the control staff.

The existing host data base structures are well developed and have reliable support software to meet the needs of the older RTUs. With the installation of the ERTUs and the ESTEL protocol, far more data elements can be accessed and telemetered to the host data base. Grouped element points can now be ungrouped and alarmed individually.

The ungrouping of the approximately 20 different sets of group elements, has prompted the SCADA staff to list all the expanded data elements required from each electrical device in a document called the Telecontrol Standard.

2.10 Telecontrol Standard

The wiring standard lists all the input status and measurement elements required from each device scanned by an ERTU Appendix 2 is a copy of the Telecontrol Standard. ESKOM is planning to install ERTUs at all its interconnected substations during the next five years.

Implementing the new Telecontrol Standard at all substations will cause the total number of elements processed by the SCADA system to increase by a daunting 250%. The details of this growth are covered in Chapter 9.

As there has not been any changes in the host data processing philosophy, these additional data points will be treated in the same manner as the current methods of data storage and display. The MMI and host data base are not currently able to use the additional facilities offered by the ERTUs and no consideration has yet been given as to how the control staff or the MMI will handle the additional data and display load.

2.11 Man Machine Interface

The existing Man Machine Interface uses DEC Workstations to run a software emulation of the CONLOG character graphics hardware. The original CONLOG display units allowed one display per screen, with multiple screens combined to form an operating console. The DEC Workstations have been configured to have four different display windows visible on one screen at the same time.

Each display window uses eight colours, 64 pre-defined graphic symbols and 64 QWERTY characters defined for CONLOG displays. Each display window is a fixed 80 x 64 character area. There are usually two workstation screens per console as indicated in Figure 2-5.

Each console has a mouse and dedicated keyboard to interact with the display hardware and call up displays in any one of the of the windows.

Display response time is usually within 2 seconds except in the case of alarm data, which can take up to 20 seconds from the time of request to display depending upon the up the number of alarms in the buffer and the I/O load on the CPU.

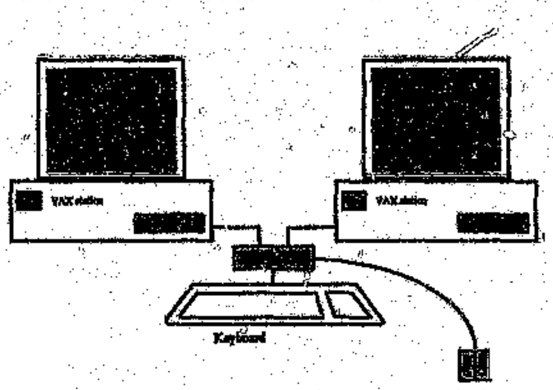

Figure 2-5 MMI hardware configuration

A new Full graphics display facility is available that can run side by side with character graphics the on the same Workstations, but as the full graphics software is still in the development stage, there are a large number of desired functions not yet available which prevent its on-line implementation.

Based on the needs of the control staff during a disturbance and the ease of use of the character graphics, there are serious reservations as to the ability of the Full graphics package (in its current form), to provide additional value over and above the character graphics package.

As the Full graphics package is designed to work directly with the host data base and not with the ERTUs there has to be a serious evaluation of its ability to replace the Character graphics package.

2.12 Summary

This chapter reviewed the physical components of the SCADA system, the network structure and the mental models used by the control staff to monitor the power system. Details of the new RTUs and the communication protocol were discussed along with the Telecontrol standard and the physical design of the MMI.

3. MMI RESEARCH REVIEW

3.1 Overview

This chapter reviews an investigation undertaken to determine the practical Man Machine Interface problems experienced by control staff while carrying out their daily tasks. The objective of the investigation was to establish a composite MMI view of the control room environment in terms of the tasks carried out by the control staff as a whole and then to examine the external factors influencing the behaviour of the control staff.

The research covers the following aspects :
1. Control room task analysis
2. Control staff interviews
3. Regional Control requirements
4. National Control manager's needs
5. SCADA vendors comments
6. Remote Terminal Unit changes
7. Data communication changes
8. Telecontrol standard

Each of the 8 items investigated are listed under headings 3.1.1 to 3.1.8 below.

3.1.1 Control Room Task Analysis

The investigation started off with a task analysis of each of the four working positions in the control room, i.e. :
1. Shift Supervisor or Head of Shift
2. Generation control
3. Network voltage control
4. Transmission or network stability control

Figure 3-1 shows the arrangement of the desks in the control room. Staff are seated in an arc facing the dynamic mapboard or mimic. There are 5 shifts working in rotation, between 8 and 12 hours a day depending upon the day in the week.

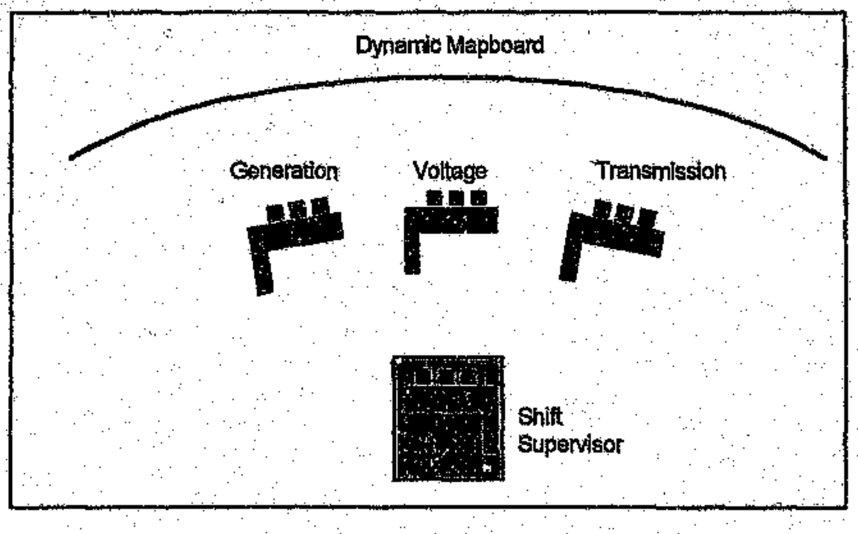

Figure 3-1 Arrangement of consoles in National Control

The task analysis was aimed at determining the basic problems experienced by the members of National Control while engaged in carrying out their daily tasks using the existing Character Graphic MMI facilities.

The details of the task analysis are documented in Appendix 3. The results of the analysis were used to guide the interviews described in section 3.1.2.

3.1.2 Control Staff Requirements

Each of the shifts at National Control were interviewed with discussions based on the task analysis described in Appendix 3. Each of their MMI actions was listed, discussed and analysed with respect to the existing Man Machine Interface both for quiescent behaviour and disturbance conditions. The questions used for the discussions are listed in Table 2.

What are the major frustrations with the MMI in general
What additional data is needed on the display
Navigation problems experienced
Is mapboard information sufficient or is additional data needed
Methods of calling up displays and associated problems
Primary displays used most often and why
Most difficult task to carry out due to data availability and MMI problems
Examples of well designed MMI
Functionality needed to make the MMI easier to use
Problems associated with alarm processing in general
Quiescent alarm processing problems
Disturbed state alarm processing problems
Symbolised alarm data compared to the text form
Advanced data processing needs at the RTU and the workstation
Potential of 3D graphics as a useful tool
Problems involving operating errors and ideas to reduce them
Use of vector or Kiviat diagrams [6]
Use of Venn diagrams to indicate protection information
Need for additional protection data and display methods
Use of sequence of event data
Need for hypermedia and hypertext facilities
Grouped alarm data details on demand
To what extent are false alarms a problem
Are there a large number of incorrect values on the display

Table 2 MMI Question topics

The responses to the questions are discussed and tabulated in Appendix 4.

The results of the interviews provided overall comments and highlighted many problems experienced by the national control staff and provided the opportunity to test a number of alternative methods and philosophies for the presentation of SCADA data using Full graphic workstations, especially during disturbances.

3.1.3 Regional Control Consideration

The data overload problem was discussed with the control staff from the five regional control centres in ESKOM during a series of meeting to establish a standard MMI philosophy for building displays using full graphic software. The regional control staff confirmed the need for a method of reducing data overload conditions experienced by the distribution and reticulation control centres. They emphasised that they required a few additional facilities over and above the basic design specified in chapters 6, 7 & 8. In general they supported the proposed philosophy and wanted to be involved in its development.

3.1.4 National Control Manager

The National Control manager was interviewed in order to determine his needs, both for current and future changes in the power system. The discussions revealed problem areas and possible solution directions. He highlighted the fact that ESKOM is expanding both locally and internationally. The expansion activities are going to add an additional work load to the National Control Staff in the near future. He supported the need to examine alternative methods to display disturbance data to the control staff.

3.1.5 SCADA Vendor Comments

Discussions were also held with the staff of European and American vendors (Westinghouse and Siemens) who are delivering Energy Management Systems in South Africa and to a number of overseas countries.

The objective was to establish whether there have been any change on either the Vendors' side or by their development staff with respect to new ideas for alarm processing and data visualisation philosophy. Both vendor representatives indicated that they had not really thought about the problem and did not have short term plans to change their existing display and data delivery facilities.

3.1.6 Enhanced Remote Terminal Units

The ERTU hardware structure and software facilities were investigated to see what functionality was available and to ensure that the needs of the control staff could be met. Interviews were conducted with ESKOM design teams that specified the ERTU functionality [19]. They indicated that the initial design of the ERTU was based on the premise that local RTU processing could and would be supported, however, at the time, they did not know what shape it would take. The design team completely supported the "secretary mode" functions suggested in chapters 7 & 8.

3.1.7 ESTEL Protocol

The philosophy and behaviour of the new protocol were investigated to see what facilities were available and what the restrictions were. [20]. The protocol design teams recognised that some changes would be needed to implement the new philosophy and supported the ideas in chapters 6, 7 & 8 in principle.

3.1.8 Telecontrol Standard

The element data requirements specified for each device in the standard were studied to determine if there were any logical groupings that the elements could be divided into. Discussions were held with the individual shift managers to obtain their feelings and needs in respect of the data in the new standard in terms of quiescent and disturbed network conditions.

Section 7 of the standard (see Appendix 2) is structured by equipment type , i.e.

1. Generators
2. Feeders
3. Bus coupler and section / transformer breakers
4. Transformers
5. Shunt Reactors
6. Shunt Capacitors
7. Series Capacitors
8. Static Voltage Compensators
9. Station Level
10. Physical Security
11. Integrated Values

From an examination of the element data per device and discussions with the shift managers and the National Control Manager, the element data for each device, can be divided into three broad categories called Health, Protection and Information.

For example, the elements belonging to Transformer Breakers (see pages 9 and 10 of Appendix 2) have be divided into the three categories as shown in Table 3.

Health	Protection	Information
Air Pressure Urgent	Pole Discrepancy	Breaker state (open/closed)
Air Pressure-Non urgent	Bus zone	Breaker Charged
Main 1 DC fail	Bus strip	Breaker control - local/remote
Main 2 DC fail	M1 protection trip	Supervisory Control - On/Off
Control DC fail	M1 HV instantaneous over current	Main 1 protection on/off
Close DC fail	M1 HV backup over current	Main 2 protection on/off
Spring rewind fail	M1 HV earth fault operated	
Isolator DC fail	M1 MV instantaneous over current	
AC/DC Converter fail	M1 MV backup over current	
	M1 MV Earth fault operated	
	M1 Tertiary instantaneous over current	
	M1 Tertiary IDMT over current	
	M2 protection trip	
	M2 HV instantaneous over current	
	M2 HV backup over current	
	M2 HV Earth fault operated	
	M2 MV instantaneous over current	
	M2 MV backup over current	
	M2 MV Earth fault operated	
	M2 Tertiary instantaneous over current	
	M2 Tertiary IDMT over current	

Table 3 Transformer breaker elements divided by category

After further discussions with the National Control manager and protection [illegible] was decided to subdivide the protection category into two groups, Main 1 or Unit protection and Main 2 or Backup protection.

There is a significant difference between the two protection categories. Generally, Main 1 protects the device from local faults, where as Main 2, (or backup) provides protection from remote faults. During a disturbance the ability to differentiate between the two categories at a glance will allow control staff to quickly identify equipment that has faulted to protect itself and that which has operated to stop a cascaded fault.

Separating the two categories can significantly reduce the time it takes to restore supply to consumers and assist Control staff to understand the nature and source of the fault. The subdivision of the protection element data also makes it possible to provide additional graphical feedback of the system state in terms of actual device protection activity and assist with dynamic fault diagnosis. Figure 7.4 has examples of how the protection element data can be used to display graphically the zones in which protection equipment has operated.

3.2 Summary

This chapter established the MMI view of the control room environment in terms of the tasks carried out by the control staff. The topics covered were :

1. Control room task analysis
2. Control staff interviews
3. Regional Control requirements
4. National Control manager's needs
5. SCADA vendors comments
6. Remote Terminal Unit changes
7. Data communication changes
8. Telecontrol standard.
9.

The chapter also lists the needs and opinions of all interest groups and factors external to the control centre influencing the new MMI design.

4. THE PROBLEM OF DATA OVERLOADING

4.1 Introduction

This chapter reviews control room activity and analyses the existing data processing philosophy which causes data overloading in power system control rooms.

4.2 Daily Tasks

The minute by minute management of a power utility is concerned with:

- Keeping the voltage and frequency within limits
- Ensuring that power is delivered to the consumer
- Preventing the overloading of lines and transformers
- Adapting to seasonal and climatic changes in consumer demand
- Planned outages of generating plant and power lines
- Managing the system in the most economic manner available
- Problems caused by thunder storms, wind, lightning, floods, fog, etc.
- Equipment failure causing generator or line trips
- Operating errors
- Primary protection equipment failure and consequent secondary protection operation
- Grass or forest fires causing line trips
- Pollution deposits on the insulators causing line trips
- False alarms from the RTU
- Network changes in the form of new equipment and new transmission lines
- Inter-utility power transactions

From the above list, it is obvious that the work of the control staff is varied and requires a great deal of background knowledge and skill to meet continuously all the consumers' expectations. A large number and many different types of problems have to be solved on a daily basis.

The primary source of information on the state of the power network is the output from computer system. The output of the existing system is in the form of alarm messages and changes to the one-line displays. Since the computer system does not provide the control staff with all the required information, the control staff have to work closely with the distribution and power station st[illegible] in order to keep the power system operating efficiently. The transmission and distribution staff have to be available to travel to the substations to provide the control staff with additional information as and when required. Substations are not permanently manned and it can take staff many hours to reach a substation. It is this reason which has prompted the existing alarm philosophy.

4.3 Alarm Philosophy

The philosophy behind the generation of alarm messages in ESKOM, and in virtually every other electric utility, is based on the assumption of a quiescent network state. This means that whenever *any* measured value crosses a limit boundary or *any* single element changes state without authority, an alarm message is produced. The alarm message is used to alert the control staff to respond to the event and take corrective action where needed.

There is a problem with this approach, because each device in a substation is independent of all other devices and responsible for its own protection. As a result, each device will produce an alarm message of a fault, detected by its sensing equipment, at the same time as the same fault is detected and reported by all other devices. This is the origin of the data overload problem.

To make matters worse, the designers of power system control rooms tend to follow the rule, "Give the control staff all the data you can and they will make the correct decision more easily and faster!" [13]. The underlying assumption is that the additional data will provide proof of the problem and help prevent further problems. The effect of this approach is to exacerbate an already difficult situation which aggravates the data overload problem. Progress messages are a case in point.

4.4 Progress Messages

The SCADA system is designed not generate alarms when equipment reaches the final state following a commanded state change. However if a device, such as a hydro generator, is requested to change state, the intermediate state changes are alarmed since they are not the final state, but change state as part of the progress of the device from one state to another. There is no way currently to suppress these messages without adding code at the RTU or at the host to suppress the messages under specific conditions.

Table 4 lists 11 messages from a single hydro generating unit as it moves from one state to another. These messages are generated each time any of 12 hydro units change state.

The messages indicate the various pre-programmed stages that the hydro unit takes as it moves from a generating mode to standstill. In the messages, G/M refers to generator/motor. The stages are;

1. Automatic power factor regulation is switched on
2. The current GEN. state is no longer true
3. The unit is not able to move directly to pumping
4. KV unit breaker is open (tripped)
5. Unit output voltage drops to 1 KV (It must as the unit has stopped generating and is not connected to the network)
6. The exciter voltage becomes 0.
7. Unit exciter voltage becomes high (note the time)
8. Unit exciter voltage goes to 0 volts 10 seconds later
9. Automatic power factor regulation is switched off
10. Unit shutdown state is reached after 4 minutes
11. Minutes later the pony motor breaker closes to allow the unit to start up again if required

1)	09:20:17	*6 DRAKN	G/M_ARPR_4	ON_OFF			ON
2)	09:20:17	*6 DRAKN	G/M_GEN_4	YES_NO			NO
3)	09:20:17	*6 DRAKN	PMP_START_NOT_READ_4	YES_NO			NO
4)	09:22:20	*4 DRAKN	G/M4_400_BKR	TRIP			
5)	09:22:26	*5 DRAKN	G/M_4	KV	9	1	LOW
6)	09:22:26	*5 DRAKN	EXCITER_VOLTS_4	VOLT	0	-58	LOW
7)	09:22:26	*5 DRAKN	DK_EXC_DLT_VOLTS_4	VOLT		1	HIGH
8)	09:22:36	*5 DRAKN	DK_EXC_DLT_VOLTS_4	VOLT	0	0	LOW
9)	09:22:38	*6 DRAKN	G/M_ARPR_4	ON_OFF			OFF
10)	09:24:38	*6 DRAKN	G/M_SHUTDOWN_4	YES_NO			YES
11)	09:26:04	*4 DRAKN	G/M_4PM_BKR	CLOSE			

Table 4 Hydro unit state change messages

The messages are generated on the assumption that the control staff can spot a potential problem with the unit in question, and react to it by noticing when a specific message does NOT appear. These messages do not appear neatly as a group but are interspersed with other messages.

If there is a problem in the network these same 11 messages (and more, depending on the number of units in use) get in the way of more important messages. The control staff do not need these hydro unit data messages, which are not related to a disturbance and they become extremely annoyed, since these messages do not assist them at all. As a result they are ignored and deleted out of hand.
During a disturbance these messages just clutter the alarm page and in the process of being deleted, useful valid messages can also be mistakenly deleted.

4.5 The Fire Hose Syndrome

Currently, working in a control room is equivalent to tying the control room operator to a garden chair and directing a jet of water at him, with the jet of water representing the rate of alarm data. See Figure 4-1. The quantity and frequency of the alarm data changes with the state of the power system and matches the quantity and pressure of the water from the hose pipe. When a disturbance occurs the hose pipe is replaced by a fire hose. (The quantity and type of alarms being reported increases significantly.) Remember, the control room operator is unable to get out of the garden chair or avoid the water.

Figure 4-1 The fire hose analogy

During a disturbance the control staff have two basic problems;
1. They can never stop alarm messages being generated.
2. All alarms have to be acknowledged before they can be deleted otherwise the alarm buffers overflow causing messages, some new and necessary, to be lost and potential computer system problems.

This situation is exacerbated when the control staff know what caused the condition, but they are unable to tell the computer they know. This is demonstrated in Appendix 1, which lists part of the first 3 minutes of alarm messages from a minor disturbance in the ESKOM interconnected network during April 1994.

The disturbance was caused by the opening of an energised busbar isolator (link) in error. The protection schemes at Tutuka power station detected this as a fault on the busbars and tripped all 5 generator breakers with consequential loss of 1750 Megawatts of generation. This minor event generated 433 alarms in 10 minutes, with 79 in the first 30 seconds as indicated in Figure 4-2.

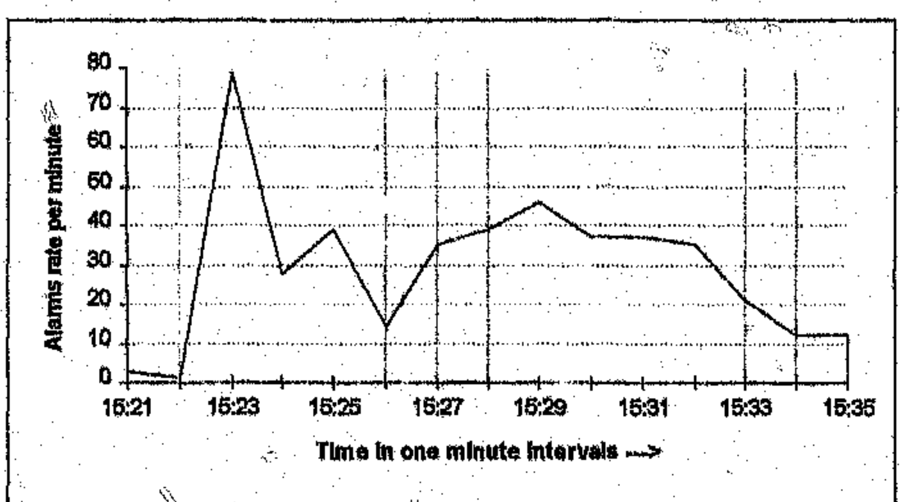

Figure 4-2 Alarm rate following a minor disturbance

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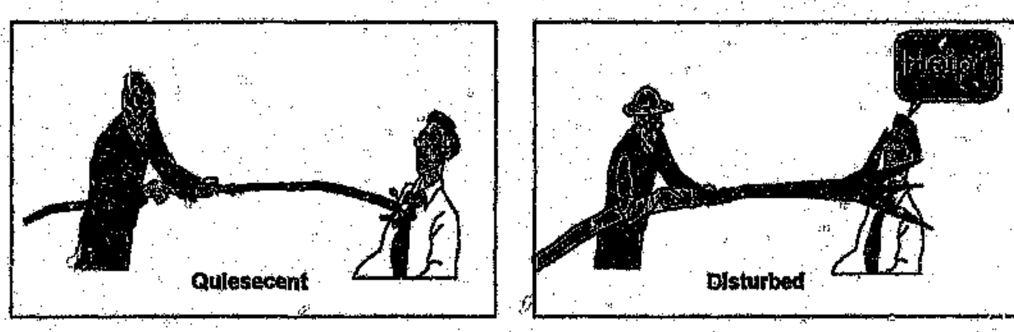

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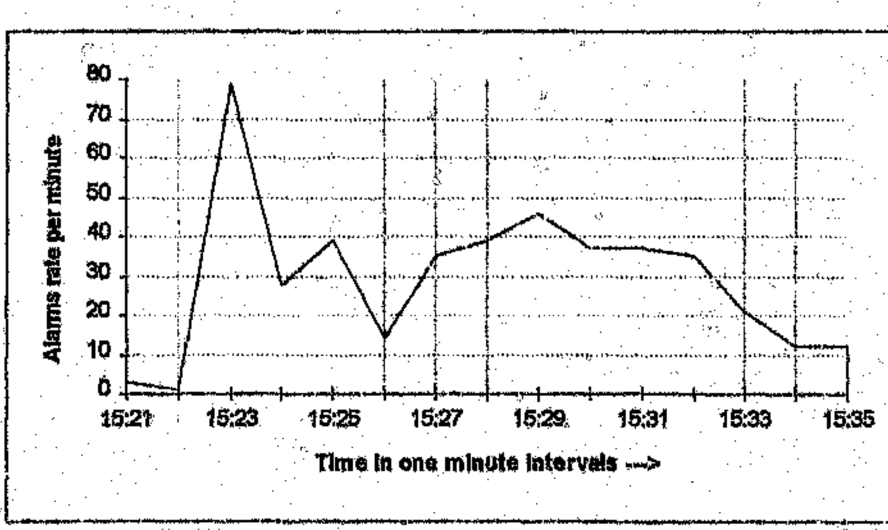


Figure 4-2 Alarm rate following a minor disturbance

The resulting sustained low frequency caused automatic load shedding to take place which returned the system frequency to normal some four minutes later as indicated Figure 4-3.

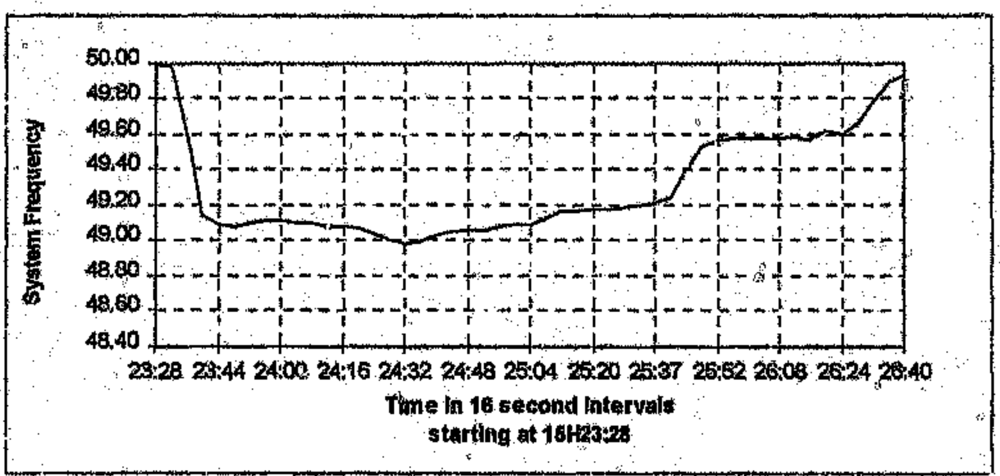


Figure 4-3 Power system frequency response

Comparing figures 4-2 and 4-3 one can see how the alarm rate changes as the frequency changes. The time intervals on the two graphs are not identical but at the start of the fault at 15:23, the alarm rate is at its highest, with messages still coming it after the frequency has returned to normal 15:27. Examining the messages in Appendix 1, illustrates how many duplicated messages are generated. If this number can be reduced without the loss of critical information, a major step would have been taken in reducing the data overload problem.

4.6 Summary

Currently no structures exist to prevent unnecessary message generation. The designers of SCADA systems do not recognise that different network conditions require different alarm handling and display tools. As a consequence the control staff suffer from the uncontrolled generation of alarm messages when more than a handful of electrical devices change state at the same time.

It can therefore be argued that the necessity for the current alarm message philosophy is primarily due to poor Man Machine Interface functionality. If better ways can be found of indicating the current state, then alarm text messages can be removed, - a view supported by ABB. [15].

A possible alternative to alarm messages is discussed in chapter 6, but before that, it is important to review the literature on the subject on Man Machine Interfaces used in power system control.

5. EVALUATION OF MMI LITERATURE

5.1 Introduction

This chapter examines the literature relating to alarm data presentation and the factors affecting the design of the Man Machine Interface used by control staff of Electric Power Systems.

The available literature on Alarm Processing, Data Visualisation and MMI developments was analysed. The primary focus was on articles related to Expert Systems and Human Computer Interaction connected with power system control.

5.2 General Philosophy

Papers covering the philosophy used in the monitoring and control of electrical power networks since 1976 were studied. An overall impression is that there has been no real change in thinking with respect to the presentation or processing of alarm data for control staff by management or vendors. The methods of data presentation used today are still the same as those defined in the proposals laid down in the EPRI report on Human Factors Review of Electric Power Control Centres [1] in 1981. Max Faxér said the same thing in 1985 [8] in the section called the "Too-much Too-Quick syndrome" on page 139 of his paper.

5.2.1 EPRI

The initial definitive reference work on the entire subject of alarm processing was compiled by the American based Electric Power Research Institute (EPRI) in 1981. The report [1] is in six volumes, three detailed and three management summaries, covering all aspects of SCADA system implementation and practices for Electric Power Systems.

The EPRI report [1], pg. 2-108 identified the problems associated with alarm processing in electrical utilities as being :

- Inconsistent significance
- Recurring alarms
- Alarm overload during a disturbance
- Alarm threshold too sensitive
- Lack of alarms on key parameters
- Too many alarms
- Need for more detail from substations
- Alarm display problems with paging
- Bottom line changes too fast

From interviews conducted with ESKOM's control staff, three other SCADA users in ESKOM and the Johannesburg Municipality, it would seem that these problems are the same now as they were in 1981. These findings are supported by papers published up to and including 1995. The problems identified in the EPRI report have been the starting point for many of the papers covered in this review and indicate that many people have tried to solve the data overload problem since 1981, with little success.

One of the papers in the EPRI journal [18] (DEC 1994) comments on the use of star plots and Kiviat diagrams to facilitate the visualisation of power system variables. The biggest problem with this idea is that currently the vendors of full graphic software tools do not seem able to offer the recommended features to the utilities.

EPRI [18] is currently sponsoring projects to develop advanced visualisation methods that can shorten the time needed bv power system operators to perform functions such as system restoration.

5.2.2 CIGRE

At the *CIGRE Conference in Japan in 1987* [5], *Van Son et al. acknowledged the problem* in the growth of alarm data arriving at control centres reaching upwards of 3000 alarms per minute during a disturbance. The paper identified 3D graphic tools as a possible solution for displaying some of the data. It does not offer any alternative ideas to the fundamental question of how alarm data should be processed or presented to the control staff.

In a similar report [9] on the Hydro-Quebec power system the number of alarm messages generated during a disturbance ranges from 20 to 75 alarms per second. It is surprising that the number of alarm messages generated by a SCADA system can be allowed to reach such high numbers, without anyone stopping to examine what the basic problem is in the first place.

5.2.3 CDC

The paper by the staff of the Control Data Corporation [12] (1989) called "Controlling Power Systems During Emergencies; The role of Expert Systems" explains the data overload problem very well. The authors acknowledge that the primary problems faced by control staff and hence by expert systems are:

- Some alarm messages do not contain enough information.
- Some alarm messages contain too much information
- Some alarms are needlessly repeated
- Multiple messages are generated for the same condition
- The number of alarms is sometimes overwhelming

Appendix 1 has examples of these problems from the ESKOM network.

CDC highlight the basic requirements of system control during disturbances as being :
- Keep the operator aware of the most urgent matters.
- Keep the operator aware of problems as they occur.
- Reduce alarm loading and present strategic situations.
- Provide the ability to perform deeper analysis.

The proposed CDC solution to solve the data overload problem is the installation of an Intelligent Alarm Processor or IAP. The IAP takes the incoming alarm messages, filters them and then divides them into four categories:
1. Those that need to be displayed immediately
2. Those that can be permanently ignored
3. Those that can be temporarily ignored
4. Those that need deeper analysis.

An expert system is not needed to dynamically filter alarms into four categories. Initial analysis of the alarm data shows that alarms belong permanently to one of the four groups. Assigning the different category to each element at data base generation time, allows each alarm element to be sorted as it arrives. By providing the control staff with four pre-defined alarm categories, one for each group, that can be called up on demand removes the need for IAP. As for the messages that can be permanently ignored why not leave them at RTU or leave them undisplayed and access them when required?

During a disturbance it is the repetition of known states that causes the data overloading as indicated by examining Appendix 1. An IAP does offer some relief by preventing duplication of similar messages but the medium of communication between the RTU and the control staff is still via alarm text messages and the potential power of the full graphic MMI hardware is neither considered nor addressed.

5.2.4 Dept. Of Electrical Engineering, Washington University

The paper "Envisioning Power System Data" published in 19§3 [6] by the staff of the department of Electrical Engineering of Washington University discusses the use of full graphic facilities to understand power systems. They make the comment,

"The easier it is to obtain insight from a computational tool, the more useful the tool," and acknowledge that "power system data does not consist of high levels of abstraction of the type that people use in the mental problem-solving process. Instead the data consists almost exclusively of numbers".

This is the only paper that mentions mental models and data visualisation with respect to power system control but they do not pursue the relationship between the physical model and the data model and seem to be locked into the display of the lowest level of the source data. They use full graphics for display of load flow data but ignore device state data.

Their comment that power system data "...consists almost exclusively of numbers" is patently false. All electrical devices have numerical components, but the ratio of binary states to numbers is nearly 20 to 1. Also, it is the attributes of the numerical data that indicate the seriousness of the value, not the value itself. If the attributes are not used to indicate the limit positions of the value, the memory demands on the control staff to keep track of all values would be completely unreasonable. For each value, there are at least 4 to 10 attribute flags that the computational tools can use to set the context of the value both locally and remotely. When the values and the device status flags are combined, greater use can be made of full graphics to match the abstraction level currently used by the control staff, during the problem solution phase of a disturbance.

The paper provides ideas to display SCADA numerical values using dynamic full graphic objects but points out that the existing methods of displaying numeric data are inefficient.

The authors touch on a number of valid aspects with regard to the presentation and visualisation of power system data, highlighting the need to find an alternative method of displaying data. They champion the benefits of human pattern recognition skills to solve the problem of numerical data display but do not offer any ideas on the presentation of alarm data. This paper is not a very satisfactory report on the use of full graphics.

5.2.5 IEEE

A similar paper on "Modem User Interfaces" (Jan 1994) [14] refers to the 1981 IEEE tutorial on the Fundamentals of Supervisory Control systems [4], which emphasises the lack of new thought on the practical (not theoretical) aspects of displaying powers system data to meet the thinking needs of the control staff. The paper commends the use of full graphic workstations using the functions of Motif and X-Windows to display power system data in an enhanced manner compared with the past. They do not consider the use full graphics for alarm data presentation, which is the prime reason why the control centre was created in the first place.

5.2.6 Helander

In Chapters 1 through 8 of his "Handbook of Human-Computer Interaction" [7], Helander takes an in depth look at all aspects of the MMI. He points the way to an alternative method of modelling data using Metaphors and Icons. The question is raised about the mental models used by Control Staff and others involved in Human Computer Interaction, among many other aspects of the MMI. There are a lot of good ideas but unfortunately he does not deal with alarm processing per se.

5.3 Expert Systems

A great deal of theoretical work has been done on the potential benefits of implementing Expert Systems to assist with the processing of "alarm messages". These specific expert systems are referred to as Intelligent Alarm Processors or IAPs. This type of expert system has been proposed for a number of years [11 and 12] as the solution to the data overload problem. There appear to be only three documented Intelligent Alarm Processing systems in operation in the Electric Power Industry which are those of EDF (of France) [10], Portugal [17] and Hydro-Quebec (of Canada) [9]. These systems are discussed below.

5.3.1 EDF

The French electricity supply utility, EDF, uses an expert system called ALOUETTE in an attempt to shield the control staff from data overloading. The objective of their Expert System is "to solve the problem caused by the massive arrival of alarms related to faults occurring in the power system".

However the EDF expert system has to wait 30 seconds to allow all alarms to be grouped into a coherent whole before deductive processing can begin. The inference engine processes the "facts" using a rule base and provides the diagnosis of the problem via an "ideal" list of alarm text messages. Control staff however are not prepared to wait 30 seconds before they do anything. The need to take corrective action during the disturbance is of absolute importance and can not be delayed due to expert system requirements.

5.3.2 Portuguese

The Portuguese SPARSE Intelligent Alarm Processor is expected to produce an explanation of a serious incident within 5 minutes of the disturbance starting. The input data to SPARSE is SCADA alarm messages with the objective of converting the flood of messages into a simple explanation of what happened. From the paper, it appears that they have succeeded, but the time delay before the explanation is available is not practical.

5.3.3 Hydro-Quebec

The LANGAGE expert system has been used by Hydro-Quebec since 1992. It is an alarm diagnosis package attached to the main computer system and uses the same SCADA alarm text data that is sent to the control staff. LANGAGE does not reduce the number of alarm messages but does attempt to provide explanations based on them. The explanations are available to the control staff on the same screen as the incoming alarm messages are displayed on.

One of the justifications used by Hydro-Quebec to install LANGAGE is the prevention of damage caused by the inadvertent re-energising of faulted transformers. A different protection scheme at the transformer, requiring manual intervention before a transformer can be energised, would be more appropriate. The authors also note that messages get lost during a disturbance. A possible solution is to create alarm categories based on device type rather than on a station basis. This will allow all transformer messages to be collected in one alarm bin rather than have them split among all the stations.

5.3.4 Strathclyde University

Staff at the Strathclyde University in Glasgow in 1992 [15] published an article on the potential of Expert systems to solve the data overload problem using the APEX (Alarm Processing Expert System) and RESPONDD (Rule based Expert System for Power Network Disturbance Diagnosis) programs.

In their opinion " the Expert System acts as buffer between the control system and the operator, which digests the vast quantities of SCADA data and supports control staff in their analysis of the system disturbance". The Strathclyde staff suggest that the CPU power at the RTU is used to perform local diagnosis on the output of the protection, then use the indications to "influence the transmission of alarm messages from the substation". This solution they indicate would "tackle the problem of voluminous data at the alarm generation side." The examples given in the paper are related to low voltage systems where disturbance activity is restricted to small local networks. The ideas offered do not appear to have been tested in interconnected systems with voltages above 275 KV which cause far more messages to be generated than at low voltages.

The most significant comment made by the Strathclyde staff is to acknowledge availability of the unused CPU power of the substation computers which, to date no other author has done.

5.3.4 Summary of Expert Systems

The most significant aspect of all the Expert System proposals (Portuguese, EDF, Hydro-Quebec and Strathclyde) is the retention of alarm text messages from SCADA, as the input to their expert systems. They neither examine nor question the basic reason for the installation of the Expert System in the first place, which initially is to reduce the quantity of alarm text data delivered to the control staff.

By changing the type of data, the point of measurement and making more intelligent use of text descriptions to convey information to the control staff, the need for a centralised expert system at the host computer to filter alarm data can be reconsidered.

Rule-based expert systems can provide some assistance to the control staff in limited domains. However the number of rules needed to cover all possible scenarios in a large power system is so large, that it would be impossible to make an expert system cost effective in a growing environment.

However, local expert systems situated at the RTU which deliver explanations of electrical protection operations are possible and form part of the RTU secretary mode activity recommended in chapter 8 of this report.

It should be remembered that, coupled to the alarm text data is the need for an efficient method of presentation that facilitates the rapid visualisation of the information, which is an essential requirement during a disturbance. At no stage, in any of the papers on expert systems, is this addressed. The installation of a centralised expert system to process alarm messages is not the answer to the data overload problem. They do have a role to play at the RTU where they can be used for many applications including alarm processing. However, the output would be a text message built up by the Expert System and sent directly to the control staff via the RTU. This is discussed in more detail in chapter 8.

5.4 Full Graphics

Since full graphic displays are very recent innovations in control rooms, there has not been much experience with them nor with their limitations. ABB. [16] have noted the problems associated with using full graphic hardware and identify the primary MMI need of the control staff as being "...to show the operator the precise information required at any particular time - and no more."

The question of what the operator actually needs during his daily work routine is then asked. The answer is not provided, but the ABB authors define the two major aspects of MMI design as being "information selection" and "display form".

The authors recommend solutions based on the arrangement of "windows" at the workstation and the use of "fish-eye" graphics to allow greater visibility of specific network items.

They also recommend the *expedient* use of expert systems and appropriate and clear summary information derived from the large volume of data arriving. This recommendation is questionable in light of the quantities of data generated during a disturbance and indicates that the authors have little knowledge of what the installation of an expert system entails.

The paper poses the question of "What ought to be displayed and what is the optimum output in terms of human engineering?". The authors do not provide concrete solutions but do provide guidelines for display staff to keep in mind when designing displays.

The staff at EDF R&D division [11] noted that future higher performance computers and visual displays would allow "...a better MMI, well adapted to the needs of the operators, not only in the normal but also in the emergency state and for restoration". This is the only instance noted which recognised that the MMI has to cater for different operating states.

5.5 Summary

From a review of the literature it is apparent that a lot of research and work has been done in an attempt to improve the working environment of Control Staff by:

a) Reducing data overloading
b) Using full graphic facilities and
c) Recommending the use of expert systems to provide summary information

However, it seems that the current designs of SCADA systems are based on the premise that the power system is quiescent. Nearly every paper complains about the data overload problem but the effort to solve the problem is concentrated at the receiving end, flow control at the source is the crucial requirement to solve the data overload problem.

In general there does not appear to have been any change in the theory or practice in the presentation of alarm data for use by Control Staff (or as input to an Expert System) since the initial design guidelines formulated in the 1981 EPRI report [1,2,3].

Solutions have been designed and implemented in an attempt to filter the data or buffer the user from the results. No attempt has been made to examine the root cause of the data overload problem nor what effect the state of the power system has on the operating needs of the Control Staff.

Three expert systems have been designed and built in an attempt to help the control staff to understand alarm messages, but there is no general move by the industry to embrace them because of the limitations imposed by retaining the old philosophy of using text messages.

6. POSSIBLE SOLUTION TO THE DATA OVERLOAD PROBLEM

6.1 Introduction

This chapter proposes an alternative approach to the data overload problem and defines the structures on which the new philosophy is built.

6.2 Disturbed state

Historically the MMI and ALARM systems were designed on the assumption that the power network is quiescent 99% of the time with limited facilities for disturbed state conditions. In fact, the facilities for disturbed state operation are the same as those for quiescent operation, the size of the alarm buffers being the only concession provided for disturbance conditions. Alarm messages are generated for each and every non commanded state change in the network and whenever an analog exceeds a limit or returns to normal. The alarm messages are used as the primary method of notifying the control staff of network element state changes. Therefore the root cause of the data overloading is the uncontrolled delivery of alarm text messages and the lack of any alternative means of network notification.

Any solution to the data overloading problem has to be based on the reduction of alarm messages delivered to the control staff, but without the loss of critical information to enable them to do their job efficiently. The solution parameters for the reduction of data overloading can be defined in terms of a design brief .

6.3 Design Brief

"Communicate the current and potential state of the electrical power network to the control staff as fast as possible and in such a manner that they are able to appreciate the problems and potential problems without the need for repeated or unnecessary alarm text messages".

The solution assumes two distinct behaviour states of the power system, disturbed and quiescent, and that the SCADA, ALARM and MMI modules of the computer system can be changed to support these two different modes of operation. The solution is designed to solve a disturbed state data overload condition first, with quiescent operation tools added once the disturbed state foundation is in place.

6.4 Solution Mechanics

In chapter 2, the mental and concept models used by the control staff were defined as a pyramid as per Figure 6-1 A and B. With respect to this pyramid structure, it was found that 99% of the alarm messagesmaking up the data overload problem are produced from changes that take place at the element level.

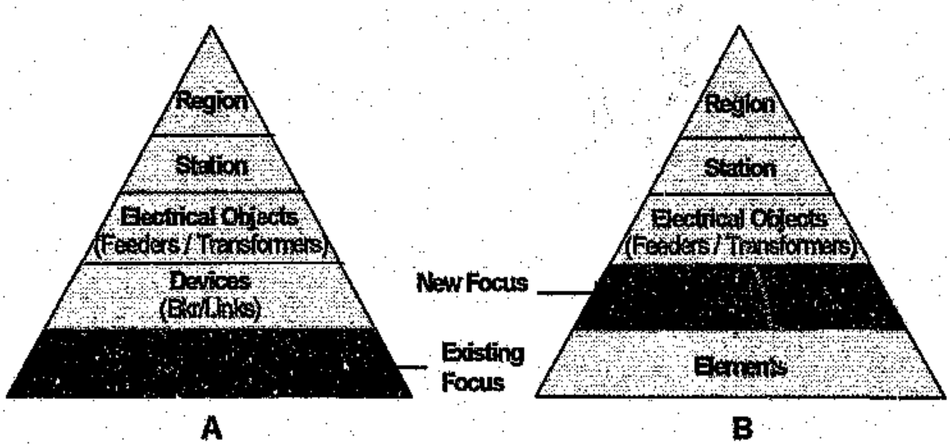


Figure 6-1 Existing and new focus levels

Re-examining the control staff behaviour and their mental models, it was found that they were focused at element level and had to use element data to determine the overall state of the device when, in effect, they needed to be focused at the device level, with the ability to examine a specific element when required. See Figure 6-1 A and B.

The same analysis revealed that a device can have a number of different states, depending upon the operational mode and state of the power network. Examining the elements belonging to each device revealed that the division into the three categories matched the initial mental models of the possible network activities referred to in the task analysis, see Appendix 3. A further division of the elements into four categories provided a better structure on which to hang the device state abnormalities.

6.5 Proposed solution

The proposed solution is:

1. Move the control staff focus from the element level up to the device level as in Figure 6-1 B.
2. Divide all element data for every device in Appendix 2 into four categories called Health, Protection Main, Protection Backup and Information
3. Count the number of abnormal elements, for each of the four categories and store the result at the device level.
4. Indicate the existence of abnormal elements in a category, using icons next to the device on the one-line display.
5. *Notify the parent level of the existence of abnormal states in the current level, as per the data pyramid.*
6. Allow the control staff to traverse the data pyramid and filter and suppress data dynamically, to suit their requirements.
7. Limit text alarms to Breaker trips, Busbar and Transformer protection messages only.

The next few paragraphs expand on these topics and provide examples of their implementation.

6.6 Categories

The elements belonging to a device are divided into four categories as indicated in Table 5. The information in Table 5 is taken from page 9 & 10 of the Telecontrol standard in Appendix 2. Each element state change causes the category counter to be updated on the parent device. There is a separate counter for each category along with space to store the time at which the last element became SET and RESET. This require changes to the data base structure.

Health	Main Protection	Backup Protection	Information
SF6 - Urgent	Pole discrepancy	M2 protection trip	Breaker state (open/closed)
SF6 - Non urgent	Bus zone	M2 HV Inst. o/c	Breaker Changed
Main 1 DC fail	Bus strip	M2 HV backup o/c	Breaker control - local
Main 2 DC fail	M1 protection trip	M2 HV E/F operated	Supervisory Control - On/Off
Control DC fail	M1 HV Inst. o/c	M2 MV Inst. o/c	Main 1 protection on/off
Close DC fail	M1 HV backup o/c	M2 MV backup o/c	Main 2 protection on/off
Spring rewind fail	M1 HV E/F operated	M2 MV E/F operated	MW jitter
Isolator DC fail	M1 MV Inst. o/c	M2 Tertiary inst. o/c	MV jitter
AC/DC Conv. fail	M1 MV backup o/c	M2 Tertiary IDMT o/c	KV jitter
MVA 70 deg. Limit	M1 MV E/F operated	Neutral Earthing Comp.	Hz jitter
MVA 90 deg. Limit	M1 Tertiary Inst. o/c	Neutral Earthing React.	ERTU Message
KV limit	M1 Tertiary IDMT o/c		

Table 5 Transformer elements divided into categories

The bottom of Figure 6-3 B indicates the logical arrangement needed to track the changes in the elements.

6.6.1 MMI indication of abnormal element states

As the focus is moved to the device level the control staff have to be notified of the existence of abnormal elements related to the device. This is achieved by assigning different coloured icons to each category that become visible the moment there is a positive abnormal count in the category field. This topic is discussed in more detail later on.

6.7 Abnormal counts

The abnormal counts are not limited to the device level but are propagated right up to the top of the data pyramid. See Figure 6-2. Each level has a set of category counters and time stamp fields. The counts at each level reflect the number of abnormal states in the level below, not the summated count of all the elements owned by the level. The station level counters indicate how many electrical objects have abnormal states, the electrical object counters indicate how many devices have categories with abnormal counts.

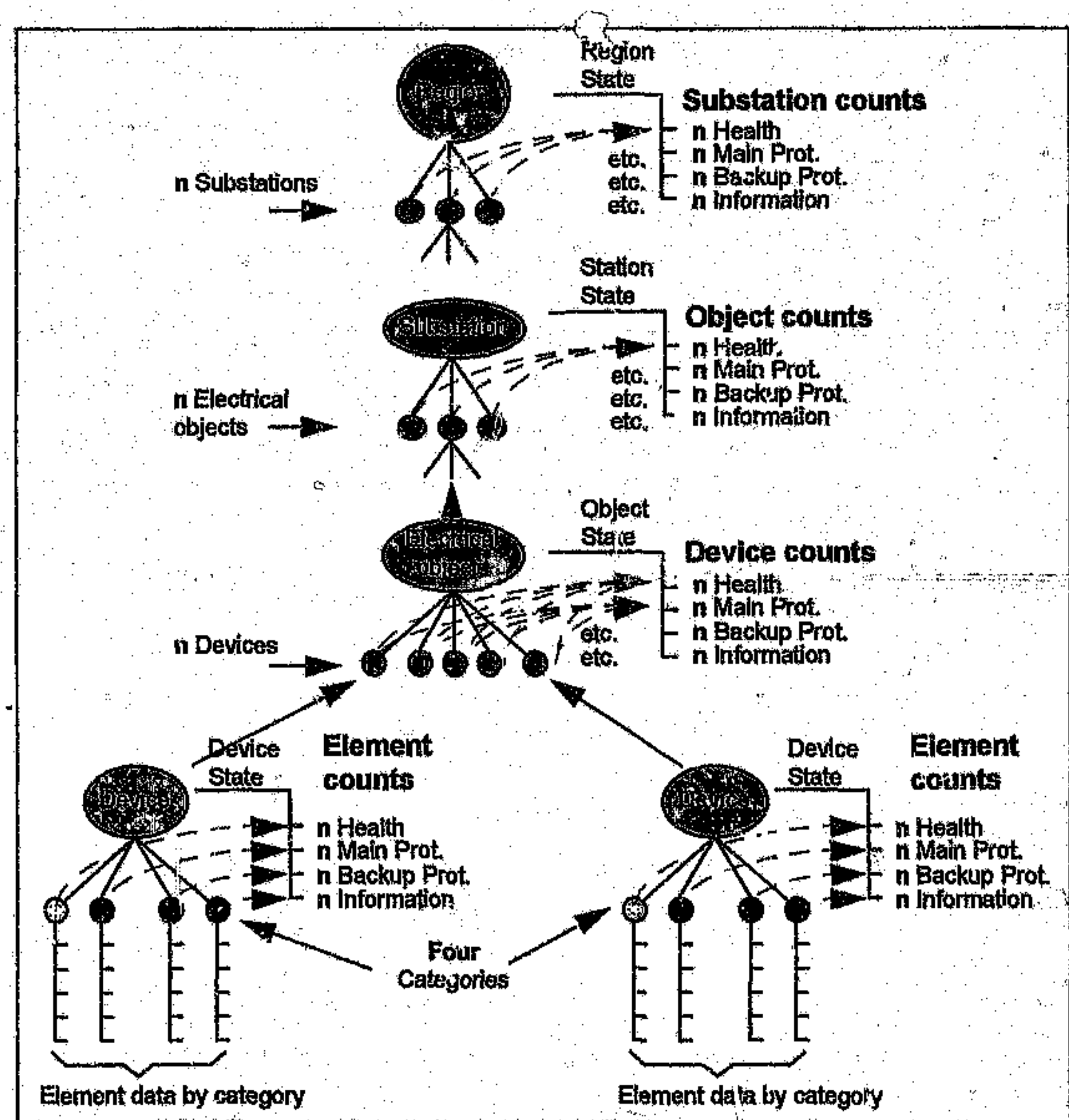


Figure 6-2 Graphical model of the proposed data structure

6.8 Text alarm messages

As mentioned in Chapter 1, currently, every time an element changes state, it causes an alarm text message to be created and delivered. Control staff still need to be notified by text message and audible tone of the existence of specific device state changes that effect the state of the network, but not each and every minor element change.

The proposed solution limits the automatic production of text alarm messages to just three types ;

1. All breaker trips
2. All Busbar zone protection operations
3. All transformer protection operations

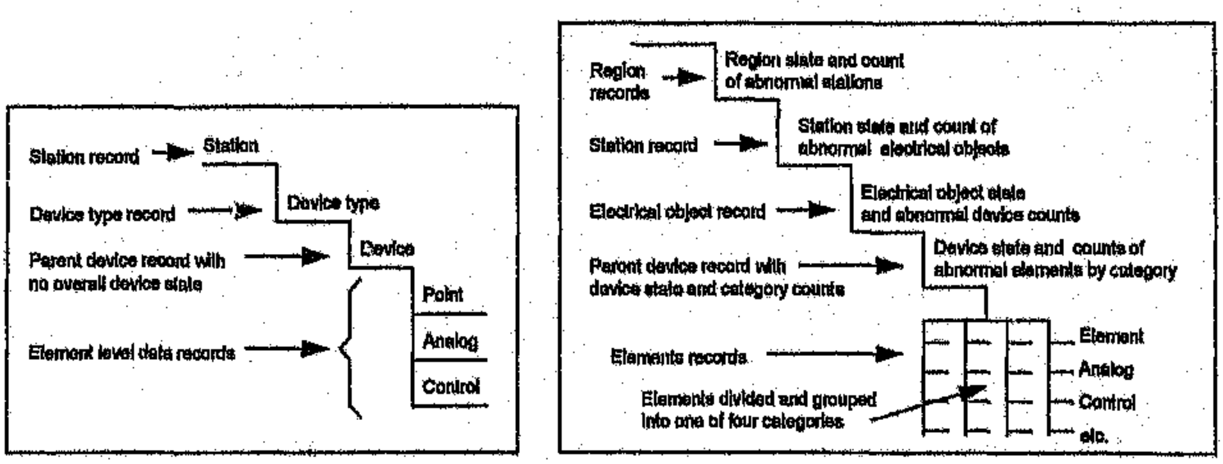
This subset of alarm messages represent the trigger that warns the control staff of potentially serious network problems and draws their attention to the site in question. All other alarm abnormal states are indicated by the category icons next to the relevant device at the device level. Since the existence of abnormal states is provided at each level of the data pyramid, the control staff are able to see where they have problems and in which category. This allows them to selectively examine the problem when time permits, knowing that they will be warned audibly if there are any disturbance related messages.

Restricting the text messages requiring manual acknowledgement and deletion represents a major reduction in the potential data overloading during a disturbance without the loss of ability to get information when required

Lists of alarm actions are still vitally important and they can be produced on demand via the MMI secretary mode tools on the workstation. Control staff have the ability to filter the alarm lists to suit their needs depending upon the network activity and the demands from management. This facility puts them in control of the data they need when they need it.

6.9 Data structure changes

In the existing hierarchical data base a pseudo-model of the network is supported as indicated in Figure 6-3 A. However provision is only made for element data modelling. The changes needed to support new philosophy are indicated in Figure 6-3 B which matches the pyramid data structure mentioned in Figure 6-1. The entire tree structure is defined in Figure 6-2. Note how the abnormal counts are accumulated at each level.



A - Classical host data base structure

B - Proposed host data base structure

Figure 6-3 Comparison of the classical and proposed data structures

6.10 Communication cycles

To support the two modes of network behaviour (disturbed and quiescent) and to allow the focus of attention to be moved to the device level, requires changes in the data acquisition philosophy as well. The changes amount to creating two different data acquisition cycles called Class1 and Class2, where Class1 is used to acquire device level and category count data, and Class 2 is used to fetch and deliver element data. Class 1 data messages not only deliver device level data but include the device category counts and associated time stamps as indicated in Figure 6-4.

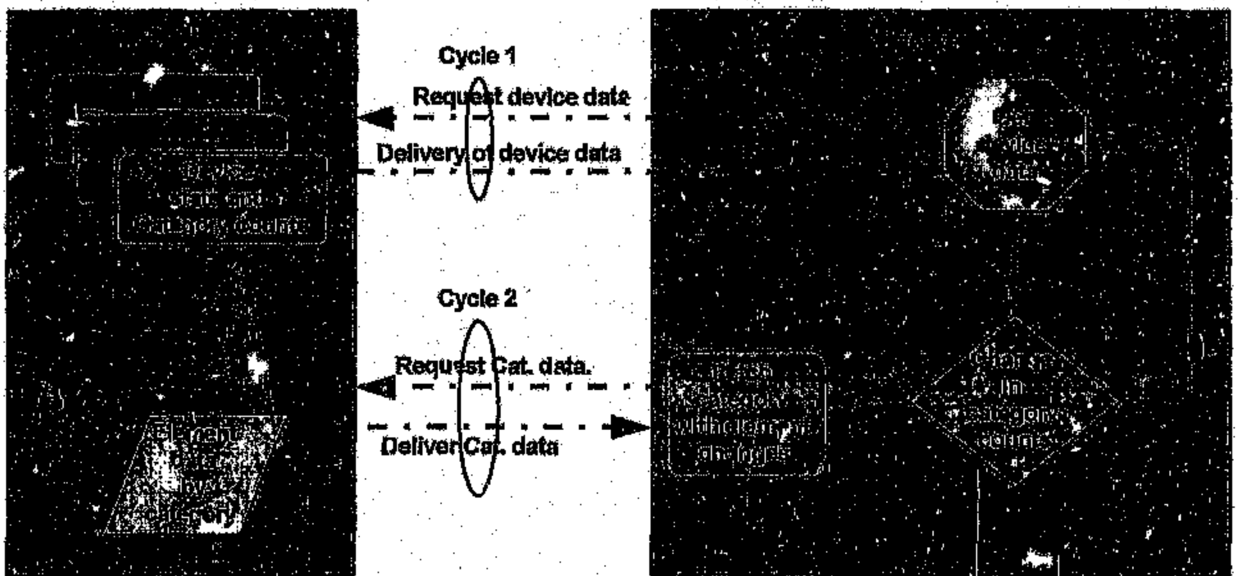


Figure 6-4 Model of the two cycle data acquisition mode

Keeping in mind the disturbed state design philosophy, the category counts in Class 1 messages are used in two ways, one to advise the data acquisition software to solicit the associated category data and secondly by the MMI to indicate the existence of abnormal elements by category on the displays. These two aspects are discussed in more detail in the next two sections.

6.10.1 Communication network loading

Dividing the data acquisition into two modes, allows the urgently needed Class 1 device state data to be delivered to the control staff without the communications network being slowed down by the clutter of Class 2 element data until actually required. Changes in the category counts sent as part of the Class 1 device level data are used by the front end data acquisition software at the host to request the delivery of all the element data for the device.

The changed elements are not transferred on their own, the entire category set is sent as a Class 2 single packet since the overhead to send a single packet is the same as it is to send an entire category. There are also maintenance reasons why category data should be transferred as a whole. This is discussed in more detail in section 6.15

An example of the two DAQ cycles is shown in Figure 6-4.

Using two different DAQ cycles, effectively delays the delivery of element state changes to the host, but as the ERTU stores both set and reset times for each element, there is no need to move the element data to the host immediately. The element change time stamping is carried out at the ERTU, not at the host. Class 2 element data remains at the ERTU until requested by the host. The host uses the category count changes in the Class 1 message to post Class 2 requests.

The host issues Class 2 requests whenever there are no more Class 1 changes, or when control staff specifically request the Class 2 category set. There will of course be a short time delay following a demanded request for a category set, but this delay is acceptable as disturbance Class 1 device state information is not held up by quiescent system needs. Class 2 data is transferred almost immediately if there are no outstanding Class 1 messages.

6.11 MMI Icons

The second use of the category counts is to indicate the existence of abnormal elements. The MMI uses the positive category counts to display coloured icons next to the device as indicated in Figure 6-5. The existence of one or more category icons notifies the control staff of the existence of one or more elements in the abnormal state. Device and element level category data is then displayed on demand by selecting either the category icon or selecting the device which will bring up all the elements divided by category.

During a disturbance when there would be a large number of icons on display, the control staff make use of the secretary mode tools to filter and suppress the icons on the one-line displays to suit their needs. Since the existence of abnormal states is known at each level of the data pyramid, Control staff do not have to examine each station to see what devices have abnormal states. The ability exists to create selected lists of elements in the abnormal state. The secretary mode actions are explained fully in Chapter 8.

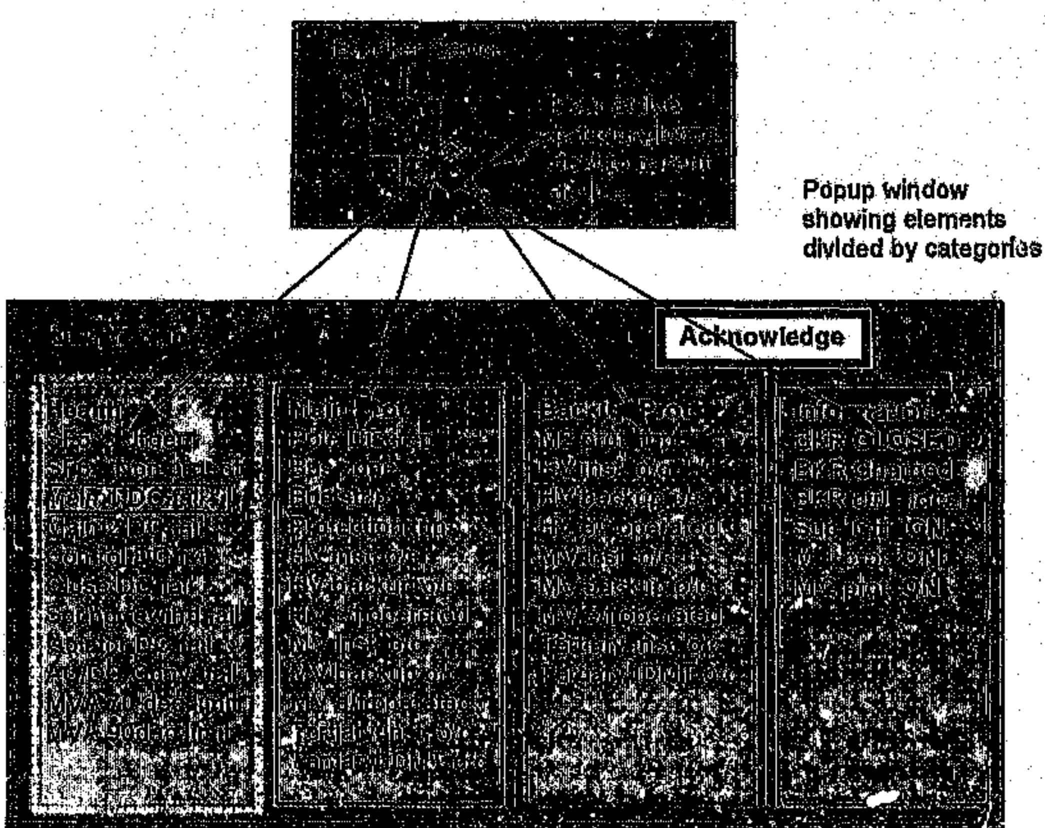


Figure 6-5 Category icons and associated popup window

An element in the abnormal state is indicated by the background text defining the element being inverted. This is indicated in the element called "Main 1 DC fail" in Health category shown in Figure 6-5. Once the element state is acknowledged the background colour will slowly become grey. They quantity of grey is a function of the time since the element was acknowledged. This match the icon duration next to the device.

6.11.1 Icon duration

One of the main aspects of the proposed solution is the storage of the time when the element or device state changed. This provides the key for the Control staff to know the age of an event and allow time based functions to be used to control the display of data on the one-line displays.

The MMI is designed on the assumption of a disturbed state and each icon will automatically disappear after a pre-set time. The visibility period can be changed by the control staff when needed via the secretary mode tools. The quiescent setting for an abnormal icon is 15 minutes and after the time has elapsed the icon disappears.

Control staff can regenerate the category icons by replaying the icons activity via the MMI secretary mode tools. This requires changing the display mode temporarily and using scroll bars to replay the state change actions using the stored time data.

It is possible to have a non disappearing mode, i.e. an infinity time out, activated on demand when the need arises.

6.11.2 Flashing icons

In order to ensure the control staff notice a new icon, the initial output mode will be flashing. The use of advanced MMI facilities can have the size of the icon and the flash rate change over time, with the initial size being larger and becoming smaller as time progresses until it eventually disappears. The flash rate and the size can be combined to indicate different conditions.

The icon will stop flashing under three conditions:

- if the category or device is acknowledged via the acknowledge button (Figure 6-5.)
- if the flashing option is deselected on the display.
- if the auto acknowledge option is selected with a given time out period.

This solution goes a long way to solving the data overload problem by reducing the quantity of messages sent to the control staff and allowing them to control the data they need.

The implementation of the solution requires changes to both the host and ERTU. The host changes involve the creation and inclusion of two new record types called REGION and ELECTRICAL OBJECT to be inserted as per Figure 6-1. Since DEVICE records do not exist at the ERTU, they need to be created and added to the ERTU data model.

6.12 Additional Fields

Additional data fields are needed on all the records in the data pyramid in the host data base. These changes enable the tracking of category changes as they occur at the ERTU which requires similar changes to element and device records.

By moving the focus up to the DEVICE level, the exact behaviour of the elements will be lost unless provision is made at the ERTU and the host to store the time and state changes as and when the monitored element changed.

This is similar to sequence-of-event recording, which is handled by a separate task in the ERTU, in that there is a limited buffer for each element that has space for 8 state and time stamps. If the buffer overflows the most recent 8 state changes are available. Analog elements use the time stamp cells to store the time when the analog value exceeded the high limit and when it returned to normal. The historical state and time stamp fields are not stored as part of the device only the current state is kept there, the rest of the data is kept in a relational data base that is accessed on demand by the MMI.

The details of the additional fields are defined in the next paragraphs.

6.12.1 Additional Host fields

The basic additional fields added to the host data base records are indicated in Table 6 The fields are ;

1. A time stamp field to store the time and date when the monitored state changed to SET or exceeded a high alarm limit.
2. A time stamp field to store the time and date when the monitored state changed to RESET or returned to normal.
3. A "presence " or active bit that defines whether or not the record is commissioned at the RTU. This applies mainly to elements but is applicable to all records including the station record.
4. A bit indicating if the record is the head of a category (normally only applicable to an element record).
5. A pointer to the location in the relational data base for the last 15 minutes of element history *minutes or to the last 16 element state changes.*

Monitored state	State SET time stamp	State RESET time stamp	Presence bit	Category indication bit	Pointer to historical data

Table 6 Additional fields needed on all host data base records

On the device, object, station and region record, four category integer counter fields and a state field are required. Each of the category fields require two time stamp records to track the time at which counters changed.

In addition to the category counters on the station, region and network records, there are also cross reference object counters that track the total number objects that have elements in the abnormal state by category for each pyramid level. There are 9 basic object types i.e., busbars, couplers, lines, transformers, loads, generators, capacitors, reactors and SVCs. The counters for these objects are updated as the elements change and are used by the control staff to determine the electrical equipment with problems and in which categories.

The cross reference counters are displayed in the "Associated level category counts" field as specified at the top of Figure 7-1. The values in the counts change as the control staff move up and down the data pyramid and track the counts in the level dynamically.

The time stamp fields for each device category are used to trace times when the category count was set and when the count is eventually reset to zero as indicated in Table 7.

Number of abnormal elements in the **Health** category	Number of abnormal elements in the **Main Protection** category	Number of abnormal elements in the **Backup protection** category	Number of abnormal elements in the **Information** category
Time when the category became abnormal	Time when the category became abnormal	Time when the category became abnormal	Time when the category became abnormal
Time when the count reset to zero	Time when the count reset to zero	Time when the count reset to zero	Time when the count reset to zero

Table 7 Category field layout.

Figure 6-6 shows a pulse trace of a selected number of elements. This is one of the secretary mode tools that allow the control staff to obtain a very quick picture of what happened amongst selected elements or devices. Multiple state changes are kept in the associated relational data base and are accessed on demand when pulse data is required. Only a latest set and reset times are stored in the SCADA data base with the historical data stored in the relational data base.

The generation of the pulse trace is a secretary mode function used to determine sequence-of-event behaviour after the event and is performed in an off-line mode.

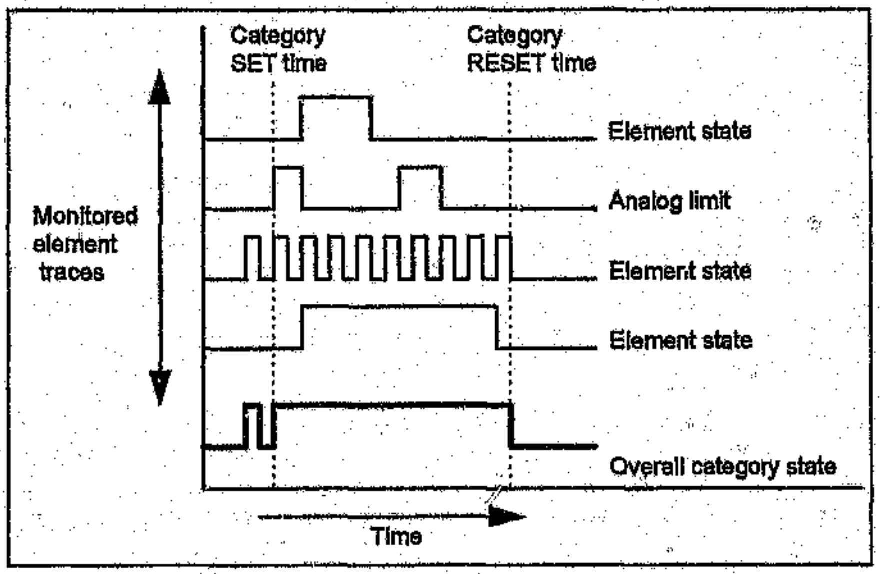


Figure 6-6 Example of pulse trace behaviour

6.12.2 Additional ERTU fields

The additional fields needed at the ERTU are :

1. A time stamp field to store the time and date when the state of the element or device changed to SET or exceeded a high alarm limit.
2. A time stamp field to store the time and date when the state of the element or device changed to RESET or returned to normal.
3. A "presence " or active bit that defines whether or not the element or device is commissioned.
4. Four category integer counter fields are required initially on each device. Future growth must be catered for and at least 4 more categories should be available.
5. Pointer to the location in the data base where the last 8 state changes and time stamps are stored.

6.13 Host changes

Once the extra records and fields have been added, the changes needed in the host SCADA data base are :

- All elements and analogs are moved and linked to their parent device.
- Elements are divided and grouped into categories.
- The electrical object, station and region records are linked to their child records as per the physical structure at the station as indicated in.
- Code is added to track and update the counters for each category on the device record. (Initially this code can be added to the host but eventually it would be installed at the ERTU). Similar code will update the counters at the object, station and region records to reflect the totals below each record.
- Code is added to store the last 16 element and analog changes received from the ERTU in a relational data base accessible by the MMI.
- The full graphics displays are modified to have a different icon for each category displayed next to the device, object, station and region if there are elements in the abnormal state in the source category

- Tools are created and added to the full graphics displays to allow the control staff to display the contents of a category by selecting the icon or the device to see the entire element set.
- Each MMI workstation has "secretary mode" tools to suit the needs of the Control staff and state of the power system. The changes to the MMI are explained in detail in chapter 8.

6.14 ERTU changes

Once the device record and the extra fields have been created, the structure and software needed at the ERTU must be changed as follows :

- Element and analog data is divided, grouped into categories and wired up according to the order in the Telecontrol Standard. If specified elements are not available, spaces are left for them and the presence bit is set to zero. This is a crucial point in the design as regards dual host access and on-line maintenance.
- Code is added to track and count the number of elements in the abnormal state in each category for each device in the ERTU. The counts and time stamps are updated whenever an element changes state. This change tracking code is initially installed at the host and moved to the ERTU once the communications protocol has been updated.
- The data acquisition processing is modified to transfer the category counts and time stamps with the device state whenever the device state is scanned or polled.
- Code is added to save the time state and time stamp when each element and analog changed in a buffer that holds the last 8 changes.
- The ERTU has "secretary mode" software programs to provide additional services to the control staff during quiescent periods and advise them of potential problems during disturbances. This is discussed in chapter 9.

6.15 Maintenance

Maintenance is one of the biggest areas of concern in large Energy Management Systems. The ESKOM ERTUs are accessed by more than one control centre, which causes serious problems when new points have to be commissioned. The problems start with the need to ensure that the plant data is correctly wired up to the ERTU for access by multiple host computers at the same time. How are new configurations of the ERTU synchronised for all users at the same time?

The proposed solution recognises the need for parallel commissioning activity and allows multiple host data bases to commission new points at their own pace. The first requirement is that each device has the category data built in the same way in all the relevant data bases including the ERTU before any element is commissioned at the ERTU.

The design is aimed at reducing the maintenance load at the different host computers by using a standard layout for all elements wired to similar devices. All missing or future elements must be wired to the ERTU. Parallel to each element state is a presence bit. These presence bits are applicable to the device and element records at both the ERTU and the host. See Figure 6-7.

The benefits of standardising the element name order in the ERTU and the host are:

- There is no need to have a separate MMI display ID for each element.
- All elements have the same pre-defined position in the category which is the same for all similar devices.
- There is no need for major data base update to commission a new element because the element already exists in the data base once the device record has been defined.

To commission an element, all that is required is that the element is wired up and tested locally and the 'presence' bit is set to the active state at the ERTU.

At first glance the advantage of not needing to have separate MMI IDs for each element is not appreciated until one considers the space required to display element data and the time it takes to add new points to the data base. By grouping the element data into pre defined categories at the ERTU and the host allows the mapping of the individual elements to be pre-defined ID text displays.

As specified, the order of the elements is the same in each category for similar devices. Thus, at display time, the elements for a given device can be displayed in the same format using pre-defined text windows. There has to be an identical copy of popup windows for each category, device, object, station and region on each workstation with the pre-defined text or symbols in it.

At run time, when the category elements are displayed, the element order, state and presence bits are used to tailor the popup, to match the state of the data and display it correctly.

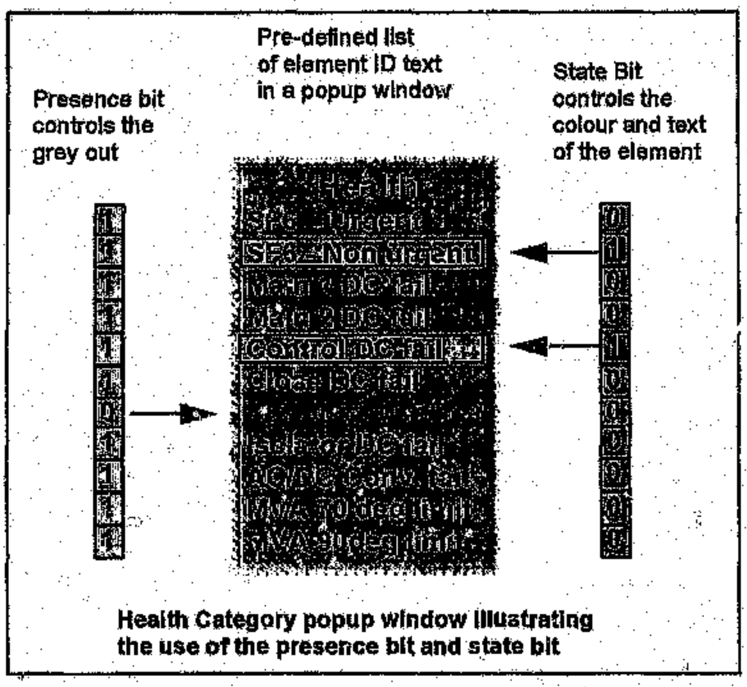


Figure 6-7 Example of the presence bit in use

Control staff know that the order of element information is always the same for similar devices. Non commissioned elements are left out and elements in the abnormal state have the background colour behind the text inverted as indicated in Figure 6-7.

When new equipment is added at the substation, a data base update has to be done at the host to add equivalent device records. The elements, category details are added automatically when the device is added. The presence bits on the device and individual elements are used to control how these items are displayed on the screen at run time. If the presence bit is inactive, the MMI will display the relevant device or element in grey out mode. When elements get commissioned at the substation the 'presence' bit is set to active at the ERTU making the device or element potentially visible on the screen. Setting the matching presence bit at the host to active, completes the data path and the relevant element or device becomes visible and usable by the control staff of the different control centres.

This technique allows the different control centres to activate new elements, devices or electrical objects at their leisure providing that the relevant record is active at the ERTU and that the host data base has been updated. For this philosophy to work, it is essential to have an agreed wiring standard in place and used by all ERTUs.

6.15.1 Plant commissioning

The plant commissioning stage of new equipment can also be reduced by negotiating with the vendor of the equipment to have the interface cables from his equipment to the bay processor match a standard wiring code. This will allow plug compatibility to be instituted across all equipment of the same type. The saving in commissioning time and labour charges will be enormous as there is no need to wire out each element state from the plant cable to the ERTU. The vendors cable is plugged in directly to the bay processor and tested automatically from the ERTU using software programs.

6.16 Example

Using the conditions in Appendix 1, to demonstrate what the control staff would see using the new philosophy, the alarm data sent to the control staff would be combined by the ERTU to form the following messages;

```
15:23:27 *4 TUTUKA MAJUB1_ BKR, 1/ /0SEC 1 & 2, UNIT 2_400 BUSZONE
           Units 3 , 6, TRIPPED ON REVERSE POWER
15:23:31 *4 MAJUBA TUTUK1_BKR TRIPPED - CARRIER RECEIVED
```

Returning to Appendix 1, the frequency analogs on the one-line displays would all be in red indicating a low frequency, but there would not have been any alarm text messages sent to the control staff. They would always be a member of the control staff monitoring the frequency who would react accordingly and notify the rest of the shift.

The next three Breaker close messages would be logged with explanations using the element details (if they were available). However in the example there are no indication as to what caused the devices to close. The text would be the same as it is in Appendix 1.

```
15:23:34 *4 TRIDENT   RUSCM__BKR        CLOSE
15:23:35 *4 MAJUBA    TUTUK1_BKR        CLOSE
15:23:41 *4 HYDRA     SVC2_CX3_BKR      CLOSE
```

The next phase of the disturbance involves automatic load shedding causing the following messages to be logged.

```
15:23:42 *4 APOLLO CNVRT FILTR2_BKR  TRIPPED on Under frequency
15:23:42 *4 AVON  UMGEN 1 & 2 BKRs  TRIPPED on Under frequency
15:23:42 *4 AVON  STANG 1 & 2_BKRs  TRIPPED on Under frequency
15:23:45 *4 HYDRA     SVC2_CX3_BKR TRIPPED on Under frequency
15:23:47 *4 KOMATIPOORT  INFLN__BKR  TRIPPED on Under frequency
15:24:29 *4 IMPALA PONGL & HILLV BKRs TRIPPED on Under frequency
15:24:31 *4 MULDERSVLEI TRFR 4 & 5 (66 Kv) BKRs TRIPPED on Under frequency
```

Effectively the first 106 messages from Appendix 1 would be reduced to12 text messages. They provided the control staff will the necessary level of detail without unnecessary clutter. The icons next to the relevant devices would be displayed and automatically cleared as the system stabilised. The control staff would be able to generate the various message listings, similar to Appendix 1, depending upon what they needed. In general the critical information was provided in the form of messages and the existence of abnormal elements in the form of icons, providing the control staff with the ability to see the detail when required.

6.17 Summary

This chapter has proposed a solution to the data over loading problem. The solution is based on the mental model of the power system data pyramid and requires a certain amount of restructuring of the host and ERTU data bases. Once the host data base has been changed so that there are distinct levels, the focus of attention is moved from the element level up to the device level. The solution also requires the standardisation of the element order for each device and their grouping into categories, both at the ERTU and the Host.

The device record at both the host and ERTU is changed to include the number of elements per category in the abnormal state. The data acquisition retrieves the device state and the category details as one pass and uses changes in the category counts to solicit the element data when time is available in the DAQ cycle. The concept of device icons and presence bits is introduced and examples are given of their MMI use. Lastly the logged messages in Appendix 1 were used to demonstrate how the number of mecsages are reduced. The ERTU combines the element information from the device to construct a text message with additional information and send it to the host.

7. HOST MMI FUNCTIONS

7.1 Introduction

In the previous chapter details were given of the data structure at the ERTU and the host. Mention was made of pyramid structure and how the category counts are propagated to the level above. This chapter explains how these category counts are used by the MMI and how the MMI is used by the control staff to control the data displayed and the options available during the two distinct network operating modes.

7.2 Data view philosophy

In classical SCADA systems the behaviour of one-line displays cannot be controlled or modified by the user at run time. However, in line with the philosophy of giving the user control of the data sent to him, facilities are provided to change the display and the data to suit his needs and the state of the power system. The difference between the classical display philosophy and the proposed solution is defined in Table 8.

Classical MMI	New MMI philosophy
Displays are built from the SCADA data base with no knowledge of the actual network connectivity or topology.	There is an additional plant model between the displays and the SCADA data base that supports network connectivity
Displays are compiled off-line and stored on the host. At run time the display is down loaded to the host and updated every 4 seconds	Displays are built off-line but propagated to all workstations. At run time all SCADA data is transferred to the workstation. The changes cause the MMI to display the icons next to the appropriate devices.
Alarm messages are built for every state change and analog limit excursion	Icons are used to indicate element changes. Control staff generate alarm lists on demand.
All alarm messages have to be acknowledged from the alarm lists	Alarms are automatically acknowledged after a pre-set interval or manually by selecting the icon or device.
No ability to change the display behaviour	Filters are available to the Control staff to dynamically alter the displays. The filters are based on the data pyramid levels, the categories and busbar voltages visible on the display at run time.
No time line facilities	A device event time line (similar to alarm list) is visible that allows the tracking of the device changes over a time period relative to the contents of the display. The range of the time line and its content are selected and based on the time stamp data stored in the relational data base on the workstation.
There are query facilities	Alarm lists can be generated by query based on the contents of the display, the data pyramid levels and the categories

Table 8 Comparison of the differences between classical and the new MMI.

7.3 New MMI philosophy

Classically the CRT is used to display data from the host with no ability to act independently of the host. The dynamic needs of the control staff are not considered and the best common denominator is used to define the contents of each one-line display, which tended to add fuel to the data overload fire during a disturbance. An alternative method of data display is needed to assist the control staff with the monitoring of the power system.

The philosophy proposes a different approach that regards the workstation window as a workbench consistin^ of a number of input and output areas. In the centre is the primary one-line display outp. area and around the periphery are the related and associated output areas as indicated in Figure 7-1.

7.3.1 Output views

The associated output view areas are:

- Current category counts for the pyramid level visible on the one-line display area
- Network navigation window
- Region navigation window
- List of the previous 20 one-line displays referenced
- Time line window
- Alarm Bin notification area

7.3.2 Input views

The input view areas are :

- Category filter selection
- Alarm message query and Secretary mode functions
- Display controls
- Time line controls
- Supervisory control and data entry input window

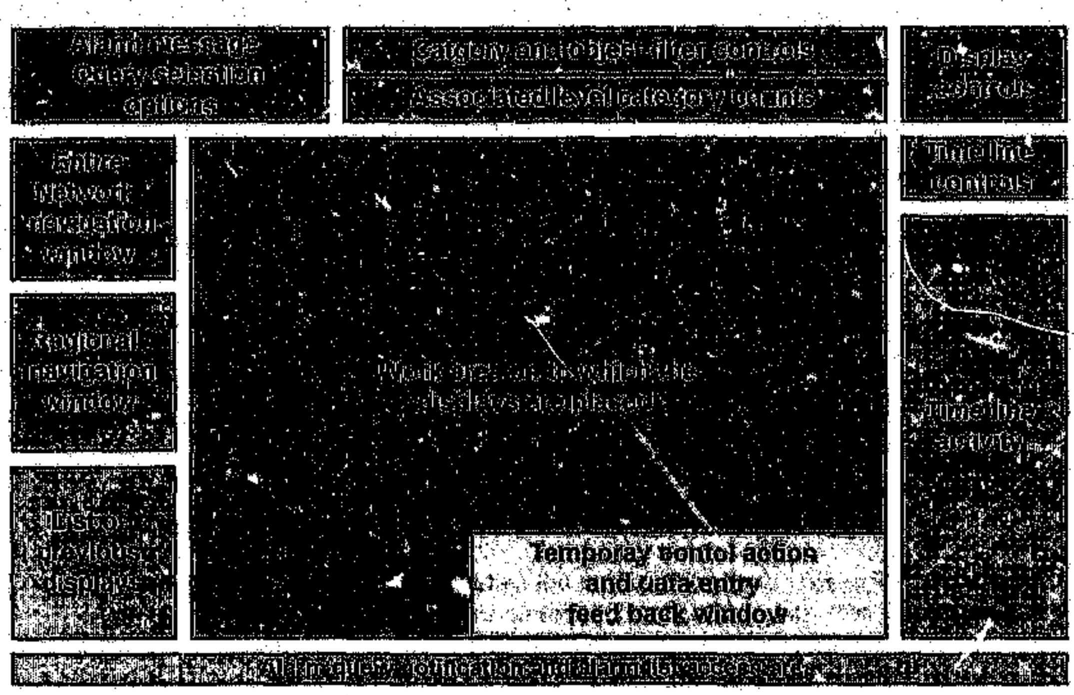


Figure 7-1 MMI Work bench layout

The view areas are updated when ever a new one-line display is placed in the one-line output window.

7.4 MMI Data flow

As indicated in Table 0, there is a complete nodal based plant model of SCADA system between the SCADA data base and the one-line displays on each workstation as shown in Figure 7-2.

Element data, device state and category counts are sent from the SCADA data base to each workstation connected to the host whenever there is an element change. It is the responsibility of the MMI software on each workstation to update the category counts at each level in its plant model to match the network behaviour.

Changes in the plant model cause the graphical model to be updated based on "if-change" logic in the plant model. Each one-line display has a list of display attributes that retain the state of the display when it was last called up on the workstation. These attributes settings are restored to the relevant output views when the display is called up.

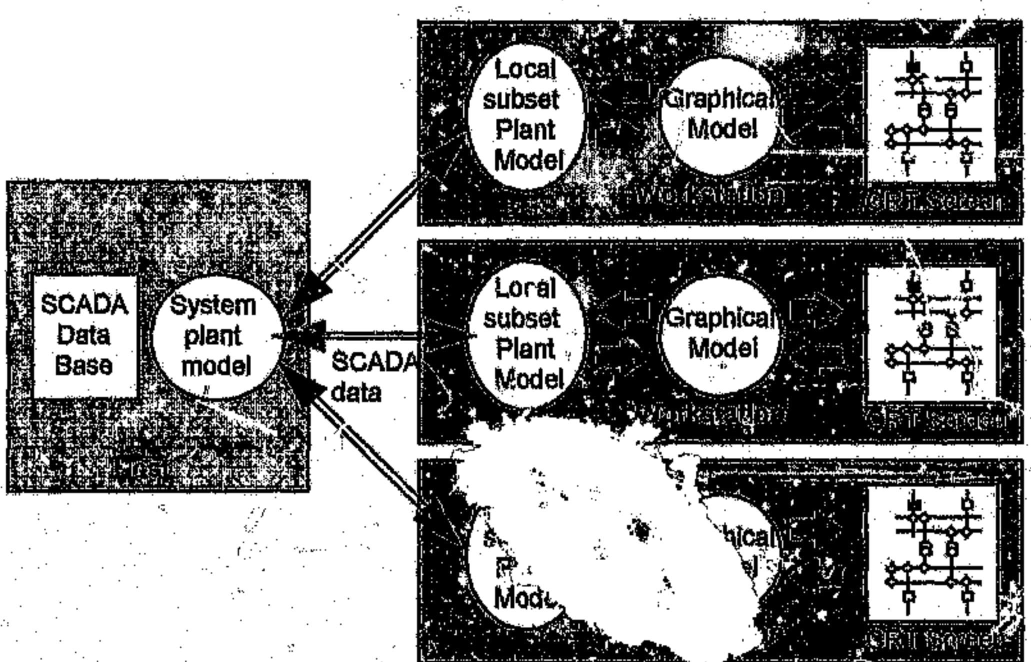


Figure 7-2 Logical data base structures at the host and workstations

7.5 Output behaviour on display call-up

When a display is loaded into the one-line work area, the workstation MMI has to determine the state of the associated output views and update them accordingly as indicated in Figure 7-3:

Each view is updated in parallel when the one-line display is requested. The output views are changed to reflect the previous stored settings last used and the current values of the dynamic values, i.e.

- New category counts for the associated level being displayed
- Grey out of all the electrical objects buttons not represented by the current on-line display
- Time line events according to the time range and category selection flags associated with the current one-line display
- Update the navigation windows to reflect the position in the network that is on display.

Once the output areas have been updated the user can alter the display by changing the input view values.

7.6 Input view areas

The input view areas are:

- Category filter selection

- Alarm message query and secretary mode area
- Display controls
- Time line controls

The content of these view areas allow the control staff to affect the behaviour of the output views. The view functions are detailed below;

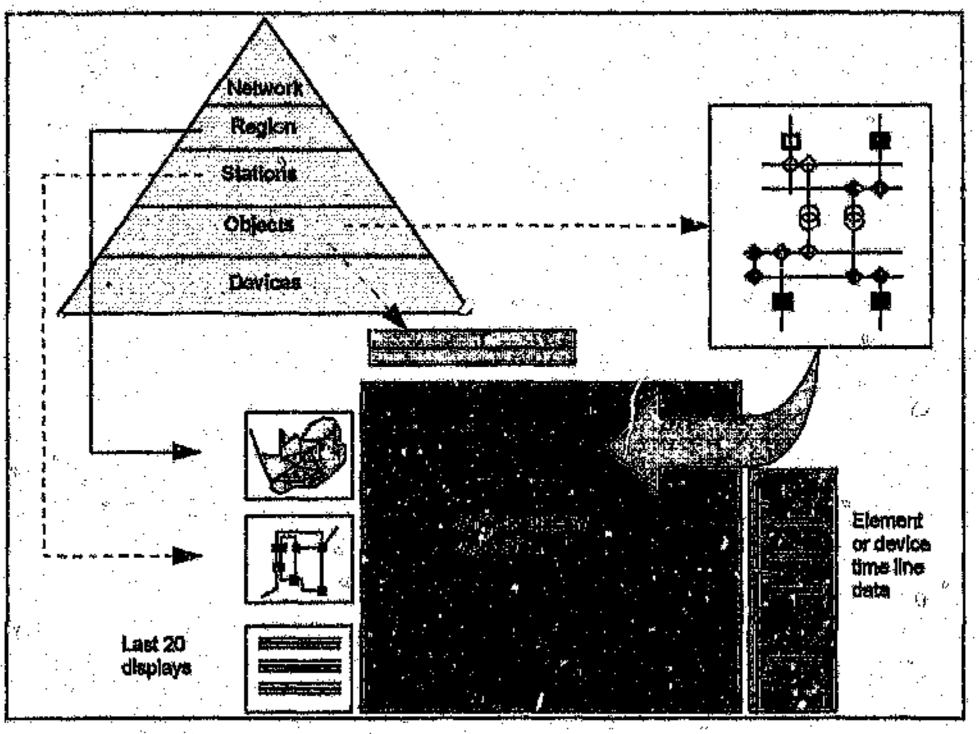


Figure 7-3 Data flow when a display in called in to the work area

7.6.1 Category Filter

The buttons allow the user to either display or hide category icons on the display

7.6.2 Alarm query

This view allows the control staff to generate a listing of alarm text messages based on selected criteria. The last 16 state changes of each element are stored in a relational data base that is used to satisfy time based queries. The options are :

- By Time (in the range specified)
- By category type
- By electrical Object type
- By Voltage level
- By region, or station , or object or device

In addition the user can set up pre-defined sets of conditions and save them by name. Saved queries are activated by selecting the saved name from the alarm bin output view at the bottom of the screen. The output from the query is a display containing the selected alarm message text data which can be printed as required.

7.6.3 Secretary mode

This activity allows the control staff to set up a series of functions to be performed on the plant model data so as to advise them of states in the network, region, station, object or device that he requires. This activity is covered in more detail in the next chapter.

7.6.4 Display controls

These functions allow the control staff to change the data on the display by using conditions in the plant model. The options available are :

- Indicate the range of protection operation on an electrical object or station or network
- Connectivity tracing of a selected object
- Grey out (or reduce the visibility) of devices, objects or stations according to the selection criteria.
- Declutter the display by removing text, analog and category indications.
- Turn off all flashing indications

Before the effects of the display controls can be demonstrated it is necessary to define the layout of a one-line display.

7.7 One-line display representation

Figure 7-4 is an example of the one-line diagram of a substation as seen by the control staff. The diagram consists of two sets of busbars, each with a busbar coupler and two transformers coupling the busbars together. There are three feeders connected to each bus with a bus section coupler on the lower 400 KV busbar.

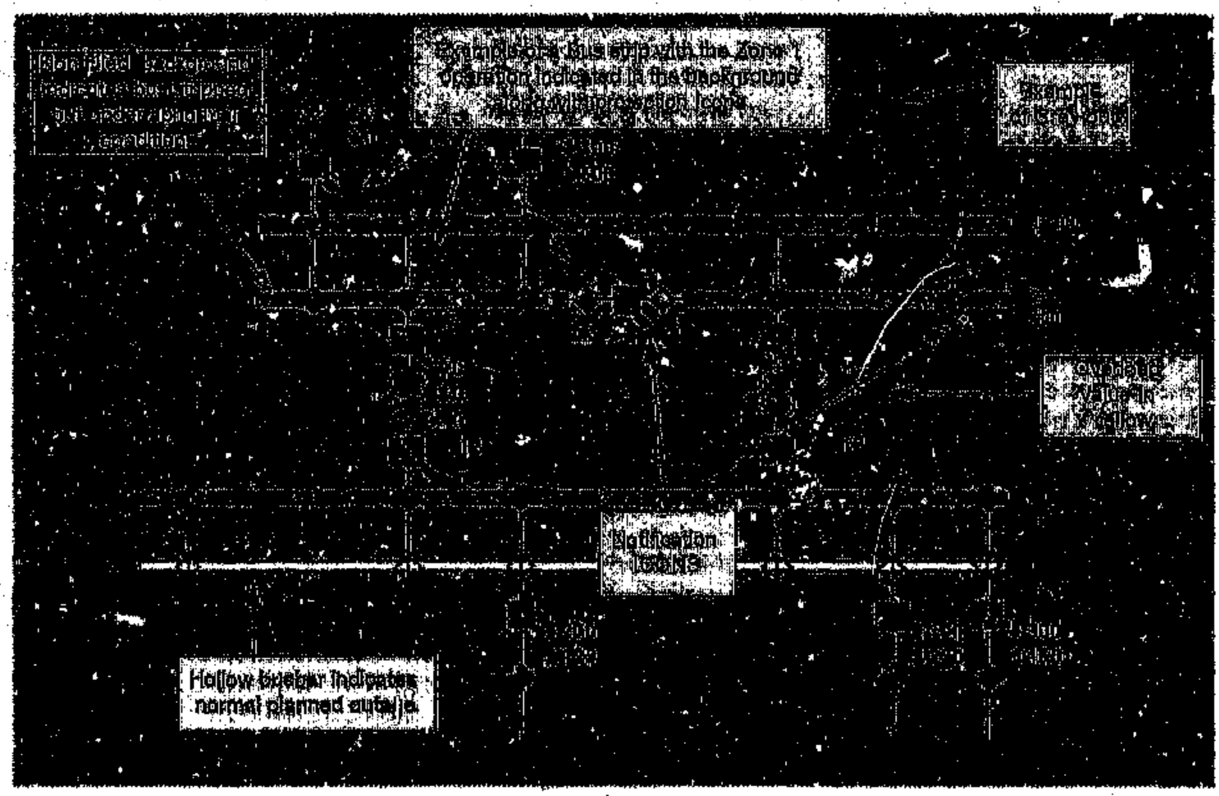


Figure 7-4 Example of a one-line display with grey out and icon indications

The diagram represents a situation where there has been a fault on the 400 KV busbar and the bus zone protection has operated causing the feeder, the transformer and the bus section breakers to trip. As a consequence of the transformer tripping, the load across the second transformer has exceeded the high limit, resulting in the analog value being displayed in yellow. The consequential category icons are displayed next to the relevant devices.

Each electrical object, device and analog are defined for display purposes using unique graphical symbols and colours;

- Breaker Rectangle (Red = closed, Green = open)
- Link/DisconnectDiamond (Red = closed, Green Open)
- Line segments Lines (solid = on load, dotted = disconnected)
- Busbars Narrow rectangles coloured according to voltage
- Analogs Numbers (Blue in limits, red = exceeded limits

7.7.1 Voltage Colours

Each electrical object is associated with a busbar and voltage. The busbars are coloured according to the voltage as follows;

765 KV	Magenta
400 KV	Green
275/220 KV	Orange
132 KV	Cyan
88 KV	Blue

Using the viewing tools the control staff can change the details of the one-line display as required.

7.8 Viewing controls

The advantages of the plant model allows the control staff to examine the effects of the connectivity between the different electrical objects. Without the plant model, it would be impossible to determine the effect of protection operation on the power network, nor how a particular transmission line is connected in a station or a region. The plant model allows the control staff to see the protection operation effects graphically by changing the background behind a feeder or transformer dynamically on demand as indicated in Figure 7-4.

By changing the background behind the electrical objects allows the control staff to obtain a very quick understanding of the protection operation "in-context" with the state of the network and not have to wade through miles of text messages to determine the current state.

7.9 Summary

This chapter explained the layout and structure of the workstation and how the control staff have different input and output windows through which they control the data on display by manipulating the different options available in the input views. Details are provided of the tools the used to control the one-line display to match the operating needs of the system. An example is provided of how the one-line display would be output following a busbar strip using the protection information to change the display background around the affected electrical objects on view.

8. SECRETARY MODE FUNCTIONS

8.1 Introduction

This chapter examines the role of an Intelligent system located at the ERTU and the type of functions that such a system can perform and how they interact with the control staff a the control centre.

8.2 Secretary actions

In most business organisations the manager has a secretary who's task it is, to provide a number of services such as:

- Shield the manager from unimportant phone calls.
- Take messages for delivery later on
- Make appointments
- Advise the manager of meetings and events
- Type letters and reports
- Do searches for specific things
- Construct cross references of various documents

For example, a manager, one can assume, has requested the secretary to "hold all calls" under given circumstances.

It can also be assumed that the secretary "knows" that calls from certain people have more weight than others or provided the caller uses the correct "passwords" such as "very urgent", "fire" or "life and death". Under these conditions, the secretary has implicit permission to interrupt the manager and put the phone call through to him.

This simile could be taken a bit further, if the ERTU is equipped with software that can detect when the rate-of-change of a particular value is about to exceed a previously set limit, causing a breaker to trip. The ERTU can use this information to formulate and send a text message to the Host advising the control staff of the impending event.

The first point to remember is the ERTU would initially have raised a Health flag against the device in question. If there is no change within a given time period the ERTU has the ability to raise the state of the alarm to a higher level, which it can do, by setting a station level alarm element. The last stage is to formulate and send a complete "text" message which can, if needed an audible alarm can be attached to it. It would be up to the control staff to take the necessary action to prevent the breaker form tripping if possible.

"Secretary Mode" activity is the result of intelligent system software installed at the ERTU and the host .The results from the Intelligent System at the ERTU are passed to the control staff via the SCADA, the ALARM and the Man Machine Interface.

8.3 The role of intelligent systems

A lot of time and money has been spent implementing Expert Systems for use in alarm processing with the Expert System centrally situated at the Host. For any Electricity Utility alarm processing Expert System to function correctly, the Host must have ALL the required data and be able to deliver a solution in real time. This is not really possible since the Expert System requires a valid network state in order for the rules to work correctly. During a disturbance, the coherent network state needed for topology processing usually takes between 10 to 20 seconds to achieve from the time the last breaker tripped. Thus a disturbance lasting minutes, effectively disables the expert system using topology software, until the last Breaker trip message has been delivered and a scan of all the analogues has been completed.

Since RTUs now have more CPU power, there is every reason to split up the Intelligent System logic between the ERTU and the Host. This provides far more opportunities to implement simple rule based algorithms at both the Host and the ERTU. Apart from the CPU power available, the ERTU has its own data base which is updated with live data between 1 and 5 milli-seconds. Adding code at the ERTU to process the live data will allow local algorithms to perform such activities as ;

- Local "simple" State Estimation or Power balancing

  For example, apply Ohm's and Kirchoff's laws to all electrical objects for example, feeders, transformers and busbars at the station. The benefits are indication of bad analogue and status indication more rapidly, clean input data to the Host State Estimator, more precise data for control staff, reduction of false alarms. There are many more advantages that affect the Power Application software than the SCADA side.

- Cross checked breaker indications

  For example, if the ERTU has to send a message that a Breaker has tripped but there is still power on the line then this fact can be added to the reported initial trip message.

- The ERTU monitoring of time based elements

  For example, transformer winding temperatures monitored, the ERTU can perform rate calculations and predict when the transformer protection will operate if nothing is done to relieve the situation. A message indicating potential trip can be sent to the Control staff, informing them of the problem. This will allow the control staff to the power system in advance and not wait for the device to trip before doing anything.

- Protection flags can be used to provide additional details of what has tripped and why

  For example, applying simple rules using the element data belonging to an electrical object it is possible to determine the cause of the protection operation. The fault diagnostic text message can be sent to the control staff under the information category of the object.

  Additional fault diagnosis algorithms can be used to offer a number of possible reasons causing the event. When the fault is between substation, both ERTUs send the list of possible reasons to the host. If the host finds matching suggestions these can be forwarded to the control staff. In the event of no matching suggestions, this too, can be used to allow the control staff to examine the offered suggestions and make decisions. It is easier, cheaper and more maintainable to set up a Intelligent System located at the ERTU, that interacts with the Host as and when required, than it is to build a complete Expert System at the Host alone.

The benefits of using the CPU power available at the RTU are substantial and inexpensive compared to using the Host to supply element data to an Intelligent system. The complexity of the ERTU fault diagnostic software does not have to be very involved or expensive as the number of inputs available for processing are not that large but the potential benefits during quiescent and disturbed states are enormous.

8.4 ERTU activities

The ERTU secretary mode activity involves the normal actions of supporting and propagating pyramid data changes and performing the algorithmic activities as required. These involve:

- Category abnormal element counting and time tracking
- Critical device state message formulation and delivery
- Status and analogue error notification to maintenance staff
- False alarm detection
- Power Balancing and mismatch error reporting

* Checking Electrical Object mode transitions and reporting on expected events not taking place.
* Sending maintenance related messages to station and maintenance staff

There are additional activities that can be implemented once the software has been installed and demonstrated to the control staff.

8.5 Host activities

These revolve around the MMI needs of the control staff and initially take the form of global, area or station summaries of specific device states, for example:

* Changing the display to indicate only those devices with the conditions as specified by the selection criteria currently active.
* Listings of specific device types current state
* List all elements in a given alarm state since a given time.
* Provide an audible alarms if a selected number of analogues exceed specific limits at the same time.
* Analog rate monitoring alarming
* Reacting and responding to ERTU secretary results

Once expert system software is introduced, a large number of additional station specific actions can be implemented.

8.6 Summary

This chapter defined the concept of Secretary Mode functions using limited versions of intelligent system software that can be installed at the ERTU and the host. The functions are designed to assist the control staff in overcoming the problem of data overloading by making use of new technology situated at the workstation and the ERTU.

9. JUSTIFICATION OF THE SOLUTION AND EVALUATION OF ALTERNATIVES

9.1 Introduction

This chapter examines the current upgrades taking place at the ERTUs and examines the consequences if nothing is done to change the existing method of data acquisition and the display of data.

9.2 Data Base Increases

The ESKOM SCADA system in its current form has 28 000 element points installed with a maximum of 45000 allowed for. With the replacement of the 140 RTUs by ERTUs during the next 4 years and plans to wire up each device according to the Telecontrol wiring standard, the number of elements being telemetered and modelled in the SCADA data base is going to increase by 71000 elements. The consequences of this action will generated enormous problems during a disturbance, unless something is done to change the method of data acquisition and display.

Table 9 lists the number of elements per Breaker device for the previous and current Telecontrol standards. The table lists the number of breakers in each of the different electrical object types in the ESKOM interconnected power system which covers voltages from 132 to 765 KV. The combined number of breakers devices for all objects is 2578.

	Generators	Feeder	Couplers	Transformer	Shunt
Breakers	121	1069	418	869	113
1990 Elements/BKR	1	8	4	6	6
1994 Elements/BKR	3	35	27	39	40
Difference	2	27	23	33	34
Extra Elements	242	2886	9614	28677	3842

Table 9 Element differences between 1990 and 1994 Telecontrol Standards

The additional elements = 71238. If all these additional elements are implemented, there will be a potential increase of 250% in the data loading of the control staff.

9.3 Installing new elements

Assuming it takes 5 minutes to add each of the 71000 new records, it will take nearly 3 man years just to add the data into the SCADA data base. This excludes time needed for display building, testing and commissioning. Once new records have been added, a data base update is required before the new elements can be scanned.

Implementing a standard where the elements of each device are pre-ordered and pre-defined for identical devices and wired up with presence bits set accordingly, will reduce the time needed to add new element significantly.

Generators	Feeder	Couplers	Transformer	Shunt Capacitor	Series Capacitor
Breaker	Breaker	Breaker	Breaker	Breaker	Breaker
Links	Links	Links	Links	Links	Links
Generator			Transformer	Reactor	Cap

Table 10 List of devices per electrical object

According to the Telecontrol standard, there are eight electrical object types and a three station related objects. Each electrical object consists of one or more devices as defined in Table 10 and Table 11. Each device requires its own pre-defined and pre-ordered element structure. Thus there have to be twelve unique pre-defined sets of element tables. These tables have in-turn to be divided into four categories

Shunt Reactor	Series Reactor	Static VAR. Compensators	Station	Security	Sent Out
Breaker	Breaker	Breaker	Bus Zone	Security	Sent out values
Links	Links	Links	DC Supply		
Reactor	Reactor	VAR. Unit	Comms		

Table 11 List of devices per electrical object (continued)

To activate a "new" element in the data base is limited to setting the presence bit to 1 in the relevant device and ensuring that the ERTU commissioning staff have wired the element to the correct "pre-defined" index. There is no need for data base updates to commission new elements as the space is already reserved. The data base staff simply change the presence flag to active and the element is in service.

Totally new devices still require a data base and display update.

Since the commissioning of new elements is carried out on-line the need for large inter control room planning by data base and RTU field staff to synchronise the commissioning of new elements largely falls away.

9.4 CPU Loading Consequences

An increase from 20 000 to 71 000 elements may require additional CPU power if the existing 2 and 4 second response time is to be maintained.

The proposed solution is based on the current trends in the computing industry, the needs of control staff and the demands for additional information in the control room.

9.4.1 Expected changes in the computing and electrical industry

The changes in the monitoring and control of the electrical utility industry are expected to be;

- Host computer power will increase by between 10 and 100 fold in and around the control room during the next five years.
- Full graphics workstations will be delivered and installed with very superior MMI facilities in comparison to the classic character graphic display devices of the past.
- Power system protection schemes will move towards digital protection equipment. This protection equipment will interface directly to the RTU, providing useful additional data to the control staff. The protection information, linked to expert systems at the RTU will provide for the rapid understanding of conditions in the power system during and following a disturbance.
- Remote terminal Units will be replaced by intelligent versions equipped with increased computer power.
- The introduction of wide area networks providing more secure data communications and wider bandwidths.
- The need for the SCADA system to provide high value, low priority data outside the control room, e.g. hourly consumer metering data and sequence of event data for protection and fault analysis.
- Multiple control centres will access the same ERTU at the same time.
- Phase three protection will provide additional element data point as indicated in Appendix 5, which lists the elements for a Static Var. Compensator. This Appendix completely changes the values in Table 11 where only a fraction of the information is used.. The consequences of adding the additional data elements will place additional burdens on the Control staff if the existing methods of display are used.

This issue of concurrent access of the same ERTU by different users causes severe maintenance problems. Currently when new points are commissioned at the ERTU, the different hosts scanning the ERTU need to have their data bases updated at the same time otherwise there could be overall loss of data until the ERTU and the host are brought into line. The proposed solution provides a possible solution to the multiple host access problem by including maintenance related data bits in the ERTU and the host data bases.

9.5 Summary

The aim of this paper is the discussion of ways and means to remove or curtail data overloading suffered by the control staff during disturbances. In addition there is also the need to speed up the time it takes to obtain a clear picture of the current power system state.

Retaining the existing methods of data storage and DAQ functionality and implementing the additional element data as per the 1994 Telecontrol standard, the *potential* consequences to be considered are;

- Massive data overloading of the controls staff during disturbances.
- Additional data base and display staff will be required to keep up with system growth.
- Additional communications bandwidth will be required to cater for the increase in data acquisition needs.
- The ability to access phase three protection indications will be restricted.
- CPU loading will have to be increased to support the additional MMI activity.
- The i.troduction of Expert Systems will be delayed and their functionality reduced.

On the other hand if the proposed ERTU, communication philosophy and MMI design is implemented in conjunction with the 1994 Telecontrol Standard, there are a number of a advantages;

- The need for large numbers of data base updates is reduced
- On-line commissioning of new elements is possible
- Clearer understanding of the total electrical state more easily achieved and in a shorter time
- Expert systems (both central and distributed) can be added at the RTU and the Host to provide real time assistance to the control staff.

10. CONCLUSION

10.1 Introduction

This chapter evaluates the proposed solution and offers a critical review of the report as a whole. Lastly, the development plan for the implementation of the new MMI philosophy is considered.

10.2 Evaluation of the new MMI

Each of the problems initially defined in Chapter 1, are re-examined in Table 12, in the light of the proposed new MMI philosophy.

Problem	Solution
a) Inconsistent significance in alarm messages.	Corrected by matching the data on display to the mental model required by the Control staff. They are no longer at the mercy of the text in the message but are able to see what-they-want-when-they-want-to.
b) Recurring alarms.	Apart from the three "required" text alarm messages types, there is very little chance of recurring alarms being sent to the control staff directly. Secretary mode functions at the RTU and the Host would detect them and it would then be up to the maintenance staff to correct the problem at the ERTU.
c) Too many alarms. *d) Alarm overload during a disturbance.* *e) The number of alarms is sometimes overwhelming.*	These problems are no longer relevant if the proposed solution is implemented. The control staff will not have unwanted text messages sent to them directly. Icons next to the devices will indicate the presence of abnormal states.
f) Alarm threshold too sensitive.	Assuming that this refers to analog alarms, Secretary mode functions can be used to ensure that in-context limit checking is within bounds to provide some relief. The initial cause of the problem is usually the inflexibility of the limits or the width of the dead band. Simple pattern recognition and ime of day checking can prevent this.
g) Lack of alarms on key parameters. *h) Need for more detail from substations.* *i) Some alarm messages do not contain enough information.* *j) Some alarm messages contain too much information.*	It appears as if these problems relate to the needs of the Control staff when attempting to construct a mental model of a particular situation. Implementing the 1994 Telecontrol standard should correct these problems as well as providing Control staff with the ability to access all the element data belonging to a device on demand.
K) Alarm display problems with paging. *l) Bottom line changes too fast (this is the current alarm list).*	Apart from the extremely limited number of Breaker text messages, this problem no longer exists as all "alarm" data is visible as icons on the display. However the inherent problems with any data list still remain, particularly where new messages are being inserted and deleted on demand.
m) Some alarms are needlessly repeated. *n) Multiple messages are generated for the same condition.*	By implementing the proposed solution the element change will only be seen if the control staff examine the device in full via a popup window. Secretary mode software would notify the control staff if something did not happen as expected.

Table 12 Evaluation of initial problem in terms of the new MMI

From the review of the defined problems, the proposed solution, it is believed, will provide a solution to the data overload problem. Only careful testing under controlled conditions will provide concrete proof of the theories in chapters 6, 7,8 and 9.

10.3 Concept model MMI

The ideas in this report were used to build a concept model of the proposed MMI using Microsoft Access and demonstrated to control staff and management. The concept model is primitive but does contain enough dynamic behaviour to demonstrate the viability of the theories.

10.4 Prototype

Based on the concept model, ESKOM management have authorised the development of a prototype to be used by the control staff under controlled conditions to prove the functionality of the new philosophy. The prototype will be connected to a power system simulator to provide disturbance data, will be used to check the precise requirements and determine the full functionality of all MMI actions and tools.

The prototype will provide a complete environment in which the control staff will have the opportunity to test all possible network scenarios using controlled network activity. The prototype will also provide the basis for controlled MMI usability engineering studies to assess performance accurately and for the accurate comparison of the existing and proposed Man Machine Interfaces.

Before the prototype can be developed, a number of areas need attention;

- What is the best hardware and software environment to be used to develop the test bed?
- Is an object model the best way to represent a power network?
- How easy is it to build an object oriented plant and graphical model and get them to talk to each other and to the data source?
- How easy will it be to assess the Control staff acceptance and the efficiency of the new philosophy?

10.5 Financial consequences

It is not easy to accurately estimate the full impact of the proposed solution in financial terms. However it is important to examine the cost to ESKOM and the country during a disturbance, if the existing alarm philosophy is retained.

The initial costs are in the design of the new MMI and the changes to the ERTUs and the communication protocol. The cost of changing the host data base and adding the category count changes is far smaller.

The initial estimates of the financial costs are;

10.5.1 ERTU costs

The Estimated costs to develop the ERTU to meet the requirements is approximately R500,000 and involve:

- Derived value code
- Data Base changes
- ERTU secretary mode functions
- Category counting
- Text message formulation and transmission

10.5.2 Host costs

The estimated cost to develop the changes needed at the host to support the workstation is approximately R300,000 and include :

- Data Base changes
- Category count propagation up the pyramid
- ERTU text message receipt

10.5.3 Protocol costs

The estimated costs to upgrade the protocol to support to changes needed for the host and ERTU communications are approximately R500,000 and include:

- Transmission of mixed data messages
- Inclusion of the time stamp data
- Text message transmission.

10.5.4 MMI costs

Once the test bed interface has been developed and tested using live data by all the interested users, it can be used as a living specification for the production version of the MMI. The estimated costs for its development by a vendor is R 300,000 and assumes that the prototype software is not reused.

10.6 Responsibilities

Once the proposed changes are in place, ESKOM would have to ensure that the pre-ordering of the data elements at the RTU are adhered to in all installations.

Training will have to be provided for the control staff and all maintenance staff involved with the operation of the control system.

All existing intelligent ERTUs will have to have changes made to their wiring and internal data bases to match the Telecontrol standard. It is possible to phase in the changes gradually, with a hybrid system in place during the implementation.

10.7 Implementation Plan

Once the prototype has been build and approved by all potential users, a joint development team should be set up to plan and install the proposed changes with the original SCADA equipment system vendor. The complete project would take about 24 months to complete.

Software and hardware staff are required in the following disciplines to assist in the implementation of the philosophy;

- Data Base maintenance
- Application Software to ensure that SCADA functions still operate correctly
- Data Acquisition staff to develop the RTU and DAQ interfaces at the RTUs and Host.
- Man Machine staff to build the support tools.
- Power Application Software staff investigate and maximise the ERTU options available to Power Engineering facilities.

There are a number of additional areas that still need to be investigated;

- The ability of the communications protocol to support the requirements.
- More work needs to be done using simulators and hands on evaluation of the proposed solution before a full acceptance by management.
- It is difficult to do a full cost benefit analysis as there are still a number of unknowns.
- No work has been done on the impact on any of the Power Application Software such as Contingency Analysis, Short Circuit Analysis or State Estimation. These modules may need changes to benefit from the ERTU secretary mode options.

10.8 Critical Review Of This Report

While it is believed that the proposals outlined in this report are, in general new and untried, they should meet what is considered a critical and growing problem facing not only ESKOM, but all major Utilities. It is, however, conceded that the proposed solution is unlikely make the work of control staff easier during quiescent network conditions. In addition the methods of monitoring the power system state in the control room will need to be examined to see if changes must be made to cater for the proposed display of abnormal element indications.

However, the enthusiasm demonstrated by the control staff during the demonstrations of the concept models indicate that they are more than ready for the offered functionality. They are also more than ready to suggest ways and means to improve the facilities that they badly need.

One of the foreseeable problem areas will be control staff reliance on the ERTU algorithms to advise them of problems at the substation. In the event that the algorithmic output is incorrect, the control staff will blame the new philosophy. The prototype will have to be used to evaluated these algorithms in more detail with the intention of making them more robust and testing the built-in self diagnostic functions.

The following sections highlight specific areas of concern.

10.8.1 Mental models

The concept of a mental model is still open to debate as there is no unanimity as to what a mental model is or how it is formed. To quote from Staggers and Norcio [19] "Mental models are created by the users as they interact with the target system images and may not be equivalent to the conceptual models. These are what people really have in there heads to guide their use of things."

The mental models used in the study are still very much based on group discussions and not on exhaustive studies of the individual Control staff members. More work is necessary, as the tools to determine what constitutes an accurate model of a physical system, are not available at present.

10.8.2 New knowledge

On completion of the prototype, the metrics used to evaluate the Control staff behaviour will be available for use in other disciplines using Industrial Man Machine Interfaces.

10.8.3 Support

Staff from a number of disciplines in ESKOM have been exposed to these ideas and have welcomed them. There are many areas that need additional work, especially in the area of non-standard elements. Decisions will be needed on the best methods of grouping the elements and selecting the category that they should belong to.

More details could by required in the area of MMI secretary mode tools, however as this is still a concept, more time is needed to develop the functionality.

10.8.4 Academic view

From an academic point of view, the suggestions in this report add to the wealth of comments on MMI in general, but do provide useful input from a practical point of view, based on first hand experience of MMI design. From an industrial aspect, they offer a possible solution that could be implemented in similar disciplines such as oil refining, ships, aircraft, mining and steel mills, to name a few.

Once implemented, there will also be a major change in the role of the Man Machine Interface as it will be able to respond to a wider range of user demands to meet the network changes.

If the ideas are implemented, there will be serious developments in "Secretary mode" tools to satisfy the needs of the control staff and protection engineers. These developments will offer many opportunities for the use of Expert and Intelligent Systems.

10.8.5 Advantages

The benefits of implementing the proposed solution are:

- Reduction of control staff stress during a disturbance.

- Control staff have more control over the data they need rather than being at the mercy of the SCADA system.
- Development and introduction of low cost "value added software" at the RTU and Host as an alternative to the very expensive centralised expert systems.
- Reduction in data base and display maintenance time.
- Enhanced matching of the mental models used by the control staff to the physical system.
- Very rapid visualisation of the power system state becomes possible.
- Better use of the full graphic workstations.
- Provide live data via standard one-line displays users outside the control room.

Moving the responsibility for the accuracy of the SCADA data to the RTU, will speed up the ability of the maintenance staff to correct problems in the field. Since the checking or power balancing software can be linked to the substation bay computers. Accuracy checks can be run "off-line" with results available to the RTU commissioning staff independently of the State Estimation software at the Host, which up until now was the only way of completely checking the analog values in a station.

10.8.6 Disadvantages

The main disadvantage of these suggestions are the number of changes needed to the existing facilities, specifically the Host data base, the ERTU software and the communications protocol. However, there does not appear to be any other alternative available.

10.9 Conclusions

After examining the problems and the benefits offered by the proposed solution, the highlights of the philosophy are;

- Control staff are not subjected to large volumes of unsolicited data.
- Element data belongs to the device and hence to the object.
  All data for a given device or object can be viewed in the same time context.
- Control staff obtain an instantaneous feel for the system and the element state in question from a single window, uncluttered by unwanted data.
- Icons displayed next to a device indicate the existence of one or more child elements in the abnormal state.
- Staff using the new MMI determine the level of abstraction that they use to view the network data and control the data is displayed on the one-line displays.
- Cross references of individual device states are indicated by Object and Device Type allowing the control staff to rapidly find information related to the problem they are working on.
- Control staff no longer have to wade through pages of text lists to "see" what the current state of the power network is.

It is believed that it is important to build a prototype MMI and test the proposed solution using live data and demonstrate the results to control staff and management. Only then will it be possible to get support to finance the installation of these ideas.

APPENDIX 1 - COPY OF THE ALARM LOG

Appendix 1 Example of ESKOM disturbance log

Introduction

Example of an event on the ESKOM network which generated 431 of alarms in 10 minutes, with 79 in the first 30 seconds. There was a BUSZONE operation at TUTUKA, caused by the opening of the Tutuka_Majuba KV line links under load conditions. This caused the loss of 1755 MW of generation and 779 MW load by under frequency load shedding. The frequency dropped from 50.00 Hz to 48.88 Hz which triggered automatic load shedding and returned to normal 4 minutes later.

15:21:45	*4	KRONOS	400CPLRA_BKR					CLOSE
15:21:51	*5	UMFOLOZI	NORRX1_BKR		TRIP CONTROL			SUCCESS
15:21:47	*4	UMFOLOZI	NORRX1_BKR					TRIP
15:21:48	*5	MERSEY	1/275B	KV	281			NORMAL
15:22:23	*6	KRONOS	400CPLRA_GROU1					NORMAL
15:23:16	*6	TRIDENT	RUSCM__GROUP1					NORMAL
15:23:20	*4	VERWOERDBURG	VERWR_TRIP_ALRM					ALARM
15:23:27	*4	TUTUKA	MAJUB1_BKR					TRIP
15:23:27	*4	TUTUKA	UNIT2_400_BKR					TRIP
15:23:27	*4	TUTUKA	UNIT3__22_BKR					TRIP
15:23:27	*4	TUTUKA	1/400SEC1_BKR					TRIP
15:23:27	*4	TUTUKA	1/400SEC2_BKR					TRIP
15:23:27	*4	TUTUKA	UNIT6__22_BKR					TRIP
15:23:29	*5	MERSEY	1/275B	KV	280		278	LOW
15:23:29	*5	TUTUKA	UNIT_3	KV	19		0	LOW
15:23:29	*5	TUTUKA	UNIT_6	KV	19		0	LOW
15:23:31	*4	MAJUBA	TUTUK1_BKR					TRIP
15:23:32	*5	LETHABO	2/275-1	HZ	49		49	LOW
15:23:32	*5	LETHABO	1/275-1	HZ	49		49	LOW
15:23:32	*5	LETHABO	1/275-6	HZ	49		49	LOW
15:23:32	*5	LETHABO	2/275-4	HZ	49		49	LOW
15:23:32	*5	APOLLO	2/400	HZ	49		49	LOW
15:23:32	*5	PALMIET	1/400	HZ	49		49	LOW
15:23:32	*5	GRASSRIDGE	1/132	KV	135		134	LOW
15:23:32	*4	TUTUKA	MAJUB1_MOLL					OPEN
15:23:32	*4	TUTUKA	UNIT6__22_MAL					OPEN
15:23:32	*4	TUTUKA	UNIT3__22_MAL					OPEN
15:23:32	*4	TUTUKA	UNIT2_400_MAL					OPEN
15:23:32	*6	TUTUKA	UNIT2_ISLANDE_ALRM					ALARM
15:23:32	*6	TUTUKA	UNIT_5	ON_OFF				ON
15:23:32	*6	TUTUKA	UNIT_1	ON_OFF				OFF
15:23:32	*6	TUTUKA	UNIT_2	ON_OFF				OFF
15:23:32	*6	TUTUKA	UNIT_3	ON_OFF				OFF
15:23:32	*6	TUTUKA	UNIT_6	ON_OFF				OFF
15:23:32	*5	TUTUKA	BATTERY_COMMO					ALARM
15:23:33	*5	POSEIDON	1/400	HZ	49		49	LOW
15:23:33	*5	DUVHA	1/400N	HZ	49		49	LOW
15:23:33	*5	MATLA	1/400N	HZ	49		49	LOW
15:23:33	*5	HIGHVELD	1/275S	HZ	49		49	LOW
15:23:33	*5	ARNOT	1/400N	HZ	49		49	LOW
15:23:33	*5	ARNOT	1/275	HZ	49		49	LOW
15:23:33	*5	GROOTVLEI	1/400N	HZ	49		49	LOW
15:23:33	*5	HENDRINA	1/400N	HZ	49		48	LOW
15:23:33	*5	MULDERSVLEI	SYNCH3	MVAR	72		82	HIGH
15:23:33	*5	MULDERSVLEI	1/400	KV	380		375	LOW
15:23:33	*5	MULDERSVLEI	2/400	KV	380		379	LOW
15:23:33	*5	DRAKENSBERG	1/400	HZ	49		49	LOW
15:23:33	*5	SALT RIVER	Y/33	HZ	49		49	LOW
15:23:34	*4	TRIDENT	RUSCM__BKR					CLOSE
15:23:35	*4	MAJUBA	TUTUK1_BKR					CLOSE
15:23:35	*5	KENDAL	2/400-1	HZ	49		49	LOW

APPENDIX 1 - COPY OF THE ALARM LOG

15:23:35	*5	KRIEL	1/400N	HZ	49	49	LOW
15:23:39	*5	KOEBERG	1/400B	HZ	49	49	LOW
15:23:39	*5	DRAKENSBERG	G/M_3	HZ	49	49	LOW
15:23:41	*4	HYDRA	SVC2_CX3_BKR				CLOSE
15:23:42	*4	APOLLO CNVRT	FILTR2_BKR				TRIP
15:23:42	*5	ACACIA	1/400	HZ	49	49	LOW
15:23:42	*5	ACACIA	1/132	HZ	49	49	LOW
15:23:42	*4	AVON	UMGEN1_BKR				TRIP
15:23:42	*4	AVON	UMGEN2_BKR				TRIP
15:23:42	*4	AVON	STANG2_BKR				TRIP
15:23:42	*4	AVON	STANG1_BKR				TRIP
15:23:42	*5	MAJUBA	2/400-1	KV	420	425	HIGH
15:23:42	*5	MAJUBA	1/400-1	KV	420	425	HIGH
15:23:42	*6	MAJUBA	TUTUK1_BKR	SIR/INIT_RESET			INITD
15:23:42	*5	AVON	CARRIER_UPS_FIL				ALARM
15:23:42	*5	AVON	BATTERY_LOW_VLTAGE				ALARM
15:23:43	*5	MAJUBA	BATTERY_COMMO				ALARM
15:23:43	*5	PORT REX	UNIT_1	HZ	49	49	LOW
15:23:43	*5	PORT REX	UNIT_2	HZ	49	49	LOW
15:23:43	*5	PORT REX	UNIT_3	HZ	49	49	LOW
15:23:44	*6	APOLLO CNVRT	FILTR2_GROUP2				ALARM
15:23:44	*5	ALPHA	BATTERY_COMMO				ALARM
15:23:45	*5	AURORA	1/400	HZ	49	49	LOW
15:23:45	*4	KRONOS	PERTURBOGRAPH				A_N_A
15:23:45	*4	HYDRA	SVC2_CX3_BKR				TRIP
15:23:47	*6	CROYDON	TRFR_3_GROUP1				NORMAL
15:23:47	*4	KOMATIPOORT	INFLN__BKR				TRIP
15:23:48	*4	ARIES	PERTURBOGRAPH				A_N_A
15:23:49	*5	MERSEY	1/275B	KV	282		NORMAL
15:23:53	*5	MULDERSVLEI	SYNCH3	MVAR	20		NORMAL
15:23:53	*5	MULDERSVLEI	1/400	KV	393		NORMAL
15:23:53	*5	MULDERSVLEI	2/400	KV	396		NORMAL
15:23:58	*6	HYDRA	SVC2_CX3_BKR_NOP				ALARM
15:24:02	*6	MAJUBA	TUTUK1_BKR	SIR/INIT_RESET			RESET
15:24:03	*5	AVON	CARRIER_UPS_FIL				NORMAL
15:24:03	*5	AVON	BATTERY_LOW_VLTAGE				NORMAL
15:24:11	*5	BOUNDARY	CARRIER_UPS_FIL				NORMAL
15:24:13	*5	THESEUS	TR_3	TAP	1	0	LOW
15:24:24	*6	KRIEL	UNIT_2	ON_OFF			OFF
15:24:29	*4	IMPALA	PONGL__BKR				TRIP
15:24:29	*4	IMPALA	HILLV__BKR				TRIP
15:24:29	*6	IMPALA	HILLV__GROUP1				ALARM
15:24:33	*5	VD KLOOF	GEN/COND_STAR....1	GEN	CONTROL		SUCCESS
15:24:31	*4	HYDRA	TR_2_400_MAL2				CLOSE
15:24:32	*5	VERWOERDBURG	220V_SUPPLY_FIL				NORMAL
15:24:32	*4	VERWOERDBURG	VERWR_TRIP_ALRM				NORMAL
15:24:32	*5	VERWOERDBURG	220V_SUPPLY_FIL				ALARM
15:24:31	*4	MULDERSVLEI	TR_4__66_BKR				TRIP
15:24:31	*4	MULDERSVLEI	TR_5__66_BKR				TRIP
15:24:31	*6	MULDERSVLEI	TRFR_8_GROUP2				ALARM
15:24:33	*5	THESEUS	TR_3	TAP	3		NORMAL
15:24:45	*5	VD KLOOF	GEN/COND_STAR_2	GEN	CONTROL		SUCCESS
15:24:46	*5	HF VERWOERD	GEN/COND_STAR....1	GEN	CONTROL		SUCCESS
15:24:43	*6	VD KLOOF	BRAKES...........1ON_OFF				OFF
15:24:43	*6	VD KLOOF	INITIATE_SHUTOWN.1ON_OFF				ON

APPENDIX 2 - ESKOM TELE-CONTROL STANDARD

Appendix 2 ESKOM Tele-Control standard

ESKOM	OPS5026/22-5 REV. 2
STANDARD FOR EMS TELECONTROL REQUIREMENTS	DECEMBER 1994
DETAILED DEFINITION OF TELECONTROL DATA REQUIREMENTS FOR EMS SYSTEMS AT MAIN TRANSMISSION STATIONS	PAGE 1 OF 26

Compiled by	Accepted By	Recommended By	Approved By
R A GUBBINS	ECS MANAGER	S-O-M	I-S-M
Accepted By	Accepted By	Accepted By	Authorised By
D-T-M	T-E-M	P-S-E-M	GM (G)

Rev.	Description of Revision
2	General Update. Added changes for the ERTU. Added changes to take into account the sharing of ERTUs by Transmission and Distribution. Removed requirements for Group 1, Group 2 and Secondary Protection combination alarms. Clarification of single/double bit indication alarms. Added requirement for battery backup of measurement transducers. Added security controls and alarms. Added station emission data for coal fired power stations (Section 7.10)

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1.0 PURPOSE

To specify the EMS telecontrol requirements for both Transmission Operations and Distribution at all M.T.S. stations.

2.0 SCOPE

Telecontrol functions at all new M.T.S. stations are to be implemented in accordance with this document.

The functions in this document are required only if they exist e.g. a carrier abnormal alarm is not required unless it exists for the particular panel concerned.

NOTE : Items have been added to this document to indicate future requirements (as foreseen) so that the necessary telemetry can be in place when required.

3.0 REFERENCES

OPS 5010/22-5	Standard defining terminology relating to the direction of power flow.
OPS 5001/22-5	Standard relating to AGC power supplies.
OPS 5016/22-5	Standard relating to Interlocking.
OPS 5015/22-5	Standard relating to Power Station Speed Governing

Durban Distributor Telecontrol Requirements
Cape Distributor Telecontrol Requirements
Johannesburg Distributor Telecontrol Requirements
Cape Distributor (East) Telecontrol Standard

4.0 DEFINITIONS

Power Stations All coal fired power stations.

Special Power Stations All power stations which can be operated remotely by supervisory control while unattended and new power stations which are not intended for Automatic Generation Control (AGC) operation. Currently these stations are the hydro, gas turbine and nuclear (Koeberg) stations.

Distribution Stations All IPS stations without generation

Abbreviations used in this document.

AGC	-	Automatic Generation Control
ARC	-	Auto Re-Close
AVR	-	Automatic Voltage Regulator.
ECS	-	Energy Control System Section at System Operations, Simmerpan.
EMS	-	Energy Management System computer located at NCC, Simmerpan.
EMS CP	-	Energy Management System Control Panel.
EOD	-	Electrical Operators Desk.
ERTU	-	Enhanced Remote Terminal Unit.
ICS	-	Integrated Control System.
IDF	-	Intermediate Distribution Frame. This is the interface between the RTU and station telecontrol functions or telemetering.
IPS	-	Interconnected Power System
IRB/IRP	-	Interposing Relay Board/Panel
IRC	-	Interposing Relay Connector
LPU	-	Line Protection Unit
MTS	-	Main Transmission System
NCC	-	National Control Centre.
RLO	-	Reset Lock Out
RTU	-	Remote Terminal Unit.
SF6	-	Sulphur Hexaflouride
SIR	-	Synchronise Initiating Relay
SSB	-	Single SideBand
UCD	-	Unit Control Desk.
UPS	-	Uninterruptible Power Supply.

5.0 RESPONSIBILITIES

Engineering, Transmission PTM and Distribution Maintenance departments shall ensure that the requirements of this standard are complied with at all new Power and Distribution Stations.

Transmission Operations shall specify telecontrol requirements for special Power Stations on an individual basis, as telecontrol facilities depend on station design.

At existing stations where improved telecontrol is essential, it may be necessary to provide functions not existing presently at the station concerned. Some new stations will require facilities not specified in this document. Special requests will be made by Transmission Operations or the Distributor in such cases.

All non-demarcated IPS equipment, i.e. equipment within Transmission boundaries, will be managed and controlled by facilities at the National Control Centre (NCC) and Standby National Control Centre (STABNAC).

Where Distribution facilities are non-existent, Transmission Operations will attempt to accommodate supervisory control for non-IPS equipment at IPS stations in the Distribution area.

Where Distribution and Transmission share an ERTU, any operation on or changes to the ERTU must be done in accordance with the respective Standards documents and with the consent of both parties. When the ERTU is in a MTS station, all operations on and changes to the ERTU must be authorised by System Operations.

6.0 ACTIONS

6.1 Standards

Wiring standards shall comply with the requirements of Section 9 (Telecontrol Wiring Requirements). Megawatt and Megavar direction of flow shall comply with ESKOM Standard OPS 5010/22-5

6.2 Alarm grouping

In IPS stations where an ERTU is installed, alarm grouping if required will be carried out by software in the ERTU. There will be no hardwired commoning of alarms in the IDF. The groupings, GROUP1, GROUP2, and SECONDARY PROTECTION, will be maintained as software groupings in the same form as when they were hardwired.

6.3 Timetag data.

Time tagging must be implemented at all IPS stations where an ERTU is installed. The points to be marked will be specified by System Operations. These points will be defined in the ERTU at configuration time.

6.4 Telemetry Indication (Status) State Conventions.

Section 8.0 specifies the recommended normal "States" of Telemetered Indications/Alarms for CONITEL RTUs. The convention is that a State 0, or closed contact, indicates the desired condition.

Section 8.1 refers to the ERTU and the convention for double bit indications when used with the ERTU.

This table should be adhered to when RTU maintenance and EMS database-engineering staff respectively commission and define new stations.

7.1 GENERATORS AT COAL FIRED POWER STATIONS

CONTROLS

NAME	OPERATION	NOTE
Breaker	Open/Close	
Links	Open/Close	
Maximum Generation	Off/On	
Emergency Generation	Off/On	
A.G.C.	Raise/Lower	See Section 10 for AGC requirements.
A.V.R. Set point	Raise/Lower	

ANALOGS

ANALOG NAME	NOTE
Megawatts generated	per generator
Megawatts sent-out	per generator
Megavars generated	per generator
Megavars sent-out	per generator
Stator Volts	per generator
Amps	per phase
Voltage	
Frequency	
MVAR Operating Limits	per generator
SetPoint Megawatts	per generator
High Regulating Limit	per generator
Low Regulating Limit	per generator

BREAKER INDICATIONS

NAME	INDICATION	NOTE
Breaker	Opened/Closed	
Pole discrepancy	Alarm/Normal	
Breaker charged	Yes/No	

LINK INDICATIONS

LINK	INDICATION	NOTE
Link	Opened/Closed	only req'd for 132kV+ if all links at a station per voltage level can be shown
Pantograph Pole discrepancy	Alarm/Normal	

A.G.C. INDICATIONS

NAME	INDICATION	NOTE
Unit Status	On/Off	
Unit Control Mode	On Reg/Manual	
High Limit	Alarm/Normal	
Low Limit	Alarm/Normal	

7.2 GENERATORS AT HYDRO, PUMP STORAGE AND GAS TURBINE STATIONS

CONTROLS

NAME	OPERATION	NOTE
Gen Mode	On	
SCO Mode	On	
Pump Mode	On	
Standstill Mode	On	
Emergency trip	On	
Automatic Power Factor Regulation	On/Off	if applicable
Autoload	On/Off	if applicable
Guide Vane	Raise/Lower	if applicable
Load Limiter	Raise/Lower	if applicable
Exciter Amps	Raise/Lower	if applicable
Stator Amps	Raise/Lower	if applicable
A.G.C.	Raise/Lower	See section 10 for A.G.C requirements
A.V.R. Set Point	Raise/Lower	

ANALOGS

ANALOG NAME	NOTE
Megawatts generated	per generator
Megawatts sent-out	per generator
Megavars generated	per generator
Megavars sent-out	per generator
Stator Volts	per generator
Amps	per phase
Voltage	per bus bar
Frequency	

BREAKER & DEVICE INDICATIONS

NAME	INDICATION	NOTE
G/M Governing Auto/Manual	Auto/Manual	
G/M Remote Control	Yes/No	
G/M Machine generate	Yes/No	
G/M Machine Mot	Yes/No	
G/M Synchronise	Manual/Auto	
G/M Generate to Pump Sequence	Yes/No	
G/M Generate to SCO Sequence	Yes/No	
G/M SCO to Generate Sequence	Yes/No	
G/M SCO to Pump Sequence	Yes/No	
G/M Pump to Generate Sequence	Yes/No	
G/M Pump to SCO Sequence	Yes/No	
G/M Standstill	Yes/No	
G/M Pump	Yes/No	
G/M Generate	Yes/No	
G/M SCO	Yes/No	
G/M Emergency Shutdown	Off/On	
G/M Sequence Auto Remote	Auto Remote	
Generator Start not Ready	Yes/No	
Pump Start not Ready	Yes/No	

7.3 FEEDERS

CONTROLS

NAME	OPERATION	NOTES
Breaker	Open/Close	
Synchronise Initiating Relay	Init/Reset	if applicable
Spring Rewind	Rewind	if applicable
Links	Open/Close	
R.L.O.	Reset	if applicable
Slow/Fast A.R.C.	Fast/Slow	if applicable
A.R.C.	Off/On	if applicable
A.R.C. Selection 1	On	}
A.R.C. Selection 3	On	} Only 1 of 3 possible modes allowed
A.R.C. Selection 1 + 3	On	}

ANALOGS

ANALOG NAME	NOTES
Megawatts	per feeder [0.2%]
Megavars	per feeder [0.2%]
Amps	per phase & per bus bar section if applicable
Phase angle (absolute)	per bus bar section if applicable
Voltage	per phase & per bus bar section
Frequency	per bus bar section at selected stations

INDICATIONS

NAME	INDICATION	NOTES
Breaker	Opened/Closed	
Breaker Auto Sync. (S.I.R)	Init/Reset	if applicable
Breaker charged	Yes/No	
SF6 or Air Pressure Alarm Non-urgent	Alarm/Normal	
SF6 or Air Pressure Alarm Urgent	Alarm/Normal	
R.L.O.	Reset/Operated	
A.R.C.	On/Off	if applicable
Slow/Fast A.R.C.	Slow/Fast	if applicable
1 Phase A.R.C.	Alarm/Normal	if applicable
3 Phase A.R.C.	Alarm/Normal	if applicable
Breaker closing inhibited	Yes/No	if applicable
Bus zone	Alarm/Normal	
Bus strip	Alarm/Normal	
Breaker Control	Local/Remote	
M1 DC fail	Alarm/Normal	
M2 DC fail	Alarm/Normal	
Control DC fail	Alarm/Normal	
Close DC fail	Alarm/Normal	
Spring Rewind DC fail	Alarm/Normal	
Isolator DC fail	Alarm/Normal	
Secure Supply DC fail	Alarm/Normal	
AC/DC Convertor fail	Alarm/Normal	
Supervisory	On/Off	
Carrier Abnormal	Alarm/Normal	

7.3 FEEDERS

BREAKER & DEVICE INDICATIONS (continued)

NAME	INDICATION	NOTE
M1 protection	On/Off	
M2 protection	On/Off	
M1 protection trip	Alarm/Normal	
M2 protection trip	Alarm/Normal	
M1 Pole discrepancy	Alarm/Normal	
M2 Pole discrepancy	Alarm/Normal	
Backup protection trip	Alarm/Normal	
Over Voltage	Alarm/Normal	
Direct transfer trip	Alarm/Normal	
Zone 2 BR	Alarm/Normal	
Earth link position	Open/Closed	
Sensitive Earth Fault	On/Off	if applicable
Backup Earth Fault	Alarm/Normal	if applicable
Over Current	Alarm/Normal	if applicable
Zone 1	Alarm/Normal	if applicable
Zone 2	Alarm/Normal	if applicable
Zone 3	Alarm/Normal	if applicable
Instantaneous Overvoltage	Alarm/Normal	if applicable
Compensated Overvoltage	Alarm/Normal	if applicable
Carrier Receive	Alarm/Normal	if applicable
Carrier Send	Alarm/Normal	if applicable

LINK INDICATIONS

NAME	INDICATION	NOTE
Link	Opened/Closed	per phase
Pantograph Pole discrepancy	Alarm/Normal	

GENERAL

NAME	INDICATION	NOTE
Distance to fault from locator	Distance value	per locator

7.4 BUS COUPLER AND SECTION/TRANSFER BREAKERS

CONTROLS

NAME	OPERATION	NOTE
Breakers	Open/Close	
Links	Open/Close	
R.L.O.	Reset	if applicable

BUS COUPLER & SECTION/TRANSFER BREAKER INDICATIONS

NAME	INDICATION	NOTE
Breaker	Opened/Closed	
Pole discrepancy	Alarm/Normal	
Breaker charged	Yes/No	
SF6 or Air Pressure Alarm Non-urgent	Alarm/Normal	
SF6 or Air Pressure Alarm Urgent	Alarm/Normal	
Supervisory	On/Off	
Bus zone	Alarm/Normal	
Bus strip	Alarm/Normal	
Breaker Control	Local/Remote	
Earth link position	Open/Closed	
M1 DC fail	Alarm/Normal	
M2 DC fail	Alarm/Normal	
Control DC fail	Alarm/Normal	
Close DC fail	Alarm/Normal	
Spring Rewind DC fail	Alarm/Normal	
Isolator DC fail	Alarm/Normal	
Secure Supply DC fail	Alarm/Normal	
AC/DC Convertor fail	Alarm/Normal	
Main 1 protection	On/Off	
Main 2 protection	On/Off	
M1 Instantaneous Overcurrent	Alarm/Normal	
M2 Instantaneous Overcurrent	Alarm/Normal	
M1 Instantaneous Earthfault	Alarm/Normal	
M2 Instantaneous Earthfault	Alarm/Normal	
M1 IDMT Overcurrent	Alarm/Normal	
M2 IDMT Overcurrent	Alarm/Normal	
M1 IDMT Earthfault	Alarm/Normal	
M2 IDMT Earthfault	Alarm/Normal	

7.5 TRANSFORMERS

CONTROLS

NAME	OPERATION	NOTES
Breakers	Open/Close	
Spring Rewind	Rewind	if applicable
Links	Open/Close	
Tap Position	Raise/Lower	if applicable
Tap Changer	Auto/Manual	if auto tap changer present

ANALOGS

ANALOG NAME	NOTE
Megawatts	HV / MV /LV, Coupling only, not on tertiary [0.2%]
Megavars	HV / MV /LV, Coupling only, not on tertiary [0.2%]
Amps	HV / MV /LV, Coupling only, not on tertiary [0.2%]
Tap position	

BREAKER INDICATIONS

NAME	INDICATION	NOTE
Breaker	Opened/Closed	
Pole discrepancy	Alarm/Normal	
Breaker charged (Spring / Air pressure)	Yes/No	
SF6 or Air Pressure Alarm Non-urgent	Alarm/Normal	
SF6 or Air Pressure Alarm Urgent	Alarm/Normal	
Supervisory	On/Off	
Breaker Control	Local/Remote	
M1 DC fail	Alarm/Normal	
M2 DC fail	Alarm/Normal	
Control DC fail	Alarm/Normal	
Close DC fail	Alarm/Normal	
Spring Rewind DC fail	Alarm/Normal	
Isolator DC fail	Alarm/Normal	
Secure Supply DC fail	Alarm/Normal	
AC/DC Convertor fail	Alarm/Normal	
Bus zone	Alarm/Normal	per level
Bus strip	Alarm/Normal	per level
Main 1 protection	On/Off	
Main 2 protection	On/Off	
M1 protection trip	Alarm/Normal	
M2 protection trip	Alarm/Normal	
M1 HV instantaneous overcurrent	Alarm/Normal	
M2 HV instantaneous overcurrent	Alarm/Normal	
M1 MV instantaneous overcurrent	Alarm/Normal	
M2 MV instantaneous overcurrent	Alarm/Normal	
M1 MV backup overcurrent	Alarm/Normal	
M2 MV backup overcurrent	Alarm/Normal	
M1 HV backup overcurrent	Alarm/Normal	
M2 HV backup overcurrent	Alarm/Normal	

7.5 TRANSFORMERS

BREAKER INDICATIONS (continued)

NAME	INDICATION	NOTE
M1 HV Earthfault operated	Alarm/Normal	
M2 HV Earthfault operated	Alarm/Normal	
M1 MV Earthfault operated	Alarm/Normal	
M2 MV Earthfault operated	Alarm/Normal	
M1 Tertiary Instantaneous overcurrent	Alarm/Normal	
M2 Tertiary Instantaneous overcurrent	Alarm/Normal	
M1 Tertiary IDMT overcurrent	Alarm/Normal	
M2 Tertiary IDMT overcurrent	Alarm/Normal	
Neutral Earthing Compensator	Alarm/Normal	if applicable
Neutral Earthing Reactor	Alarm/Normal	if applicable

LINK INDICATIONS

NAME	INDICATION	NOTE
Link	Opened/Closed	per phase
Pantograph Pole discrepancy	Alarm/Normal	

TRANSFORMER DEVICE INDICATIONS

NAME	INDICATION	NOTE
M1 Buchholz protection operated	Alarm/Normal	
M2 Buchholz protection operated	Alarm/Normal	
M1 Main tank pressure relief	Alarm/Normal	
M2 Main tank pressure relief	Alarm/Normal	
M1 Differential	Alarm/Normal	
M2 Differential	Alarm/Normal	
Restricted Earthfault	Alarm/Normal	
Master trip relay operated	Yes/No	
HV winding temperature alarm	Alarm/Normal	
MV winding temperature alarm	Alarm/Normal	
Tertiary winding temperature alarm	Alarm/Normal	
Oil temperature alarm	Alarm/Normal	
HV winding temperature trip	Alarm/Normal	
MV winding temperature trip	Alarm/Normal	
Tertiary winding temperature trip	Alarm/Normal	
Oil temperature trip	Alarm/Normal	
Cooler fail	Alarm/Normal	
Low Oil level	Alarm/Normal	

TAP CHANGER INDICATIONS

NAME	INDICATION	NOTE
Out of step	Alarm/Normal	
Tap Changer Control	Auto/Manual	
Master/Follower	Master/Follower	
Tap changer failure	Alarm/Normal	
Tap changer overcurrent	Alarm/Normal	
TC surge	Alarm/Normal	
Tap changer Locked Out	Yes/No	
Tap changer DC Fail	Alarm/Normal	
Tap changer AC Fail	Alarm/Normal	

7.6 SHUNT REACTORS

CONTROLS

NAME	OPERATION	NOTE	
Breakers	Open/Close	if applicable	
Links	Open/Close	if applicable	

ANALOGS

ANALOG NAME	NOTE
Megawatts	[0.2%]
Megavars	[0.3%]
Amps	per phase

REAKER INDICATIONS

NAME	INDICATION	NOTE
Breaker	Opened/Closed	
Pole discrepancy	Alarm/Normal	
Breaker unhealthy	Yes/No	
SF6 or Air Pressure Alarm Non-urgent	Alarm/Normal	if applicable
SF6 or Air Pressure Alarm Urgent	Alarm/Normal	if applicable
Supervision	On/Off	
Breaker Control	Local/Remote	
M1 D.C. Fail	Alarm/Normal	
M2 D.C. Fail	Alarm/Normal	
Bus zone	Alarm/Normal	per level
Bus strip	Alarm/Normal	per level
Main 1 protection	On/Off	
Main 2 protection	On/Off	
M1 protection trip	Alarm/Normal	
M2 protection trip	Alarm/Normal	
M1 Differential	Alarm/Normal	
M2 Differential	Alarm/Normal	
Restricted Earthfault	Alarm/Normal	
M1 INST overcurrent	Alarm/Normal	
M2 INST overcurrent	Alarm/Normal	
M1 IDMT overcurrent	Alarm/Normal	
M2 IDMT overcurrent	Alarm/Normal	
M1 Inst. overcurrent (High Set)	Alarm/Normal	
M2 Inst. overcurrent (High Set)	Alarm/Normal	
M1 IDMT Earthfault	Alarm/Normal	
M2 IDMT Earthfault	Alarm/Normal	
M1 Inst Earthfault (High Set)	Alarm/Normal	
M2 Inst. Earthfault (High Set)	Alarm/Normal	
M1 Def Time Earthfault	Alarm/Normal	if applicable
M2 Def Time Earthfault	Alarm/Normal	if applicable

7.6 SHUNT REACTORS

BREAKER INDICATIONS (continued)

NAME	INDICATION	NOTE
M1 Thermal Protection	Alarm/Normal	
M2 Thermal Protection	Alarm/Normal	
M1 Buchholz Protection	Alarm/Normal	
M2 Buchholz Protection	Alarm/Normal	
M1 Pressure Relief	Alarm/Normal	
M2 Pressure Relief	Alarm/Normal	
Winding Temp	Alarm/Normal	
Oil Temp	Alarm/Normal	
[illegible] Temp	Alarm/Normal	
M1 Breaker Fail	Alarm/Normal	
M2 Breaker Fail	Alarm/Normal	
M1 Master trip relay operated	Yes/No	
M2 Master trip relay operated	Yes/No	

LINK INDICATIONS

NAME	INDICATION	NOTE
Link	Opened/Closed	per phase
Pantograph Pole discrepancy	Alarm/Normal	

7.7 SHUNT CAPACITORS

CONTROLS

NAME	OPERATION	NOTE
Breakers	Open/Close	
Links	Open/Close	

ANALOGS

ANALOG NAME	NOTE
Megavars	[0.2%]
Amps	per phase

BREAKER INDICATIONS

NAME	INDICATION	NOTE
Breaker	Opened/Closed	
Pole discrepancy	Alarm/Normal	
Breaker charged	Yes/No	
SF6 or Air Pressure Alarm Non-urgent	Alarm/Normal	if applicable
SF6 or Air Pressure Alarm Urgent	Alarm/Normal	if applicable
Breaker closing inhibiter	Yes/No	
Supervisory	On/Off	
Breaker Control	Local/Remote	
Main 1 D.C. Fail	Alarm/Normal	
Main 2 D.C. Fail	Alarm/Normal	
SF6 or Air Pressure Alarm	Alarm/Normal	2 alarms
Bus zone	Alarm/Normal	per level
Bus strip	Alarm/Normal	per level
Main 1 protection	On/Off	
Main 2 protection	On/Off	
M1 protection trip	Alarm/Normal	
M2 protection trip	Alarm/Normal	
M1 Def time overcurrent stage1	Alarm/Normal	
M2 Deftime overcurrent stage2	Alarm/Normal	
M2 Def time overcurrent stage1	Alarm/Normal	
M2 Def time overcurrent stage2	Alarm/Normal	
M1 Def time Earthfault stage1	Alarm/Normal	
M1 Def time Earthfault stage2	Alarm/Normal	
M2 Def time Earthfault stage1	Alarm/Normal	
M2 Def time Earthfault stage2	Alarm/Normal	
M1 Deftime overvoltage	Alarm/Normall	
M2 Deftime overvoltage	Alarm/Normall	
M1 Unbalance Protection	Alarm/Normal	
M2 Unbalance Protection	Alarm/Normal	
M1 Cascading overcurrent	Alarm/Normal	
M2 Cascading overcurrent	Alarm/Normal	
M1 Breaker fail	Alarm/Normal	
M2 Breaker fail	Alarm/Normal	
M1 Master trip relay operated	Yes/No	
M2 Master trip relay operated	Yes/No	

LINK INDICATIONS

NAME	INDICATION	NOTE
Link	Opened/Closed	per phase
Pantograph Pole discrepancy	Alarm/Normal	

7.8 SERIES CAPACITORS

CONTROLS

NAME	OPERATION	NOTE
Breakers	Open/Close	
Links	Open/Close	

ANALOGS

ANALOG NAME	NOTE
Megawatts	[0.2%]
Megavars	[0.2%]
Amps	per phase

BREAKER INDICATIONS

NAME	INDICATION	NOTE
Breaker	Opened/Closed	
Pole discrepancy	Alarm/Normal	
Breaker charged	Yes/No	
SF6 or Air Pressure Alarm Non-urgent	Alarm/Normal	if applicable
SF6 or Air Pressure Alarm Urgent	Alarm/Normal	if applicable
Breaker closing inhibited	Yes/No	
Supervisory	On/Off	
Breaker Control	Local/Remote	
Main 1 D.C. Fail	Alarm/Normal	
Main 2 D.C. Fail	Alarm/Normal	
SF6 or Air Pressure Alarm	Alarm/Normal	2 alarms
Bus zone	Alarm/Normal	per level
Bus strip	Alarm/Normal	per level
Main 1 protection	On/Off	
Main 2 protection	On/Off	
M1 protection trip	Alarm/Normal	
M2 protection trip	Alarm/Normal	
Cascading overcurrent	Alarm/Normal	
Subharmonic protection	Alarm/Normal	
Transmission channel failure	Alarm/Normal	
Optronic auxilliary power failure	Alarm/Normal	
M1 low set unbalance overcurrent	Alarm/Normal	
M2 low set unbalance overcurrent	Alarm/Normal	
M1 high set unbalance overcurrent	Alarm/Normal	
M2 high set unbalance overcurrent	Alarm/Normal	
M1 spark gap protection	Alarm/Normal	
M2 spark gap protection	Alarm/Normal	
M1 platform overcurrent protection	Alarm/Normal	
M2 platform overcurrent protection	Alarm/Normal	

LINK INDICATIONS

NAME	INDICATION	NOTE
Link	Opened/Closed	per phase
Pantograph Pole discrepancy	Alarm/Normal	

7.9 STATIC VOLTAGE COMPENSATORS

CONTROLS

NAME	OPERATION	NOTE
Start Sequence	On/Off	Remote start of automatic control
Stop Sequence	On/Off	Remote stop of automatic control
Reactors On Auto	On/Off	Enables/Disables compensator control of all selected reactors
Capacitors On Auto	On/Off	Enables/Disables compensator control of all selected reactors
Set Point	Raise/Lower	Changes set point voltages
Compensator Mode	Voltage Mode/Q Mode	Select between Voltage and Reactive Power Control
Q Set Point	Raise/Lower	For Reactive mode
Slope Set Point	Raise/Lower	

INDICATIONS

DEVICE	INDICATION	NOTE
Breakers	Opened/Closed	
Links	Opened/Closed	
Compensator Mode	Voltage / Q	Voltage Control or Reactive Power Control
Master Trip Relay Operated	Yes/No	
Static Compensators in parallel	Yes/No	
Reactors On Auto	Yes/No	Indication that reactors selected to compensator control are on auto
Capacitors On Auto	Yes/No	Indication that capacitors selected to compensator control are on auto
Start Sequence in progress	Yes/No	
Stop Sequence in progress	Yes/No	
Reference Voltage	Local/Remote	
Supervisory Isolated		Status of remote contrtol compensator
Compensator Control Isolated		Status of compensator control of reactive devices
Group 1		Commoned alarms associated with the compensaor breakers
Group 2		Commoned alarms associated with the transformer reactor, capacitor and control equipment that make up a static compensator

ANALOGS

ANALOG NAME	NOTE
Megavars	
Voltage	This may replace the busbar voltage at a station with compensators installed
Reference Voltage	The set point voltage which is adjusted by supervisory control to alter the target control voltage of a compensator
Slope Setpoint	The value of the Slope setpoint

7.10 STATION LEVEL

BUS ZONE INDICATIONS

NAME	INDICATION	NOTE
Bus zone	Off/On	
Bus strip	Off/On	
Bus zone operated	Yes/No	
Bus strip operated	Yes/No	
Bus zone Disagreement	Alarm/Normal	
Bus zone DC Fail	Alarm/Normal	
Bus zone unhealthy	Alarm/Normal	

AUXILIARY SUPPLY INDICATIONS

NAME	ACTION	NOTE
Battery Common	Alarm/Normal	
Battery Low Voltage	Alarm/Normal	
Battery Unhealthy	Alarm/Normal	
Battery Urgent	Alarm/Norma	
Battery Fail	Alarm/Normal	
Battery Charger fail	Alarm/Normal	
Battery Charger Unhealty	Alarm/Normal	
Battery Earth Fault	Alarm/Normal	
50 Volt Charger Clean	Alarm/Normal	
50 Volt Charger Dirty	Alarm/Normal	
50 Volt Supply fail	Alarm/Normal	
220 Volt Charger Common	Alarm/Normal	
220 Volt Charger Unhealthy	Alarm/Normal	
220 Volt Charger fail	Alarm/Normal	
220 Volt M1/M2 Charger	Alarm/Normal	
220 Volt Supply Fail	Alarm/Normal	
Voltage supply to Main meter	Alarm/Normal	if applicable (ITM requirement)
Voltage supply to Check meter	Alarm/Normal	if applilcable (ITM requirement)

GENERAL INDICATIONS

NAME	ACTION	NOTE
Person in Substation	Yes/No	
Earth tremor detected	Yes/No	1 per station
Under Frequency Load Shedding	Yes/No	if applicable

7.10 STATION LEVEL

COMMUNICATIONS CONTROLS

NAME	ACTION	NOTE
Comms Channel Select	Alternate/Normal	Req'd where alternate channel is available

COMMUNICATIONS INDICATIONS

NAME	INDICATION	NOTE
Carrier U.P.S fail	Alarm/Normal	
Carrier S.S.B. Transmit fail	Alarm/Normal	
Carrier S.S.B. Receive fail	Alarm/Normal	
Communication Channel	Alternate/Normal	
[illegible]	Alarm/Normal	
[illegible]	Alarm/Normal	
Control Alarm	Alarm/Normal	
Microwave Tx/Rx	Alarm/Normal	if applicable
NSD 70 Tx/Rx	Alarm/Normal	if applicable

COAL FIRED POWER STATION EMISSION INDICATIONS

NAME	INDICATION	NOTE
Emission levels per stack	Emission level	
Wind Speed	Km/Hour	
Wind Direction	Direction	
Ambient Temperature	degrees C	

WEATHER INDICATIONS

NAME	INDICATION	NOTE
Temperature	degrees C	
Wind Speed	Km/Hour	
Wind Direction	Direction	
Relative humidity	% humidity	
Rainfall	mm	

7.11 SECURITY

CONTROLS

NAME	ACTION	NOTE
Gate Open/Close	Open/Close	
Alarm Accept	Accept	
Alarm Reset	Reset	

INDICATIONS

NAME	INDICATION	NOTE
Gate Open	Alarm/Normal	
Perimeter Conf	Alarm/Normal	
Perimeter Unconf	Alarm/Normal	
Transformer Conf	Alarm/Normal	
Transformer Unconf	Alarm/Normal	
Cabinet tamper	Alarm/Normal	
System failure	Alarm/Normal	
Panic alarm	Alarm/Normal	
Gate open timeout	Alarm/Normal	
Alarm mode	On/Off	
Lethal mode	On/Off	
Non lethal mode	On/Off	
Switch mode A	On/Off	
Switch mode B	On/Off	
Switch mode C	On/Off	

7.12 INTEGRATED VALUES

SENT OUTS PER GENERATOR AND PER TRANSMISSION LINE

NAME	NOTE
Megawatthours	2 values. Import and Export
Megavarhours	4 values. Import lead PF/lag PF Export lead PF/lag PF

8.0 ALARM STATE CONVENTION

CONITEL RTUs

In the table below, STATE "0" indicates the normal state for devices and indications, and the alarm state for ALARMS. The CONTACTS column gives the state of the contacts when this state is selected. The convention is that a closed contact indicates the desired state.

See Section 8.1 for ERTU and double bit indications.

CONTACTS CLOSE FOR ALARM CONDITION
CONTACTS OPEN FOR BREAKER/LINK OPEN CONDITION

DESCRIPTION	CONTACT CLOSED "0"	CONTACT OPEN "1"	CONTACT AT STATE "0"
Breakers	Closed	Opened	Closed
Links	Closed	Opened	Closed
Breaker Closing/Inhibited	Yes	No	Closed
Breaker Auto Sync (S.I.R)	Init	Reset	Closed
Generator Islanding	Alarm	Normal	Closed
Governing (Freq Bias)	On	Off	Closed
A.V.R.	On	Off	Closed
Reactor/Capacitor On Auto	Auto	Manual	Closed
Static Compensators In Parallel	Yes	No	Closed
Start Sequence In Progress	Yes	No	Closed
Stop Sequence In Progress	Yes	No	Closed
Reference Voltage	Local	Remote	Closed
Supervisory Isolated	On	Off	Closed
Compensator Control Isolated	Yes	No	Closed
Single Phase A.R.C.	Alarm	Normal	Closed
A.R.C. (In ALARM category)	Off	On	Closed
Slow/Fast A.R.C.	Slow	Fast	Closed
Tap Changer	Auto	Manual	Closed
Master Trip Relay Operated	Yes	No	Closed
Breaker Alarms	Alarm	Normal	Closed
Trfr/Cap/Reactor Alarms	Alarm	Normal	Closed
Secondary Protection Alarms	Alarm	Normal	Closed
Bus Zone Operated	Alarm	Normal	Closed
Bus Zone Off	Alarm	Normal	Closed
Bus Strip Operated (Breaker Fail)	Alarm	Normal	Closed
Bus Zone Disagreement	Alarm	Normal	Closed
Bus Zone D.C. Fail	Alarm	Normal	Closed
Carrier U.P.S. Fail	Alarm	Normal	Closed
Carrier S.S.B Fail	Alarm	Normal	Closed
Battery Common	Alarm	Normal	Closed
Battery Low Voltage	Alarm	Normal	Closed
S.F.6 Urgent	Alarm	Normal	Closed
S.F.6 Non-Urgent	Alarm	Normal	Closed
R.L.O	Lockout	Reset	Closed
Conitel Indication	Normal	Alarm	Closed
I.R.B./I.R.C/I.R.P.	Normal	Alarm	Closed
Comms. Channel Indication	Alternate	Normal	Closed

8.1 ALARM STATE CONVENTION FOR ERTUs

In the case of the ERTU, the indication is the inverse of the CONITEL RTU. Column 4 of Sect... 8.0 gives the relevant contact states for devices and indications on CONITEL RTUs, when applied to the ERTU, the STATE "0" and STATE "1" references must be reversed.

DOUBLE BIT INDICATION CONVENTION

In the case of double-bit indications, the following conventions should be followed.

The two bits in the table below will be referred to as the X and the S bit, where the X bit is the Most Significant Bit and the S bit is the Least Significant Bit.

STATE TABLE

BIT VALUES	CONTACT STATE
X = 0, S = 0	IN TRANSIT
X = 0, S = 1	CLOSED
X = 1, S = 0	OPEN
X = 1, S = 1	INVALID

INDICATION CONVENTION

INDICATION TYPE	CONTACT STATE	CLOSED INDICATION	OPEN INDICATION
Open / Closed	Closed	Closed	Opened
Yes / No	Closed	Yes	No
Init / Reset	Closed	Init	Reset
Alarm / Normal	Closed	Alarm	Normal
On / Off	Closed	On	Off
Auto / Manual	Closed	Auto	Manual
Local / Remote	Closed	Local	Remote
A.R.C (In Alarm Category)	Closed	Off	On

9.0 TELECONTROL WIRING REQUIREMENTS

9.1 SCOPE

Telecontrol wiring is the electrical connection of the telecontrol functions between originating contacts or supervisory relay coils, supervisory interposing panels and the IDF or bay input/output units (IO Unit) located within or in close proximity to plant control, protection and alarm panel equipment.

9.1.1 There shall be no station-level interlocking on NCC or STABNAC EMS control facilities by Integrated Control System (ICS) equipment. Interlocking shall comply with ESKOM Standard OPS 5016/22-5.

9.1.2 The telecontrol functions are designated thus

"C" Commands or Controls
"M" Fleeting or momentary change detect indications
"S" Status or alarm indications
"T" BCD tap position indications
"A" Analog telemetering quantities
"U" Energy Counters. Units of power imported/exported in terms of MW or MVar per hour.

9.1.3 "C" The relay coil is momentarily operated (50-1000ms) from the Master Station via the RTU's own 50 volt DC power supply or plant Control-panel power supplies. Thus the coil should be totally isolated on both sides and potential free. Each trip and close coil must be wired out to the IDF or bay IO Unit on a twisted pair of telephone type cable. Any spring rewind must be automatic.

9.1.4 "M", "S" or "T" are binary input indications or alarms from conditions at the station for transmission via the RTU to the Master Station. These indications must be provided in the form of normally open contacts, which close when the breaker/isolator is closed, or close when an alarm has been activited e.g. a closed contact, referred to in Section 8.0 as State 0, indicates the desired signal for the CONITEL RTU. This will be a State 1 for the ERTU. Each individually referenced alarm or status is to be wired out on an individual twisted pair of telephone type cable to the IDF or bay IO units. In power stations it will be necessary to use screened type cable to eliminate noise. In no case is there to be any commoning of individually referenced status or alarms. All contacts must be potential free and able to tolerate 50V DC interrogation. Indications are currently only required to be single bit, but where double bit indications are available both should be wired in.

9.1.5 "A" Analog or Telemetering. The connection between the transducer and the IDF or bay IO Units must be on a twisted pair of screened telephone type cable. All analogs to be 0 - 5ma or 0 - 20ma signal range. New stations will be standardised as 0 - 5ma.

9.1.6 "U" Energy Counters. This function must be provided on a potential free, Form "C" type change-over contact. It is essential that the relay coil operating the potential free contact is DC driven with surge suppression. If the originating contact is connected to an AC supply then the share relay must be modified, using a bridge rectifier, for DC operation and with surge suppresion. Where a CONITEL RTU is installed the output pulse rate must not exceed 4096 pulses per hour, this restriction does not apply to the ERTU.

10.0 AUTOMATIC GENERATION CONTROL REQUIREMENTS

This section gives a functional outline of AGC requirements and some details of the equipment to be provided together with specific functions. Before proceeding with the interface design for connecting the AGC to the turbine units, please refer to drawing 0.64 /134971, contained on page 26 of this document. This drawing shows all the signals currently required by System Operations for AGC. The general outline of the modifications that have been made to more recent Power Stations are shown in this diagram. Further information can be obtained from System Operations and/or the EMS co-ordinator at Simmerpan.

This section should be read in conjunction with the ESKOM Standard on Power Station Speed Governing (OPS 5015/22-5 Rev. 1)

The Setpoint Megawatts analog, specified in the Analog table of Section 7.1 and Section 7.2 must be provided for all stations that are required to be on A.G.C. to enable setpoint control to be performed.

The following nomenclature is used in this schedule:-

AGC is Automatic Generation Control as carried out by the National EMS facilities, at National Control, Simmerpan.

EMS AGC CONTROLLER is a self-contained unit control system at the station that communicates with the EMS computer via the EMS Remote Terminal Unit at the station and forms part of the EMS equipment adjacent to the RTU in the Communication and Metering room.

EMS CP - EMS Control Panel (Provided as part of the EMS equipment) located on the EOD in the main control room or unit control room.

RTU - EMS Remote Terminal Unit at the station (Provided as part of the EMS equipment) located in the Communication and Metering room.

UCP - Unit (turbine-generator) Control Panel, or relay panel, located in the relay panel room.

UCD - Unit Control Desk, located in the Unit Control Room.

10.1 FUNCTIONS TO BE PROVIDED BY POWER STATION DESIGN

10.1.1 SUPERVISORY ISOLATION SWITCH

As the National EMS is part of the Supervisory function, it is necessary that each UCD (Unit Control Desk) be provided with a supervisory isolation switch. The switch must provide isolation of the EMS AGC controller raise and lower signals from the load controller or turbo-generator control equipment. When the switch is "ON" the unit is available for EMS control. When "OFF" the unit is not available and the external trip circuit must be open. See drawing 0.64 /13497.

10.1.2 SUPERVISORY INDICATION LAMPS

Two indication lamps of different colours, as per Power Staton Standards are required at the UCD.

- Governor Control-AGC "RED" (preferably).
- Governor Control-UCP "GREEN" (preferably).

See drawing 0.64 /13497

At the UCD, the suggested location is adjacent to the existing load dispatch ON/OFF indications.

10.1.3 ANALOG INDICATIONS

GENERATOR MEGAWATTS

An analog indication (preferably 0 - 5mA transducers, 0 - 20mA are acceptable) of generator megawatts is required. The signal must be provided over a twisted pair to the IDF.

SET POINT MEGAWATTS

An analog indication (preferably 0 - 5mA, 0 - 20mA acceptable) of generator set-point megawatts is required. This signal must be provided over a twisted pair.

HIGH/LOW REGULATING LIMIT

An analog indication (preferably 0 - 5mA, 0 - 20mA acceptable) of maximum and minimum permissible MW's for control of the machine is required if available and applicable.

10.1.4 DESIGN CONSIDERATIONS

CONVERSION CONSTANTS

At an early stage in the design work, the conversion constants of the transducer output milliamps against megawatts are required to enable the correct scaling resistors to be ordered.

NATIONAL EMS "ON/OFF" CONTROL

Potential free change-over contacts within the AGC controller give an indication to the station that AGC is "OFF" or "ON". It is operated by push buttons on the EMS Control Panel. If power is removed from the AGC controller, the contact will fail over to the "OFF" position. See drawing 0.64 /13497
The supervisory isolation switch on the UCD should isolate the AGC controller raise/lower function connections from the load controller or the turbo-generator control equipment, towards the (heavy current) MDF. See drawing 0.64 /13497

NOTE:
The AGC controller can only be selected to "AGC ON" if external trip is not activated (i.e. machine healthy), and supervisory isolation switched to "ON". (Contacts on this switch are in series with EXT TRIP).

RAISE/LOWER CONTROL INPUTS

A raise and lower control input connection is required, by means of which the turbine governor set point (or target load) setting can be increased or decreased by the National EMS AGC controller. This control input connection could be connected to the same control input used by power station operator to effect load changes. It shall not be possible, however to simultaneously perform control from both Nat. EMS and the UCP or Mimic. Since the EMS will make regular and precise load changes it is essential that no intermediate contactors or relays be present between the AGC controller output and the governor set point control circuits. Otherwise this will result in distortion of, and delay of, control pulses from the AGC controller. However, control of the turbine unit at the unit can be affected in the normal way. When the unit is controlled in this manner, a "set point" operated contact, to be provided, opens and effects external trip to the EMS AGC software.

In the case of governor control gear with selectable ramp rates, the maximum or another pre-defined ramp rate shall be automatically selected when the unit is selected to AGC. This is necessary because the AGC control system tuning will be based on the set ramp rate. There is no danger that AGC will cause the unit to exceed the maximum permissible ramp rate due to extensive ramp rate protection provided in the computer as well as the AGC controller of the individual generating units.

10.1.4 DESIGN CONSIDERATIONS (continued)

EXTERNAL TRIP FUNCTION

The purpose of this function is to allow the station to regain control of the machine in the event of abnormal operation of the machine. The trip will be caused by an abnormal condition on the turbine or boiler (e.g. if the turbine driver operated the unit, or a unit capability restriction exists).

This will cause the AGC controller to trip itself (i.e. change from AGC "ON" to "OFF"). This indication is also telemetered to the National EMS computer, by the National EMS RTU. One or more of these series normally closed contacts are to be operated by the raise and lower controls on the BOD mimic to initiate a trip. Generator islanding should also initiate this trip.

EXTERNAL BLOCK - RAISE AND LOWER

This facility is for future use, where it may be necessary to temporarily inhibit the AGC - Auto raise/lower pulsing, whilst other station operations are in progress.

10.2 LOCAL RAISE AND LOWER PROGRAM

An internally generated program allows the power station operator to raise or lower the machine output to the limits set on the EMS Control Panel. Use of this function is telemetered to the Nat. EMS computer. The EMS Control Panel push button ON/OFF must be "OFF" before a local raise or lower program is initiated, however when the local raise or lower program is initiated, for the duration of pulses, an indication is sent to the UCD that AGC is "ON".

11.0 POWER REQUIREMENTS

11.1 RTU/ERTU AND RELATED EQUIPMENT

The National EMS Remote Terminal Unit (RTU) together with the EMS Automatic Generation Control System (AGC controller) and EMS Control Panel (EMS CP) require three (3) separately fed 50 volt DC power supplies derived from a battery and charger system which can maintain supplies for a minimum period of 8 hours at the following rates:

New RTU installations will be supplied with an ERTU which requires a supply as shown below

1 CONITEL : "Clean" 50V DC 6 amps, 8 hours)
) e.g. 150 A/H
ERTU : "Clean" 50V DC 10 amps, 8 hours)

2. "Clean" 50V DC 9 amps, 8 hours;

3. "Dirty" 50V DC 3 amps, 8 hours;

The "fall of" voltage should not be less than 35 volts at the end of the 8 hour period. It follows that 1 & 2 can be from the same system.

Supply No.1 powers the RTU logic and modems.

Supply No.2 powers the AGC logic.

Supply No.3 powers the optical isolating equipment used to transmit indications from the H.V. yard.

The above requirements are laid down in OPS 5001/22-5.

The ERTU can be supplied with a number of different input voltages as indicated below

1. 110V DC 5A
2. 220V AC 2,5A
3 220V DC 2,5A

11.2 TRANSDUCERS

The measurement transducers must be fed by power supplies derived from a battery and charger system which can maintain supplies for a minimum period of 8 hours.

12.0 DOCUMENTATION

Nil.

13.0 RECORDS

Nil.

14.0 REVIEW DATE

This document is due for review by 15 December 1995

15.0 DISTRIBUTION

G-E-M	Megawattpark	1 copy
E-E-M(Generation)	Megawattpark	10 copies
T-C-E-M	Megawattpark	10 copies
NPTM&C Manager	Megawattpark	1 copies
PM&C Manager	Simmerpan	10 copies
S-T-M	Megawattpark	5 copies
T-P-M	Megawattpark	5 copies
T-O-M	Megawattpark	5 copies
P-S-M	All Power Stations	2 copies (16 stations)
PS Library	All Power Stations	1 copy (16 stations)
D-T-M	Simmerpan	10 copies (All Distribution Engineering)
DTAB Chairman	Belville, Cape Town	20 copies
N-P-M	Simmerpan	10 copies
S-O-M	Simmerpan	2 copies
ECS Manager	Simmerpan	20 copies
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APPENDIX 3 - CONTROL STAFF TASK ANALYSIS

Appendix 3 National Control staff Task analysis

Introduction

The methods of working and the behaviour of members of National Control were analysed for both quiescent and disturbed network conditions. The task analysis took the form of observation followed by group question and answer sessions with each shift. The questions were divided into two basic groups , one for quiescent conditions and one for disturbed network conditions. The responses from the five shifts were almost identical with some of the shifts expanding on one or two areas based on the individual members experiences in other utilities.

Overview of the National Control Room

ESKOM's National Control has a four control desks. One for the shift supervisor and three for the controllers who are responsible for ;

- System frequency and generator loading
- System voltages
- Transmission network state

The primary task of each shift is to maintain the health of the network. Th... ...ia by which the system state is determined are ;

- System Frequency
- Voltage profile across the network
- Total system losses
- Automatic Generation Control performance
- Overall electrical security of the network

The instantaneous state of the power sy... n is determined from the displays and alarm messages sent to the controllers from the RTUs.

Display Facilities

Each desk is equipped with two or three 425 mm (or 17 inch) high... solution colour monitors, a Qwerty keyboard, dedicated station selection keyboard and a mouse.

An audible tone is triggered when ever a Breaker trips. This audible alarm has to be silenced manually by the control staff each time it is triggered.

Each controller has a dedicated telephone link to each regional control room, power station and distribution station. He is thus able to contact all his customers directly and to be contacted by staff in the field.

Along one wall of the control room is mimic or Map...oard. The Mapboard indicates the state of all power lines belonging to National Control dynamically via light emitting diodes. Each line has an embedded meter displaying the instantaneous megawatt load and its direction.

CRT Displays

The state of the power system is determined from the following displays available at each workstation,

1. Station one-line displays
2. Station alarms pages
3. System alarm message pages
4. System voltage page
5. Tie-line overviews
6. Generation status display

PPENDIX 3 - CONTROL STAFF TASK ANALYSIS

Station one-line

These operator displays are bird's-eye model of the actual physical structure and layout of a single power station or distribution station.

The one-line representation supports the abstract view and the bottom layer of the mental model used by the control staff during daily operations. The order of the electrical equipment on the display matches the physical arrangement at the station.

The graphical data on the one-line display is limited by character graphics functionality to device states (breaker and link) and analog values. See fig 1 in appendix 7.

Station Alarm page

This is a tabular list of the status elements and their current state at the station as indicated in Figure 3 of Appendix 7. The alarm points are displayed under the headings of

- Communication Alarms
- Station Alarms
- Panel Alarms

The elements are displayed as a list since there is no other suitable means of representation on the one-line displays. The relationship of the alarm or status element data is usually alphabetical.

It is important to note that there is no position relationship between the alarm elements and the points on the one-line displays other than by the name of the alarm will match one of the electrical objects on the one-line display.

Alarm messages

When ever there is an unauthorised change of state in the network, the data acquisition system or SCADA software notifies the control staff via message otherwise known as an "alarm message". This can be seen in Figure 3 of Appendix 7. At the same time the corresponding element will reflect the new state with a change of colour and shape or text on the displays.

Each alarm message consists of at least five fields;

- o Time indicating when the event occurred
- o Priority of the message
- o Name of the station at which the state change occurred
- o Name of the point changing state
- o The current state of the point

Alarm Bins

At national control all elements are associated with a device alarm bin. This is in contrast to the classical manner of displaying alarms by station.

Alarm bins are defined by the name of the device type. For example;

- Breakers (1 national and 3 regional)
- Generator Unit Breakers
- National analog limit infringements
- Regional analog limit infringements (we have three set of regional alarm bins)
- Feeder bay or panel alarm bins (1 national and 3 regional)
- AGC alarms
- KV and frequency limits

There are approximately 40 alarm bins in use on the ESKOM system at National Control. The alarm bins are displayed in the two lines at the bottom of every display and are 8 characters in length. A maximum of 20 bins can be viewed at any one time.

APPENDIX 3 - CONTROL STAFF TASK ANALYSIS

Each desk is set up to receive a specific sub-set of the alarm messages. It is the responsibility of the controller manning the desk to take the necessary action following the arrival of the message. Each messages has then to be acknowledged and deleted.

System Voltage

This display provides the control staff with a complete list of all busbar voltages from every station under national's control. Each station is listed vertically and the associated voltages at the station are placed horizontally next to the station name.

The stations on display are grouped by region rather than alphabetically as shown in Figure 4 of Appendix 7.

Tie-line overview

These displays and the Mapboard are the top layers of the mental model used by the control staff to establish position relationships between the different stations in the power network. See figure 5 in Appendix 7.

The information on the tie-line displays is a subset of the data from all the one-lines within the view area. The factors determining the size of the one-line subset on display is a function of the space allocated to each station. The smaller the space, the less data displayed per station.

The control staff influence the design of the tie-line displays based on the level of abstraction needed for disturbance control and restoration.

The various Man Machine Interface tasks carried out by the 5 man shift (four active and one spare) for each of the four work areas are listed below;

Staff tasks

Each shift has five members - four active and one spare. The actual tasks carried out by each staff member depends upon which desk he is on. Each desk has its own responsibilities. The scope of this task analysis is limited to the MMI actions related to the use of the National Control computers and not to the full range of responsibilities. Details are included where applicable to MMI interaction of other activities.

The individual tasks for each of the four desks under quiescent conditions are ;

Supervisor

Continuously monitor the overall state of the power network and the performance of shift members using the system displays. Offer guidance and assistance to the shift members when required.

The primary outputs for the Shift supervisor are;

- Sufficient generation
- Valid load flow
- Optimised loading
- Acceptable voltage profile
- Short term contingency plan
- Accurate Morning report
- Secure power system

During disturbances make decisions on system restoration, liaise with management on the state of the power system. Once the disturbance has started and after the system has settled down he has to;

- Determine the cause of the disturbance
- Inform management of the event and the scope of the damage.

- Determine the sequence of events
- Start restoration
- Write up the incident report

To find out the details of the fault his only source of information is the alarm logs and the one-line displays. Discussions with field staff assist in isolating the exact problem but this usually takes place after the system has settled down.

Frequency Control

This task involves the frequency of the power system. The primary display used to monitor the generation is the AGC display shown in Figure 6 of Appendix 7.

The minute by minute quiescent tasks are:

- Ensure that the system frequency is kept at 50.00 Hertz.
- Optimise the use of coal reserves at the various power stations to achieve the lowest cost of electricity using the economic dispatch program
- Ensure that there is sufficient spinning reserve for the Automatic Generation Control (AGC) program to use in the event of an unexpected losses of generation.
- Ensure that there is always sufficient plant available for the next 24 - 48 hours.
- Inform the head of control and the rest of the shift on the current state of the electricity supply at the power stations.
- Liaise with the power stations on actual and potential loss of generation particularly in respect of "risk-of-trip" activities on a generating unit or feeder.

Transmission Control

This task involves getting the power from the power station to the distribution stations. The minute by minute quiescent tasks are;

- Look after the security of the network by ensuring that there are multiple connections between the different stations in the power network.
- Authorise the handing over equipment to the regions for maintenance.
- Do the necessary switching of lines in accordance with daily maintenance schedule.
- Where possible ensure that the system voltages are at there correct levels.
- Read, understand, acknowledge and delete all the alarms sent to work station CRT.
- Call out maintenance staff to investigate and correct problems highlighted by the alarm messages.

Voltage Control

The primary task is to ensure that the system voltages are kept at there correct values following any network switching or any change in generation. This is particularly relevant when the transmission desk is very busy or there has been a sudden loss of generation. The role of the voltage controller considered to be the most crucial of all the tasks in the control room.

The quiescent activities are;

- Monitor all the system voltages.
- Monitor the state of voltage control equipment such as reactors and capacitors and switch them in and out as required.
- Monitor the tap positions of all transformers and change them if required

SCADA Design

In principle SCADA is designed to report the change of state of every point monitored by the system. This theory of operation is based on the assumption need to be informed of what is happening

APPENDIX 3 - CONTROL STAFF TASK ANALYSIS

Disturbance conditions

During a disturbance the quiescent tasks still continue but added them are the problems of the disturbed system.

Once the disturbance starts or becomes apparent, two phases of activity take place. On the one hand there is the system activity and on the other is behaviour and activity of the control staff.

Their objective is to determine the cause and extend of the problem.

- Sudden increase in the number of alarm messages sent to all control staff
- Audible alarms are triggered
- Failure of communications to and from the area of concern at the crucial moment
- Slow down of the system response due to increased alarm load and display demand.

Appendix 4 MMI functionality comments

Introduction

This appendix contains the comments made by the control staff on topics related to their daily activity while using the Character Graphics Man Machine Interface. These comments are in response to the questionnaire sent to all the shifts.

Topic	Comments by National Control staff
Alarming in general, Alarm Page layout and content.	After a failover, all the 120 comms alarms are re-output, both in alarm and return to normal - Question - why cant the exceptions be reported?
	Need to be able to mark or reserve alarms to prevent them from being deleted by accident.
	The existing layout of alarm data is not easy to read
	Need notification and audible alarm if the alarms PC logger fails
	Need to be able to move directly to the station name mentioned in the alarm message. Not have to use the system menu.
	Time delay between the audible alarm and the display of the Breaker alarm messages is far too long
	Far to many unnecessary alarms, each of which has to be acknowledged and deleted - particularly during a disturbance.
	Why are alarm messages sent to National Control from manned stations (e.g. Drakensburg)
	Why cant the Hydro and Gas station alarms be sent to the Loading or Frequency desk instead of the Transmission desk
	There is a constant number of nuisance alarms generated by the Hydro and Gas stations - can these not be eliminated?
	There are an enormous number of false alarms- need to prevent them at the RTU.
	General problems with the transformer alarms from Ingagane
	Need sequence of event data if possible from the RTUs.

Disturbance alarm problems	Too much time is spent acknowledging and deleting alarms messages than fixing the problem during disturbances.
	Pages and pages of frequency alarms are generated each time the frequency moves in and out of limits during a disturbance.
	Following a disturbance, once the basic cause of the problem has been found the remaining alarms are ignored and deleted. The problem with doing this is that an important alarm message may be missed in the heat of the moment. Need a better way to display alarm data in general.

Navigation	Need to be able to move to the station one-line display from any place in which the station name is displayed.
	When traversing a menu - preference is for automatic wrap around at the top and bottom
	Definite need for cordless mice to drive the display call-up.
	On dual headed consoles would like the cursor to move from CRT to CRT automatically when moving off the screen boundary.
	Need geographic map indicating physical layout of stations and lines
	Need global indication map - on demand , to indicate current view in system overview display.

Automatic Generation Control	Need to be able to base load a whole power station at the same time and to cancel the request during a low frequency incident.
	On standby display need colour change in the sent-out-megawatt values if the value changes by more than 5%
	Very big need for capability diagrams of all generating units

APPENDIX 4 - MMI FUNCTIONALITY COMMENTS

Mapboard	Need to indicate on the Mapboard that live line maintenance is in progress..
	Need to be able to indicate split busbars at a station
	Like direct access to station one line displays from dedicated push buttons rather than from a CRT menu.
Tie-line or overview displays	Not happy with the existing 6 page (2x3) overview displays
	Would prefer to have system overview display match the Mapboard layout. Have four or five display pages horizontally rather than 2 by 3 that don't line up with the Mapboard.
	Need to indicate live line work on the tie-lines
	Need to indicate when a feeder is not-in-service
	Need to indicate helicopter line spraying.
Voltage page	Mixed feelings with the voltage page layout and structure.
Supervisory control	Provide global indication that a device in under supervisory control so all staff, particularly the head of shift can see what is happening.
Audible alarms	Need means to prevent continuous tone from the audible alarm during a disturbance, as each time a new Breaker message comes in an additional button depression is required.
	Need to indicate the different Breaker audible tones, need a different tone for Generator Breakers, Transmission Breakers and BUSZONE protection breakers.
Data acquisition	Need to have the ability to demand scan a particular area or group of stations
	Would like to have colour coding of the different group alarms
	Need detailed breakdown of group alarms.
Additional data from the RTU	Need to be able to access additional data on demand from the RTU about the state of the protection and group alarm details following Breakers, Transformers, SVC etc. problems.
Manual Entry , Tags, Inhibit, Manual etc.	Provide intelligent and look ahead spelling checks when entering station name data to avoid text entry problems
	Get consistency for all data entry activity (Tag and NIS have are not consistent.)
	Need to move the manually entered data for the regions onto separate lists to reduce the time it takes to find national data.
	Be able to enter text or information against a point and to have an indication of the message on demand and prior to issuing a control to the device
	Provide indication of live-line work and helicopter washing on the overview displays
	Provide the ability to inhibit all the alarm elements at a device and an entire electrical object, e.g. a feeder, generator or transformer etc.
Supervisory Control	Indicate that the Supervisory Inhibit state of a device on the one-line
	Before allowing a control to be sent to a device, display any operator entered notes in a popup window
	Provide the ability to cross check parallel lines prior to issuing a control, if one line is already open warn the controller
	Warn the controller if he is tripping the wrong breaker of a set of double lines after opening one end.

APPENDIX 5 - STATIC VAR COMPENSATOR

Appendix 5 Static VAR. Compensator

Introduction

Sample of Status and Analog element data available from a Static VAR. Compensator. This device is a good example of the phase three protection scheme that uses digital inputs fed directly to the ERTU from the protection equipment that monitors and protects the whole Compensator.

Signal Description Digital Inputs	**RTU Plug No.**	**RTU Pin No.**
SVC OFF (COMMAND 1)	PB1	C32
SVC ON (COMMAND 1)	PB1	C31
SVC OFF (STATUS) - HIGH	PB1	C30
SVC ON (STATUS) - LOW	PB1	C29
SVC TRIP (COMMAND 1)	PB1	C28
RAISE VOLTAGE SET POINT (COMMAND 1)	PB1	C27
LOWER VOLTAGE SET POINT (COMMAND 1)	PB1	C26
RAISE REACTIVE OUTPUT (COMMAND 1)	PB1	C25
LOWER REACTIVE OUTPUT (COMMAND 1)	PB1	C24
MANUAL CONTROL SELECTION (COMMAND 1)	PB1	C23
AUTOMATIC CONTROL SELECTION (COMMAND 1)	PB1	C22
MANUAL CONTROL SELECTION (STATUS)	PB1	C21
AUTOMATIC CONTROL SELECTION (STATUS)	PB1	C20
MASTER TRIP MAIN (-K9)	PB1	C7
MASTER TRIP BACK-UP (-K19)	PB1	C6
TNS SWITCH(-S1) IN TEST POSITION	PB1	C5
SPARE		
SPARE		
CONTROL SYSTEM SLOPE RAISE (COMMAND 1)	PB4	C30
CONTROL SYSTEM SLOPE LOWER (COMMAND 1)	PB4	C29
CAPACITIVE DYNAMIC RANGE (STATUS)	PB4	C28
REACTIVE DYNAMIC RANGE (STATUS)	PB4	C27
AUXILIARY AC SUPPLY ESKOM (STATUS)	PB4	C26
AUXILIARY AC SUPPLY AUX. TRANSFORMER (STATUS)	PB4	C25
MMI CONTROL SYSTEM HEALTHY	PB4	C24
MMI CONTROL SYSTEM FAILURE	PB4	C23
AUXILIARY AC SUPPLY UNHEALTHY	PB4	C22
AUXILIARY AC SUPPLY FAILURE TRIP	PB4	C21
EXPANSION UNIT FAILURE	PB4	C20
HV VT MCB'S TRIPPED	F	C19
VALVE ROOM 1 AIRCON (ALARM)	P	C18
VALVE ROOM 2 AIRCON (ALARM)	PB4	C17
CHARGER 1 FAILURE AC	PB4	C16
CHARGER 2 FAILURE AC	PB4	C15
CHARGER 1 FAILURE DC	PB4	C14
CHARGER 2 FAILURE DC	PB4	C13
CHARGER 1 DC SYSTEM ABNORMAL	PB4	C12
CHARGER 2 DC SYSTEM ABNORMAL	PB4	C11
DC BOARD 1 DC FAIL	PB4	C10
DC BOARD 2 DC FAIL	PB4	C9
DC BOARD 1 DC ABNORMAL	PB4	C8
DC BOARD 2 DC ABNORMAL	PB4	C7

APPENDIX 5 - STATIC VAR COMPENSATOR

DC BOARD SYSTEM PARALLELED	PB4	C6
DC BOARD 1 VENTILATION FAILURE	PB4	C5
DC BOARD 2 VENTILATION FAILURE	PB4	C4
VALVE ROOM 1 FIRE ALARM	PB4	C3
VALVE ROOM 2 FIRE ALARM	PB4	C2
BREAKER POLE DISAGREEMENT	PB2	C32
PANTOGRAPH POLE DISAGREEMENT(ATHENE ONLY)	PB1	C1
PROTECTION UNHEALTHY	PB2	C31
BREAKER SF 6 NON-URGENT ALARM	PB2	C30
BREAKER SF 6 URGENT ALARM	PB2	C29
BREAKER SPRING NOT CHARGED	PB2	C28
DEGRADED MODE TCR 1 OFF	PB2	C27
DEGRADED MODE TCR 2 OFF	PB2	C26
DEGRADED MODE TCR 1 + TCR 2 OFF	PB2	C25
LV DISCONNECTOR TCR 1 OPEN (COMMAND 1)	PB2	C24
LV DISCONNECTOR TCR 1 CLOSED (COMMAND 1)	PB2	C23
LV DISCONNECTOR TCR 1 OPEN (STATUS)	PB2	C22
LV DISCONNECTOR TCR 1 CLOSED (STATUS)	PB2	C21
LV DISCONNECTOR TCR 2 OPEN (COMMAND 1)	PB2	C20
LV DISCONNECTOR TCR 2 CLOSED (COMMAND 1)	PB2	C19
LV DISCONNECTOR TCR 2 OPEN (STATUS)	PB2	C18
LV DISCONNECTOR TCR 2 CLOSED (STATUS)	PB2	C17
LV EARTHSWITCH TCR 1 OPEN (STATUS)	PB2	C16
LV EARTHSWITCH TCR 1 CLOSED (STATUS)	PB2	C15
LV EARTHSWITCH TCR 2 OPEN (STATUS)	PB2	C14
LV EARTHSWITCH TCR 2 CLOSED (STATUS)	PB2	C13
SPARE		
SPARE		
SPARE		
SPARE		
HV DISCONNECTOR D1 OPEN (COMMAND 1)	PB3	C32
HV DISCONNECTOR D1 CLOSE (COMMAND 1)	PB3	C31
HV DISCONNECTOR D2 OPEN (COMMAND 1)	PB3	C30
HV DISCONNECTOR D2 CLOSE (COMMAND 1)	PB3	C29
HV DISCONNECTOR D1 OPEN (STATUS)	PB3	C28
HV DISCONNECTOR D1 CLOSE (STATUS)	PB3	C27
HV DISCONNECTOR D2 OPEN (STATUS)	PB3	C26
HV DISCONNECTOR D2 CLOSE (STATUS)	PB3	C25
HV DISCONNECTOR D3 RED PHASE OPEN (STATUS)	PB3	C24
HV DISCONNECTOR D3 RED PHASE CLOSED (STATUS)	PB3	C23
HV DISCONNECTOR D3 WHITE PHASE OPEN (STATUS)	PB3	C22
HV DISCONNECTOR D3 WHITE PHASE CLOSED (STATUS)	PB3	C21
HV DISCONNECTOR D3 BLUE PHASE OPEN (STATUS)	PB3	C20
HV DISCONNECTOR D3 BLUE PHASE CLOSED (STATUS)	PB3	C19
HV DISCONNECTOR D4 RED PHASE OPEN (STATUS)	PB3	C18
HV DISCONNECTOR D4 RED PHASE CLOSED (STATUS)	PB3	C17
HV DISCONNECTOR D4 WHITE PHASE OPEN (STATUS)	PB3	C16
HV DISCONNECTOR D4 WHITE PHASE CLOSED (STATUS)	PB3	C15
HV DISCONNECTOR D4 BLUE PHASE OPEN (STATUS)	PB3	C14
HV DISCONNECTOR D4 BLUE PHASE CLOSED (STATUS)	PB3	C13
SPARE		

APPENDIX 5 - STATIC VAR COMPENSATOR

Signal Description Analog Inputs	RTU Plug No.	RTU Pin No.
SVC HV VOLTAGE	PA1	C32-A32
SVC LV VOLTAGE	PA1	C31-A31
SVC CURRENT (RED PHASE)	PA1	C30-A30
SVC CURRENT (WHITE PHASE)	PA1	C29-A29
SVC CURRENT (BLUE PHASE)	PA1	C28-A28
Q - CONTROL (MEASUREMENT)	PA1	C16-A16
SPARE		
SVC REACTIVE POWER (TOTAL)	PA1	C24-A24
SVC REACTIVE POWER (RED PHASE)	PA1	C27-A27
SVC REACTIVE POWER (WHITE PHASE)	PA1	C26-A26
SVC REACTIVE POWER (BLUE PHASE)	PA1	C25-A25
NEGATIVE PHASE SEQUENCE VOLTAGE	PA1	C23-A23
SPARE		
SPARE	PA1	C15-A15
SVC VOLTAGE SET POINT	PA1	C22-A22
AMBIENT TEMPERATURE	PA1	C8-A8
VALVE ROOM 1 TEMPERATURE	PA1	C7-A7
VALVE ROOM 2 TEMPERATURE	PA1	C6-A6
THYRISTOR COOLING SYSTEM TCR1 WATER TEMP.	PA1	C5-A5
THYRISTOR COOLING SYSTEM TCR2 WATER TEMP.	PA1	C4-A4
SPARE		
SPARE		
SLOPE	PA1	C21-A21
GAIN	PA1	C20-A20
SPARE		
SPARE		
FILTER 1 CURRENT	PA1	C19-A19
FILTER 2 CURRENT	PA1	C18-A18
FILTER 3 CURRENT	PA1	C17-A17
BSVC RED	PA1	C3-A3
BSVC WHITE	PA1	C2-A2
BSVC BLUE	PA1	A1-C1
TCR 1 CURRENT RED AND WHITE PHASE	PA1	C14-A14
TCR 1 CURRENT WHITE AND BLUE PHASE	PA1	C13-A13
TCR 1 CURRENT BLUE AND RED PHASE	PA1	C12-A12
TCR 2 CURRENT RED AND WHITE PHASE	PA1	C11-A11
TCR 2 CURRENT WHITE AND BLUE PHASE	PA1	C10-A10
TCR 2 CURRENT BLUE AND RED PHASE	PA1	C9-A9
SPARE		
SPARE		

APPENDIX 6 -GLOSSARY

Appendix 6 Glossary

The following are explanations of words and abbreviations used in the document.

Alarm processing

This is the service provided by the ALARM program to all other software modules in the computer system. Applications needing to alert the control staff of specific alarm conditions, send the ALARM program the necessary values as parameters in a message packet. The ALARM program unpacks the values, builds up the ASCII text according to predefined structures and places the text message in the appropriate buffer.

The MMI detects the existence of new messages in the buffers and re-displays the ALARM buffer name in the bottom line of all displays. To see the alarm text, the control staff select the buffer name and the appropriate alarm message display is sent to the screen. The control staff then acknowledge and delete the alarms once they have read them.

Bay Processor

In high voltage substations there are so many signals that it requires a dedicated computer to handle and record all the changes taking place for each electrical object such as a feeder, transformer, etc. Figure 2-3 show the relationship between the individual Bay Processors and the ERTU.

The word "bay" comes from the physical structure and location at the substation in which the feeder is installed. Thus the processor associated with a particular feeder, is referred to as the "bay processor".

BKR or Breaker

A large switch used to turn on and off the electricity at the power stations and distribution stations.

The general terms used to indicate the state of the breaker are tripped (open) and closed (on). A breaker is operated either manually, remotely from a control room or automatically by protection equipment.

Communication Line loading

The overall communication line loading for a single comms line or channel is a function of :

- The number of RTUs on the communications line
- The number of group addresses per RTU
- The rate at which each group is scanned
- The number of data bits per group
- The number of interlaced control requests sent to the RTUs

The communication line loading should not exceed 80% of the maximum line carrying capacity in any one cycle period. The period is determined by the scan interval of the group with the lowest priority. The 80% limit is important if the quality of the communications lines are poor and there are a large number of retries needed to cater for missing or lost data. Later versions of software incorporate algorithms to maximise the data acquisition rate so as to avoid inactive periods while keeping the line load below 80%.

Communication processing

Due to the limited bandwidth in the communications links, there are usually 6 to 8 RTUs per circuit, set up in a party line fashion.

Each communications link also provides alternate communications paths to another 6 to 8 RTUs should the primary communications link fail. The maximum number of RTUs per party line was determined by the vendor and the data loading, i.e. the data quantities at each remote required to be scanned. Each RTU, depending upon the RTU vendor, would have up to 64 unique group addresses which would allow between 300 and 400 bits of data per group

APPENDIX 6 -GLOSSARY

address to be sent back to the Host per scan. The historical restrictions being a combination of the baud rate the Host computer functionality and power.

The current SCADA systems make use of fibre optic communication links and with the latest computer hardware the CPU power is not a problem for data acquisition but is for the control staff, due to the quantities of data presented to them. Historically, there were in-built restrictions in both communications ability and CPU resources, that limited the quantity of data that could be sent to the Host for processing from the RTUs.

These restrictions acted as a physical filter both to the data that could be transmitted and the speed at which it arrived. These delays gave the control staff time to breath and take stock of the situation during a disturbance. With the faster and more powerful CPUs and better communications (via satellite and fibre optics) the problem of data overloading becomes a very serious indeed.

DAQ — **Data Acquisition.** The process of moving data from the RTU to the Host.

Data Base — A storage area in the form of a tables used to hold the all the data needed by the computer programs.

The data brought back by the SCADA module, is stored in a central data base. The type and structure of the data base is vendor specific. The market does tend to drive the design but currently it is determined by the needs of the tasks that interface to it.

Since SCADA activity has to run in real time, all I/O to the SCADA data base has to be as fast as possible. Thus, the design of the data base is around the storing of the latest data from the RTUs and not the ease of maintenance. In a large real time process control system, there are many different data bases usually one per application. The vendor provides means of cross linking data between the data bases to avoid duplication.

Data processing — It is the responsibility of the SCADA software to determine what has changed at the RTU by comparing the current scanned data with the previous scan and issuing the appropriate text message to the ALARM program for any changes detected. The text messages are usually hard coded and there is little or no way the control staff can verify the accuracy of the majority of the messages, short of sending a someone out to the station to get confirmation that the message is valid.

The data coming back from the RTU can only be identified by its group address and an associated index. Currently there is no additional processing done to confirm the validity of the message received from the SCADA system. Depending upon what has changed, it is sometimes possible to verify the reported action by observed changes in associated elements of the power network.

EMS — **Energy Management system.** The abbreviation used in the Electrical Industry to refer to the complete supervisory and control computer system used in the monitoring and control of an integrated power system.

ERTU — Enhanced Remote Terminal Unit. It is similar to the standard RTU but contains on board computers that provide additional functionality over and above the RTU.

ESTEL — **ESKOM Standard Telecommunications** Protocol. This protocol was designed and specified by ESKOM to avoid the problems of being locked into proprietary vendor communication hardware and software. The ESTEL protocol is based on the Open Systems Interconnect Reference Model (OSI-RM), developed by the International Standards Organisation (ISO) and CCITT. The protocol uses the current international Telecontrol standards proposed by the IEC.

IAP

Intelligent Alarm Processor. A software program used to summarise the results of multiple alarm messages and reduce the number of messages sent to control staff. They are usually "rule" based which makes them very expensive to maintain in a changing environment.

Interconnected Power System

Electricity is transmitted from power stations to distribution stations and to consumers at different voltages. The National Control Centre is only concerned with the distribution of power above 132 KV. Voltages below 132 KV are the responsibility of the regional distribution stations.

The power network above 132 KV is referred to as the **Interconnected Power System** or Main Transmission System.

MMI -

Man Machine Interface

This covers both the hardware and software used by control staff to monitor and control the integrated power system. In general terms it refers to the method and means of exchanging information between a person and a machine. It primarily encompasses the method of displaying data on a computer screen.

The primary reason why data is brought back from the RTU is to allow Control staff to "see" what is happening at the remote site. This is done via the Man Machine Interface (MMI).

The MMI up until quite recently was limited to character graphic CRTs that provided about 96 possible shapes apart from the normal alphabet in 7 or 8 colours. The electrical industry is in the process of moving towards what is know as Full Graphics. In which the conventional CRT is replaced by a desktop workstation offering Pan, Zoom, Declutter, Popup windows and Pull down menus.

The displays built with these tools have up to 32 000 colours and the user creates the shapes required from the simple primitives of Circle, Box, Polyline etc.

At present the development of the Full Graphics MMI is still it its infancy and it will be a number of years before formal trends and needs have been identified and incorporated into the control rooms.

One-line display

A bird's eye view of a single substation drawn symbolically. Figure 7-4 is an example of a one-line diagram.

Periodic Data Acquisition

During "periodic" data acquisition, the Host requests specific pre-defined data sets or groups of data from the RTU pre-set intervals.

All groups at the RTU are scanned at different rates depending upon the data type and the rate at which data changes. Obviously the faster the better! The data in each group is transferred to the Host irrespective of what has changed at the RTU. This is an overkill in one way but during a disturbance the communication line loading does not change where as the Host processing does.

Protection

All electrical equipment used by utilities is protected against faults that can potentially destroy it. A protection scheme has two parts, the detection equipment and the physical method of interrupting the electric'';. The detection equipment uses the rate change in voltage and current to determine where the fault is located and acts to trip the breakers nearest to the fault.

APPENDIX 6 -GLOSSARY

Phase 3 protection

Electronic rather than physical protection sensing equipment used by ESKOM to protect the power system from faults. This form of protection does not rely on mechanical relays to determine the existence of a fault. The PHASE 3 electronic protection equipment interfaces directly to the Bay processor RTU.

Polled exception reporting

The data at the RTU is divided in to a number of categories (between 2 and 8). The Host initiates data transfer from the RTU by sending a "request for changes" message, specifying the category of data it is expecting.

If the RTU has any changes to report for the selected category, then the change, identified by its group address and index into the group is dispatched. This same addressing structure is matched at the Host which decodes the change message and produces the appropriate canned message for the MMI.

If no elements have changed in the requested category the RTU returns a "no data" response.
Once all the RTUs have been "polled" for the current category the next category is processed until it is time to start over again.

The RTUs are polled at least once a second depending on the baud rate and the amount of data returned to the Host. It becomes obvious that the line loading will change considerably during a disturbance for "exception" reporting as will the Host processing.

Power Application Software

Software used to carry out "what-if" studies of different states of the electrical network as well the automatic control of generator output.

PLC

Programmable Logic Controller, a device in which a series of programmed commands can be inserted. The device is used to control industrial plant. In the case of a feeder, all the functions that would have required physical relays are replaced by logical relays in the PLC. The PLC outputs are used to drive the physical plant to match functions sent to the PLC from the ERTU.

Prototype

A model of the real thing, mainly used to testing ideas

RTU

Remote Terminal Unit

A Remote Terminal Unit, is an electronic devices situated at a power station or distribution station. This device acts as a link between the plant and the SCADA system. It is the interface between the plant and the Energy Control computer system situated at the control centre. An RTU is connected to the electrical equipment via optically isolated wiring. (The optical isolation is to prevent fault currents and induced high voltages destroying highly sensitive low voltage RTU equipment.)

The Host communications to and from the RTU are provided by various means e.g. Microwave links, Power line carriers and Telephone data circuits.
The older RTUs are made up of a number of standard hardware components such as :

- Host request address decoding and requested data export
- Status inputs (from 1 to 8 bit values)
- Analogue inputs (8 to 16 bit values)
- Host computer control request execution
- Accumulated power measurements (12 to 32 bit values)
- Communications channel selection hardware
- PC I/O connections
- Power supply

Electrical equipment status inputs are interfaced to the RTU at various voltage and current levels such as 20 milli amp current loops. (Fieldbus protocol is starting to make an appearance though there appears to be a reluctance by most vendors to offer it.)

In the older RTUs, Measurement or "Analogue" inputs are converted to digital values by a shared Analogue to Digital converter in the RTU just prior to the value being telemetered to the Host computer.

In the latest RTU designs, the RTU is not longer a hard wired inactive device but is actually a powerful micro processor with considerable facilities.

These facilities allow it to provide a number of additional functions and to add value to the data sent to the Host. It is this, so far, unused capability that can greatly change the way SCADA systems operate in the future.

For example the latest generation of RTUs process all input data from the yard every milli-second. They have their own data base into which all status and analogue values are stored in digital form. This allows the RTU to do limit checking on the analogues and advise the Host of the fact when an Analogue has exceeded limits or is in an alarm state!

SCADA The general name that refers to the process of obtaining data from an RTU or ERTU. Electrical Utilities (such as ESKOM) are monitored and controlled via computer based Supervisory Control and Data Acquisition (SCADA) facilities from a central control room.

The Substations and Power Stations comprising the power network are linked to the control room via a network of communications circuits in a radial mode. The state of equipment in the power network is retrieved and delivered to the central computer via the "Data Acquisition" part of the SCADA module.

When the control staff need to alter the state of an electrical element, such as a Breaker, they send a control signal to the Breaker instructing it to change state. The control message is delivered to the device by the "Supervisory Control" part of the SCADA module.

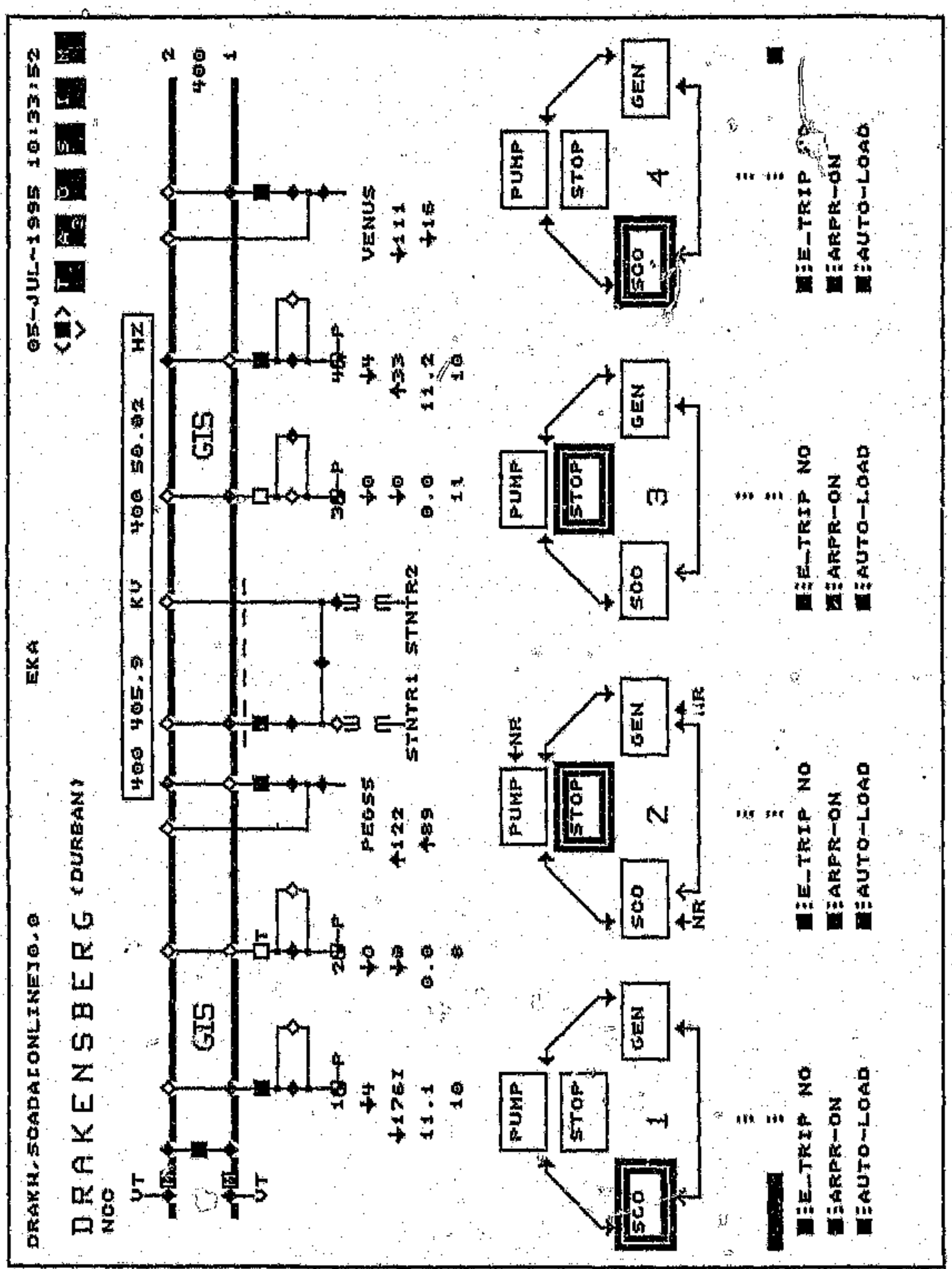
Thus there are two distinct parts to SCADA, firstly the acquiring of network data and the subsequent supervisory control of the network objects.

Simulator A device used to emulate an active industrial process without the risk of damaging real plant.

Tie-Line Displays Similar to one-line displays but showing inter-station connection data from many stations. The tie line data includes power flows, voltages and breaker states for all stations on display. There are tie-line displays for all regions in the power network.

Appendix 7 Copies of displays from the ESKOM control system

Figure 1 : One-line display of the Drakensburg pump storage station.
The top of the display indicates the electrical configuration and the state diagram at the bottom show the current modes of the four units.



APPENDIX 7 - COPIES OF DISPLAYS

Figure 2 : Copy of the first alarm page from the Drakensburg pump storage station. Note how the alarms are divided into three groups.

DRAKN, SCADACONLINE10, -1 EKA 05-JUL-1995 10:34:02

DRAKENSBERG

NCC

COMMUNICATION ALARMS

NOR	BATTERY_COMMON	NOR	BEARER_LPU_REC__FL
NOR	BEARER_LPU_XMIT_FL	NOR	CARRIER_SSB_REC__FL
NOR	CARRIER_SSB_XMIT_FL	NOR	CARRIER_UPS_FAIL
NOR	CONITEL_1_IND_FAIL	NOR	CONITEL_2_IND_FAIL
NOR	CONITEL_3_IND_FAIL	NOR	CONITEL_4_IND_FAIL
NOR	CONITEL_CHARGER_FAIL	NOR	DRAKN_IT_URGENT

STATION ALARMS

NOR	BUS_STRIP_OPERATED	NOR	BUS_ZONE_DC_FAIL
NOR	BUS_ZONE_DISAGREEMNT	NOR	BUS_ZONE_OPERATED
NOR	CONTROL_COMMON		
		NOR	400_INTER_SUPPLY_FAIL
NOR	AUTO_U/F_CONTROL_FAIL	NOR	DRKLF_DATA_EQ/FSE_FAIL
NOR	DRKLF_WATER_LOW_TRIP	ALRI	FIRE_ALARM
NOR	HEAD_RACE_GTE_CNT_FAIL	NOR	KLBRN_DATA_EQ/FSE_FAIL
ALR	KLBRN_WATER_LOW_TRIP	NOR	KLBRN_WATER_HIGH_ALARM
NOR	MDF_ZERO_VOLTS	NOR	SEQ_START_DC_FAIL
NOR	STATION_EMERGENCY		

PANEL ALARMS

NOR	400CPLR_GROUP1	NOR	400_SF-6_URGENT_ALRM
NOR	400_SF-6_NON_URGENT	NOR	G/M1_GENERAL_ALARM
NOR	G/M1_U/F_PMP_TO_STND	NOR	G/M1_U/F_SCO_TO_GEN
NOR	G/M1_U/F_STND_TO_GEN	NOR	G/M2_GENERAL_ALARM
NOR	G/M2_U/F_PMP_TO_STND	NOR	G/M2_U/F_SCO_TO_GEN
NOR	G/M2_U/F_STND_TO_GEN	NOR	G/M3_GENERAL_ALARM
NOR	G/M3_U/F_PMP_TO_STND	NOR	G/M3_U/F_SCO_TO_GEN
NOR	G/M3_U/F_STND_TO_GEN	NOR	G/M4_GENERAL_ALARM
NOR	G/M4_U/F_PMP_TO_STND	NOR	G/M4_U/F_SCO_TO_GEN
NOR	G/M4_U/F_STND_TO_GEN	NOR	PEGSS__GROUP1
NOR	PEGSS__SF6_DIFF_PROT	ALR	TRFR_1_GROUP1
NOR	TRFR_1_GROUP2	NOR	TRFR_2_GROUP1
NOR	TRFR_2_GROUP2	NOR	VENUS__GROUP1
NOR	VENUS__SF6_DIFF_PROT		

APPENDIX 7 - COPIES OF DISPLAYS

```
LIST.ALARMIONLINEJ0.0                  EKA                     05-JUL-1995 10:34:40
                                 GLOBAL ALARMS
       CURRENT PAGE      3        PRIORITY STATES : 1 2 3 4 5 6 7 8
                                 SELECT TO REFRESH THE DISPLAY. ORDER BY :SEVERITY:
  TOTAL NO OF ALARMS   130  PERMISSION :CONTROL  :AUDIBLE  :  READ   :NOCHECK
                            SEVERITY   |  *  |  *
                            BIN   -      *          GROUP       *        GLOBAL
                            SELECT TO UPDATE PERMISSION MAP.
10:20 04 *3 RTU      GRTVLM                    ONLINE     CHANGED STATE TO
10:20:02 *3 LINE EKFV1B-CTRL_DMF-WATCHDOG      ONLINE     CHANGED STATE TO
10:25 .5 *5 SIMPAN LOCAL LO_DUVHA_S_O_M W      HIGH     MVA   3450   3457
10:01:30 *5 WATERSHED ER BATTERY_COMMON        ALARM
08:16:29 P3 RTU      ARIES                     FAILED     CHANGED STATE TO
08:02:42 P3 EKA DEVICE: NATIONAL_AOBFN1A       FAILED     (BFN CONSOLE 1 HEA
09:56:24 P5 THESEUS       CARRIER_LPU_REC__FL ALARM
08:41:40 P5 ATHENE ERTU   CARRIER_LPU_BEARER  ALARM
07:33:56 P5 RYGI          CARRIER_LPU_XMIT_FL ALARM
                     END OF ALARM LIST
```

Figure 3 : A typical listing of the type of alarm text messages sent to the control staff. Note how cryptic the messages are. This is caused by the "canned" text imposed by the SCADA data base structure.

APPENDIX 7 - COPIES OF DISPLAYS

Figure 4 : This is the voltage page used by the control staff to see what the different voltages are across the entire network. The stations are ordered by region. The capital "F"s indicate the loss of telemetry from the stations in question.

VOLT_SUM.SOADAIONLINEI0.0 EKA 05-JUL-1995 10:35:06

NAME	765KV	400KV	220KV 275KV	132KV	
MERSY		399	285	134	
IMPAL			282	133	
INVUB		400	281		
UMFLZ		402			6
NORMN		398		135	89
GRGDL			283	137	93
VENUS		412	284		
DRAKN		406			
PEGSS		405			
OHIVL		396			
INCND		404		135	
KLRWT			281		
CAMDN		404			
TUTUK		404			
ALPHA	754	409			
BETA	755	410			
LNDER		410		135	
THESS		401 F		135 F	
PERSS		412	279		
HYDRA		401	228	129	
POSDN		398	226	132	
GRASS		393	219	135	
NEPTN		401		135	
PEMBR			217	136	
KRONS		406			
ARIES		403 F			
AGGNS		404	223		
HELS		392 F			
JUNO		403			
AUROR		402		132	
KOEBG		395		130	
ACAC		393		133	
MULDR		395		133	
BACCH		405		136	
PALMT		0			
PROTS		403			
DROER		411		139	
BUFFL				135 F	
ILLOV			278	135	
KRIEL		403 F			
SOL		405		134	
ZEUS		405 F			
KOMAT			262		
KRSPN			274 F	137 F	
ARNOT		402	281		
HENDR		404		136	
VULON		398		136	
KENDL		414 F			
DUVHA		414			
MATLA		407	289		
ROOKD				134	
SIMPL			286	138	

NAME	765KV	400KV	220KV 275KV	132KV	
MARTH			281	139	
PRAIR			283	139	
FOSKR			279	139	
MERNS		412	288	139	
WITKP		405 F	287 F	134 F	
MATMB		403		133	
MIDAS		399		135	
MERCR		396		133	
TABOR			281 F	137 F	
HERMS		395		136	
PLUTO		401	286		
TRIDN			279		90
BIGHR			278		90
WARMB			[illegible]	138	
WATRS			271	133	
SPITS		2	286	139	91
ARART			282		88
KOMTP			276	138	
MINRV		404	285		
APOLL		399	289		
OROYD			278 F	135 F	
JUPTR			279 F		89 F
ESSLN			285 F	0 M	
LETHB			291		
MERAP			270	134	
EVRST			279	132	
GLOCK		413	290		
BERNN			282 F	138 F	
HERA		399 F	285 F		
KKFN					92
VERDN			289		

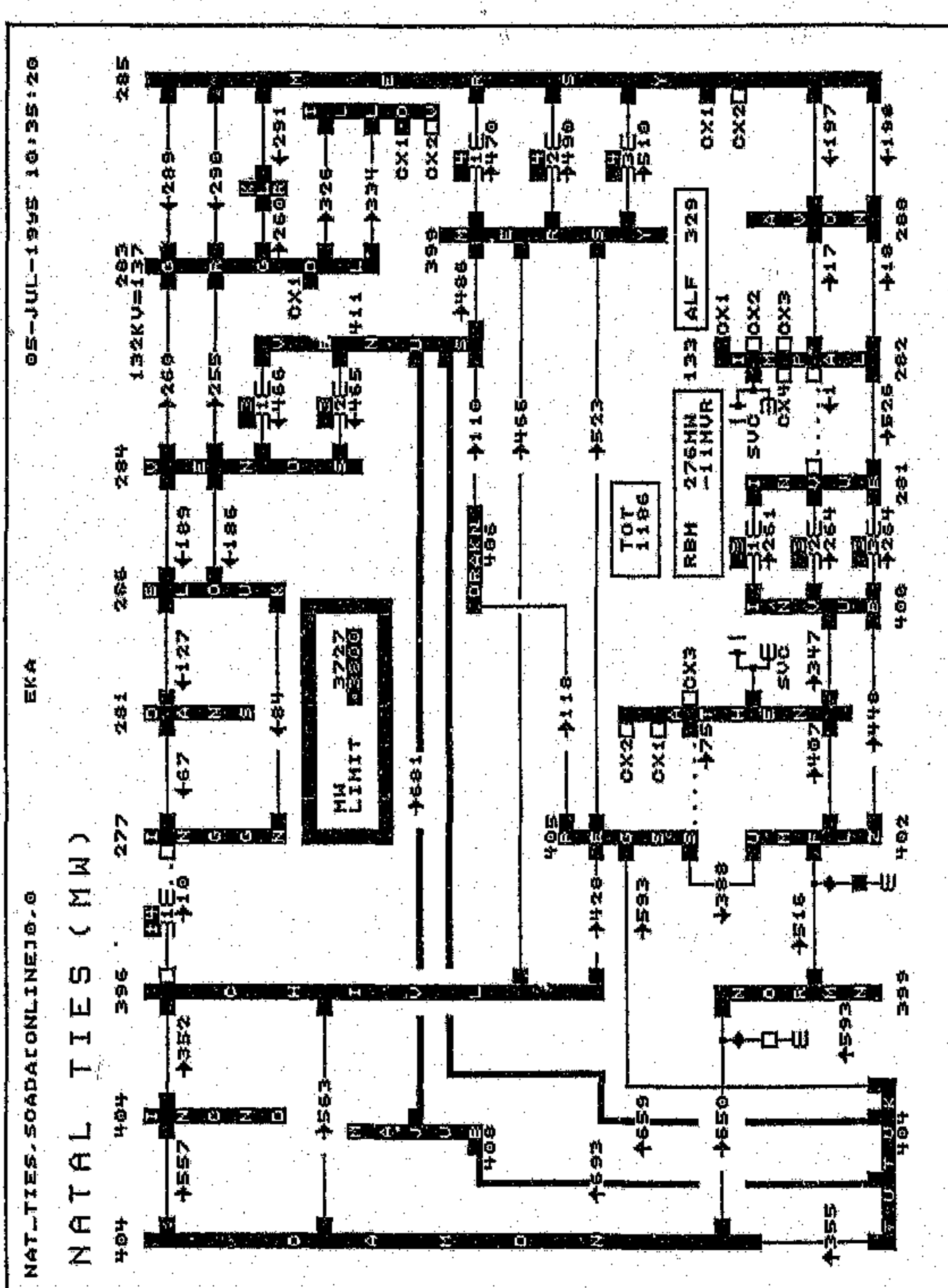
	1	2	3	4
DRAKN	-188I	-0	-0	33
GARPS	-0	-0	-0	-0
VDKLF	-0	-0		
PORRX	-0	-0	-0	
PALMT	-0	-0		
MULDR	0		- 7	
ACOPS	19	18	19	
KOEBG	-46	-30		

	1	2	3	4
NESTR	□	□		□
LUCKH	□ F	□ F	□ F	
VIDTR	□	□		
KOMSB	□	□		

	SVO1	SVO2
PERSS	- 46	53 F
HYDRA	-96	-89
POSDN	-29	
GRASS	-2	
BUFFL	-0 F	
IMPAL	- 7	
ILLOV	2	

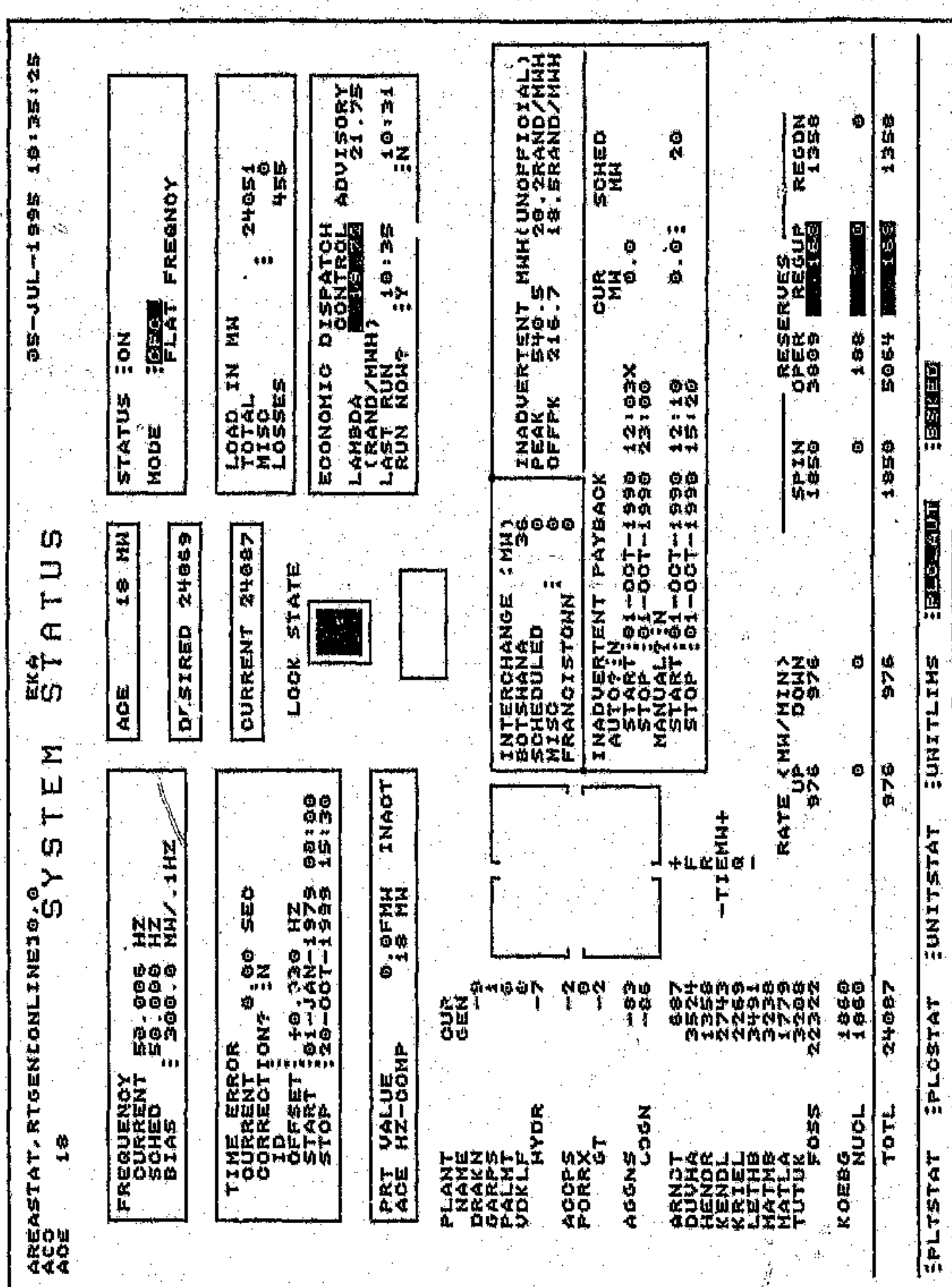
APPENDIX 7 - COPIES OF DISPLAYS

Figure 5 : This is a typical regional Tie-line display indicating the MW line flows and various voltages of the stations, The solid rectangles indicate closed breakers, hollow ones show that the breaker is open.



APPENDIX 7 - COPIES OF DISPLAYS

Figure 6 : The AGC display is used to indicate the state of the Automatic Generation taking place on all the coal fired power stations controlled by National Control. The large solid rectangle in the centre of the display is coloured Red, Orange or Green depending on how well the Generation staff are balancing the load, the fuel cost and the availability of generation plant.



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APPENDIX 8 - REFERENCES

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