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MAN MACHINE INTERFACE

USING FULL GRAPHICS

FINAL DRAFT

Working Group 01

of

Study Committee 35

(Communication and Telecontrol)

July 1992

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1 INTRODUCTION

There is a major change in technology in progress in the energy control centres today, and this will reflect in the use of work stations with full graphics for the man - machine interface.

Semi-graphics display technology has been in use in the power industry for some years. It provided high speed display response at reasonable cost and was sufficient and flexible enough for many implementations, particularly in the field of transmission telecontrol. But parallel to the use of semi-graphics in the power industry, other industries, especially the CAD /CAM industry, have been working on refining the full graphics technology to meet their requirements on a wider range of display and information presentation capabilities.

Full Graphics systems which at one time were thought to be an extremely expensive luxury to be used only when all other possibilities had been exhausted are now a fact of life, and although not yet used universally, are greatly increasing in use and are now available at little, if any, incremental cost.
Full graphics is a term that refers to systems that use vector addressed displays in which each pixel can be individually addressed. In practice, a display can consist of 1024 * 1200 pixels.
Although the potential application of such systems has been seen for many years, it is only in very recent times that the performance of available equipment has been sufficient (and now exceeds) what is necessary to fulfil users' requirements. This has led to the full graphics technology that is now available for industrial control purposes and is spreading rapidly into the power industry. Today, most of the SCADA /EMS suppliers offer full graphics capabilities as part of their basic system, and the customers consider the full graphics capabilities as an important feature. A number of systems are now available for Distribution System control, which, because of the enormous number of plant items they display, can only be implemented with full graphics displays.

This specific display technique with full graphic display functions as a man-machine interface in control rooms for power systems is now setting wider and wider limits for the control room facilities for the improvement of the quality of information.

At this stage of the development, it was considered more important to report the current state of the art to help to raise the level of knowledge and awareness in the power industry, rather than to attempt to set new Standards or Regulations. In order to collect information on man-machine interface techniques, a survey was launched, and a number of users, vendors and consultants were asked about their experience and views on the subject. The information supplied forms the basis of this report.

The sections of the report are:

State of the Art;
User Experience;
Future possibilities.

Regrettably only a limited number of replies were received from each category. Of these replies, only a few relate to systems that are fully commissioned and operational. Others refer to systems which have been ordered but are not yet commissioned, and to systems which have been specified, but are not yet ordered. The statistics are regarded as too small to draw reliable and far reaching conclusions but they do provide some indication of how those utilities which have identified the benefits of the technology are proceeding or are planning to proceed.

In conclusion, this contents of report are intended as an outline of a powerful new technology that offers considerable potential, but is not yet well established in the field of Power System Control. They describe what has already been achieved and draw attention to the opportunities that the new technology presents but do not attempt to define new System Standards.

A copy of the questionnaire, and an analysis of the replies are included in the appendix to this report.

2 STATE OF THE ART

This chapter identifies the benefits that can be derived from the use of Full Graphics techniques and shows how those features that are now available can usefully be applied in the field of power system management and control. In some cases, the techniques offer improvements on what is otherwise available; in others, they offer facilities not otherwise available. Although some of the features identified are currently seen as applicable only to transmission or only to distribution control, no distinction has been made in this report, so as to encourage a cross-fertilisation of ideas.

The day to day operation of a modern power system generates vast amounts of data, all of which is important to some aspect of its safe and efficient operation. In order to be effective, this information must be readily available, and must be presented in a way which is appropriate to the current task so that it can be clearly understood. Good presentation of accurate information is a powerful aid to making correct decisions and it is here that Full Graphics can make a major contribution.

A modern database linked to a full graphics man-machine interface can provide great assistance in data management and presentation, leading to improved effectiveness in control room operations and power system management.

2.1 Benefits of Full Graphics systems

2.1.1 The use of high resolution full graphic VDUs as a Man-Machine Interface to a SCADA or Energy Management System is a major breakthrough in giving the operator new insights into understanding the condition of the power system.

Specific instances of where full graphics systems offer benefits are :-

Alarm and switch state information displayed directly on a schematic diagram, where their effects can readily be understood.

Initiation of telecontrol sequences directly from the schematic diagram ensuring that the operator can clearly see the results of his intended actions, and reducing the risk of selecting the wrong plant item.

Action replays for analysis and for operator training;

Circuit loading or condition represented by line thickness or colour, giving a quickly understood indication of circuits that are excessively loaded, operating beyond their security limits, or not available for service.

2.1.2 In addition, Full Graphics is an enabling technology which allows a number of features to be implemented which improve control room flexibility and efficiency:

Integration of schematic diagrams with Automated Mapping/Facilities Management (AM/FM) mapping systems;

Transfer of control responsibility between control centres at different locations. This may enable a co-ordinated control room strategy to be implemented, resulting in fewer control centres being manned during quiet periods, and better support and flexibility in crisis situations.

2.1.3 Whilst not essential to the applications, full graphics displays can be used to display the output of other software tools used to evaluate the power system, and to present them within the context of the Operational Diagram display. Such applications include:

Display of Optimum Power flow analysis;
Display of Contingency analysis;
Display of Short circuit analysis;
Display of Fault reconfiguration analysis.

2.1.4 The technology removes the limitations imposed on traditional control rooms by making possible the elimination of wall diagrams. Projectors can be used for the map board, or diagrams and maps can be displayed on the VDU alleviating the need for a wallboard. This has had a major impact on how utilities are viewing wallboards. Some are replacing them with projectors to display the dynamic one-line diagram images. This has the advantage of being much easier to build and to change. The wallboard changes are also in synchronism with those in the operator's console. The projection system also makes it easier to have a separate room for visitor demonstrations and to have a place for management to view the system without bothering the operators. It is also good for media and government officials' presentations.

2.1.5 It can be clearly seen that the use of full graphics and of not using the conventional wallboard can have a significant impact on the control centre design and location. The ceiling can be normal height, meaning that the control centre does not have to be different from other floors in the same building or be a specially designed structure. Operator consoles can be placed so they are located for co-ordinating work efforts rather than so they can see the wallboards.

2.2 Features of Full Graphics systems

Some of the attractive features of this technology are :
Continuous pan
Continuous zoom
Magnification
Navigation (locator)
Declutter with overlays
Windows
Pop-Up Menus
The use of standard soft keyboards with mouse and/or trackball
Several displays on one VDU
One display spread across several VDUs for World Maps
Projectors can be used for the map board
Maps can be displayed on the VDU alleviating the need for a wallboard .

2.3 Specific applications of Full Graphics features

Some examples of how the features of full graphics systems can be applied to help the operators to better understand their system by the creation of specialised displays are as follows:

Islanding and Limits Management:
Show system island including actual and predicted locations
Colour or display distinction of islands.

Stability limit lines:
Show contour lines on the system.

On-line diagram of power system:
Zoom to see limits
Zoom to see present capacities.

Short circuit limit lines:
Show contour lines of limits on the system one-line diagram
Zoom to see limits
Zoom to see present capacities
Voltage profiles in 3-dimension across the system.

Display of Circuit Breaker limits:
Pop-up window to Fault Level display
showing load or faults.

Line and component limits:
Pop-up windows or line width or colour
change to Fault Level display
showing load or faults.

Switching and Safety Management.:

Show possible grounding (earthing) points, even on transmission lines
- Use declutter level.

Show possible isolation points in substations on transmission lines
- Use declutter level.

Develop and display equipment/point/record relationship
- Pop-up window.

Switching procedures:
- Pop-up window.

Safety hold card
- Pop-up window.

Sign-off records
- Pop-up window.

Safety records
- Pop-up window.

Substation, transformer, feeder:
- Real and reactive load curves.

Outage and Restoration Management:

After outage real and reactive load pick-up curves
- Pop-up window or declutter level.

Meter and relaying drawings:

Static or dynamic
- Zoom from station one-line diagrams
- Pop-up window.

Storage and display of diagrams:

Schematic diagrams

Breaker control panels (dynamic)

Substation mimic panels.

Station annunciator.

Protection Information:

Relay curves
- Pop-up window.

Relay-fuse co-ordination curves
- Pop-up window.

Relay settings
- Pop-up window.

Relay test cards
- Pop-up window.

Breaker limits
- Pop-up window.

Line limits
- Declutter
- Pop-up window.

3D voltage profiles:

Voltage angles across open breakers:

- Analogue meter
- Numerical value
- Pie chart.

Substation split indication:

- Colours indicating elements connected together (beach balls).

Line width indicating line loading and overloading:

Analogue representations of meter, gauges, angles:

Substation, transformer, feeder:

- Real and reactive load curves
- After outage real and reactive load pick-up curves
- Pop-up window.

Power Production and Scheduling Management.

Unit Commitment:

- 3D bar chart
- Colour graduation of economics of units and must-run units.

Load weather curves:

- Forecast
- Actual.

Unit schedules :

- bar chart.

Dynamic reserve management/availability curve:

Dynamic regulating margin curves:

Production cost curve:

- Forecast
- Actual
- Optimum
- After-the-fact comparison.

Dynamic plant heat rate curves:

Dynamic plant loading curves:

VAR availability curves:

Generation use curves

- By fuel type
- On-line
- Reserve.

Drawing Management:

Physical to electrical drawings

- Mapping to 3-line diagram
- Three-line to one-line diagram.

Electrical drawings:

- Meter and relaying diagrams.

Physical and Surveillance Monitoring:

Video images from:

- Substations
- Power plants
- Control centres access.

Management of Weather and Forecast Information:

Place weather radar information on a window.

- Overlay weather radar information on the system map and the system one-line diagram.
- Overlay real-time lightning stroke location, magnitude, polarity and frequency of occurrence on the system map and system one-line diagrams.

From weather radar data or lightning data plot:

- Actual storm track.
- Predicted storm track.
- Zoom to see details.

Load-weather curves.

- Forecast.
- Actual.
- Deviation from forecast.

2.4 Networked systems

Once operational displays and data are stored on computers in a vector format, it requires relatively little data to describe changes to the diagram. It then becomes possible to take advantage of the great flexibility provided by computer networks, and the speed with which they can exchange data, including complete graphics displays, between different physical locations. Using these techniques, all information necessary to control any aspect of a power system becomes immediately available on multiple sites. The possibilities offered by this technology include:

> Transfer of control responsibility between different locations to take account of planned or emergency workload. Hence several control rooms may be in use during the working day, with control being transferred to a reduced number of sites during the quiet hours.
>
> One control centre can provide back-up to another without changing the basic MMI.
>
> Emergency control centre MMI can be identical to the main control centre.

2.5 Operator training

Full graphics will have a significant impact on operator training. The increased use of graphical information instead of tabular information will make it easier for the operator to have an insight into the operation of the power system. It should make the training more dynamic. If the utility chose to use a projector for displaying the overview map instead of a wallboard, then the trainee would see the same display on his or her VDU as an operator would in the control room. A separate projector for the training simulator would make the MMI identical to the workplace.

2.6 Hardware

Until recently, control room systems involving high resolution graphics displays each required considerable development to meet the needs of individual purchasers, and therefore had considerable lead times. Also, the time required for all data capture and validation was considerable. In a climate of rapid developments in computer technology, the consequence was that when such control room systems were commissioned, their technology was often obsolescent rather than 'State of the Art'.

The constant quest for 'State of the Art' can result in 'development systems', which are never commissioned or recover their initial investment.

It is only recently that the performance of graphics displays has been sufficient to meet the needs of real time control room applications. Now that this criterion has been achieved, it makes possible a wide range of facilities and possibilities which could not be achieved by any other means.

2.6.1 Supply Authorities require a long and stable life from their equipment, and may require to use it long after the original suppliers are willing or able to provide support. It is therefore important that only the most reputable suppliers are selected, particularly for single sourced equipment such as graphics displays, on which the continuing operation of the system may depend.

2.6.2 The recent rapid growth of X-Windows technology has provided a common standard, with comparable equipment available from several suppliers. Also, graphics workstations, often based on a common operating system - generally Unix, and claiming to offer 'Open Systems Architecture', have become a growth market. It is arguable that it is this development of Open Systems and Common Standards that should be regarded as 'State of the Art'. It is these developments that will ensure that the long term future of operations control is independent of the policies and fortunes of individual hardware manufacturers.

2.7 Software

State of the Art in software is represented by very high level software tools that enable a specific application to be generated with a minimum of application-specific code. This, together with the use of Industry Standards for components of the application, such as the database, presentation graphics, and user interface, will minimise the lead time, debugging and cost of such systems, and will minimise the dependence on a single supplier. The majority of suppliers of current software said they operate in this way.

2.7.1 Current 'State of the Art' products:

Most current products described by vendors supported Open Systems, making use of Unix workstations that supported OSI and X-Windows standards, the Motif user interface standards.

All systems currently available offered high performance, high resolution (generally 1280 x 1024 pixels, and at least 16 colours) together with some form of pan, zoom and declutter.

Systems generally included a proprietary database management system, often running on a computer dedicated as a database server.

Most systems offered had duplicated systems providing hot standby security. Some took advantage of computer networking facilities to provide the possibility of transfer of operational responsibility between control rooms.

3 USERS ADVICE

Only a small number of replies to the questionnaire referred to systems which were fully commissioned and in operational use. This section is therefore based on a limited number of reports, but is considered useful in that it reflects to actual systems in use. It may be that the survey results are too small for reliable detailed conclusions to be reached, but it is interesting that the applications cover the entire spectrum of Production, Transmission, Distribution and Substation control.

Although (or perhaps, especially because) there are only a small number of Full Graphics power system control systems in use world-wide, the detailed experience of those users has been collated for the benefit of potential purchasers. The advice covers a wide range of aspects, from system specification through display layout, data capture to full implementation.

3.1 Specification

3.1.1 System Specification:
Several replies indicated that purchasers had trouble with their systems achieving the expected level of graphics performance. The purchaser has a requirement to specify the expected performance of the system in terms of graphics behaviour. To avoid ambiguity and possible dispute, it is essential that this is very clearly defined, preferably by the preparation of detailed benchmarks, which are totally representative of the users' needs. The behaviour of the display can then be specified; however, there are several parameters relating to the computer and display technology that must be considered.
This includes:
Is the display regenerated from memory local to the display, or is it being downloaded from a host?
In the latter case, how will the system behave when the display memory was previously occupied?
Other factor such as the number of displays being loaded, the performance of the communications circuits, and the loading on the host machine also can have an effect, and these must be considered when the system is specified.

It is also important that the entire scope of the proposed system is clearly defined from the outset; this includes a detailed definition of the extent of the High Voltage network, the total number of substations involved; those which are operated by telecontrol, the typical and maximum rates of imcoming telemetry data, and expected performance under worst state conditions.

3.1.2 Involvement of Users in Preparing Specification

It appears that considerable benefits can be derived from the involvement of users in the preparation of the Functional Specification:

Specification will more closely match users exact and not perceived needs;

Authoritative advice on what will be acceptable to the final user.

User will be exposed to the potential of full graphics and will identify how the various features can best be applied to meet operational needs;

User will recognise and accept what is practical at an early stage;

Eventually, a better understanding between the supplier and the actual user will improve working relationships; each is helped to identify with the problems of the other, leading to a more effective system.

3.2 Data capture

Whilst most systems in use or on offer provided facilities for data capture and for the creation of displays, some systems depended entirely on the import of data and graphics from other systems. Display technologies, particularly those of older systems, are often system specific, and the cost or effort of converting displays from such systems may well compare unfavourably with that of re-capturing the data or re-constructing the displays.
Respondents suggested that the complexities of data capture, and the time required for this work was often underestimated, and by a large margin. One reply indicated that the total effort for data capture exceeded twelve man-years. Often, the construction of such systems depends on the import of large quantities of data from other applications; it is essential that this data is of the highest quality. Some organisations have found that the quality of existing data, although acceptable for previous applications, has not been sufficiently accurate or complete for immediate use in this application.

3.3 Environment

Proper consideration must be given to the environment in which the graphics displays are to operate, and it is reported that lighting, and the avoidance of glare and flicker effects, is particularly important. Electromagnetic interference from adjacent equipment such as VDUs and power supplies has been found to interfere with displays. Displays with interlaced displays should be avoided as these have been found to cause very unacceptable flicker problems.
The ergonomic design of workstations is important, and there has been some useful research in this area. Users recommended that the workstation layout should not be finalised until operational experience has been gained.

3.4 Power supplies

Graphics display equipment is very sensitive to even very short disruptions to power supply, and may take some time to recover as a copy of a lot of information is typically stored in each display. Critical components must be supplied from un-interruptable power supplies, recognising that such supplies must be rated to support the pulse mode power supplies in general use in computer and display equipment.

3.5 User acceptability: Control operations

Several Suppliers claim that control staff will adapt to display based control systems in a remarkably short time, with a modest amount of training; reports from users suggest that this is generally the case.
Operators have been particularly demanding on the performance of the workstations, and demanded a high level of response and agility from the system. It has generally been found that a delay of more than three or four seconds to load a picture is unacceptable; most systems currently on order expect update within 2 seconds. User acceptance has been highest in those locations where end users were properly represented during the specification and acceptance testing of the equipment. Several replies noted that user acceptance varied with the age of the operator, with younger staff keen to accept the new technology.

3.6 User acceptability: Data capture

Some reports show that greater problem was found in selecting staff for data capture as the work demands a high degree of patience and skill, and a high level of quality control is necessary.

Most diagrams are schematic, and are laid out with a geographic basis. They can generally show substations either in detail, or as single line representations. Often, diagrams have been created by the personnel who will use them, according to a set of company standards.

Most show production trends and forecasts, both numerically and as bar charts. All showed alarm states as text, and only one system used icons for this purpose.

Database maintenance has been identified as particularly critical, and most users restrict this work to specialist personnel.

3.7 Display layout

Advice from suppliers and users is that the use of some colour is essential, but it must be used in moderation to avoid displays becoming too cluttered: there is need to experiment.

Many systems offered no more than sixteen colours. It is likely that this is sufficient; users who had the option of 64 colours, (and in one case, 1024 colours) used no more than 16 or occasionally, up to 32. Some users have reported that symbols coloured yellow were particularly visible, and have reserved this colour for safety related symbols.

If a diagram is to remain visible over a wide magnification range, then the design of the associated symbols becomes critical as they will also be scaled over the same range, and at their smallest, may appear only as coloured dots. Whilst they cannot impart much useful information at that scale, they perform the essential function of alerting the control operator to their existence. It then becomes a matter of operational good practice to ensure that they are taken proper account of by detailed examination before any operations take place in that area.

There are major differences between wall diagrams using reflected light, and graphics displays using transmitted light. Existing colour conventions and standards cannot necessarily be transferred successfully from wall diagrams to graphics displays. Light coloured backgrounds, which tend to be a feature of wall diagrams, can cause glare and loss of contrast in graphics displays.

All reported systems used schematic layouts, generally with a geographic orientation.

3.8 Wallboards

Most users have expressed the view that some sort of wall diagram needed to be retained, at least until complete confidence in display technology had been established. Only two respondents intended to completely eliminate the wall diagram, although some used it purely an overview drawing. A small number are using projection systems for this purpose.

3.9 Reliability

Some users have reported initial problems with software following commissioning, although once resolved, the system has operated reliably. This shows the difficulties found in simulating a live situation for test purposes.

4 FUTURE POSSIBILITIES

This chapter explores some of the future features, functions and techniques made possible by the emergence of Full Graphics-MMI.

The discussion that follows is by no means complete. As with any new technology, the features of the Full Graphics-MMI are just beginning to be incorporated. In the far term, additional advances in technology will produce many new ideas and methods that cannot be foreseen at this time. It is up to the utilities and vendors to utilise these capabilities to improve the decision making process of utility operators.

4.1 Possible features of future Full Graphics-MMI

4.1.1 Unlimited Colours, Characters and Symbols

Future Full Graphics-MMI will take great advantage of unlimited colours. For example, the blending of colours can create a smooth transition from one colour to another. This can provide an analogue measure by colour. A typical use would be in a temperature meter. At one end of the spectrum, the meter would be dark blue. As the temperature increased, the colour would gradually change from blue to green to yellow to red.

Characters and symbols will also undergo dramatic changes. The amount of detail possible will make the new symbols more useful. For example, a meter symbol can be created which will display an actual analogue readout; a dynamic transmission line symbol can be created with varying colour and thickness to indicate loading of a transmission line.

4.1.2 Windowing

Windowing, although possible with character-based graphics, is more closely associated with full graphics. In addition to providing access to more information on a single screen, windowing provides a level of redundancy should the operator lose use of one of his screens. Soft key windows can also be used to replace or back-up traditional function selection keypads.

4.1.3 Three-dimensional displays

Three dimensional displays provide information on three separate axes and show the correlation between the three variables. Three-dimensional displays have been used in examples of unit commitment showing simultaneously the number of units available and their unit cost over a 24 hour period.
Three-D capabilities will also be essential for the display of engineering CAD drawings.

4.1.4 Smooth Pan and Zoom

Panning and zooming are a feature of the current Full Graphics-MMI. Future Full Graphics-MMI will continue to improve on this feature, providing smoother panning and zooming. This will make the movement across, into and out of a 'world' much faster and, therefore, a more used and useful tool.

4.1.5 De cluttering

Automatic de cluttering will be used in conjunction with the zoom feature to produce a zoom which continuously displays only useful information relevant to the 'world' area displayed.

Layering information, which is the opposite of de cluttering, will become more prevalent. Geographical Information Systems (GIS) and weather maps will make extensive use of this feature.

4.1.6 Animation of objects

Animation can bring another dimension to the display of real-time data. An example of animation is the movement of arrows along a transmission line to represent power flow. The speed of the arrow's movement can provide yet another measure of the data's characteristics; e.g. the proximity of the lines loading to its thermal limit.

4.1.7 Object-Oriented database programming

Object-Oriented Programming (OOPs) creates software with the following characteristics:-

Encapsulation - This refers to the hiding of the details of how a routine works from other routines that don't need to know (and should not be able to change).

Grouping - OOPs groups objects that share all or most of their attributes into a class.

The development of object-oriented databases will provide an ideal tool to utilise the capabilities of Full Graphics. Used in conjunction with windowing and pull-down menus, object orientation will provide faster access to information as it is required. For example, a pop-up window or a pull-down menu can provide access to the operating procedures of a displayed breaker. The procedures can then be quickly and easily accessed by the software by taking advantage of an object-oriented database's characteristics.

4.1.8 Faster Information Access

Two new design methods for real time database computer systems will provide faster access to information:-

Large Screen Projection Wallboards

Projection screens currently use CRT technology. In the future, all screens will use more advanced technology such as solid state displays (LCD, etc.). This will permit more widespread use of computer generated wallboards as the deterrents such as cost, reliability, life-span, control room lighting and space requirements are improved.

4.1.9 Geographical Information Systems (GIS)

The linking of SCADA and EMS systems to Automated Mapping /Facilities Management (AM/FM) systems can provide the capability to display transmission/distribution lines and real time data overlaid on a geographical representation of the area. This would assist the dispatcher in directing road crews to the problem area.

4.1.10 Weather Maps

Weather can be an important factor in how a utilities transmission system is operated. Full Graphics-MMI will provide the resolution to display these maps. Weather maps may also be superimposed as a layer on top of a geographical representation of the transmission system, revealing any areas of concern.

4.1.11 Voice recognition

Voice recognition, like windowing, is possible with character-based graphics but is more closely associated with full graphics. It is the next logical step beyond cursor control devices such as a trackball, mouse, electronic pen, etc.

Since the voice recognition processing could be done in the operator's workstation, very fast response can be obtained. This should relieve the operator from the point-drag-click procedure, allowing him to take advantage of the extensive functions and features of the Full Graphics-MMI with little or no additional effort.

Also, security access can be readily implemented into a voice recognition algorithm.

4.1.12 Multimedia - video and sound

The use of more human senses can convey information in a more meaningful format. Multimedia incorporates several media types - text, graphics, animation, video and sound - in a single document. The key characteristic that distinguishes multimedia from video is that multimedia is interactive.
The interactive nature of multimedia makes it an ideal tool for training. Multimedia can also provide more comprehensive and useful 'Help' information by 'showing' the operator what to do and allowing him to stop the 'Help' and direct it towards the exact function of interest.

It should be noted that the object-oriented database feature would be an integral part of the multimedia workstation. A single database may be required to store and access text, photos, spreadsheets, digitised voice and video clips using a consistent database interface.

4.1.13 Virtual Reality

This technology is still in its infancy. The concept is to provide 3-D images and other sensory inputs; i.e. touch and sound to the user via stereoscopic goggles and sensor fitted gloves such that it is virtually indistinguishable from actually being there. This could be quite useful as a training simulator or as an actual operator tool. The control room may become the relay room or switchyard of a remote transformer station where the operator would 'virtually' open a switch with the actual operation carried out by telecontrol.

4.2 Future functions made possible by Full Graphics MMI

4.2.1 Operator access to additional information

Access to information regarding a particular item of equipment by the operator can be made faster, more efficient and easier by the use of an object-oriented database in conjunction with the use of pop- up selection menus and the display of text/graphics by the Full Graphics-MMI.

As well, the use of standard workstations as the MMI platform allows operators to access systems and applications outside of the EMS/SCADA environment. For example, an operator will select a breaker to close from a station single-line display. Before closing, he displays a window with an up-to-date Design/Drafting Department switchyard arrangement CAD drawing to ensure all aspects of the operation are acceptable.

4.2.2 Access to Operations data by other departments

The general trend in the Full Graphics-MMI area is towards standard interfaces with increasing use of the mouse, icons and menu bars, etc. This evolution not only helps the operators but also provides an opportunity for other support staff, e.g. engineering and management to access operational data. Standard interfaces mean that the engineer or manager's desktop workstation will be fully compatible with the operations computer system. In addition, the increased user-friendliness will allow staff to access the information they require without extensive training.

4.2.3 Remote screen mirroring

Using the Full Graphics-MMI features of standard interfaces and the networking capabilities of Unix, an operator will be able to communicate with operators at other locations via remote screen mirroring. In remote screen mirroring, the operator at one location displays the same picture as the other operator. Operations on the screen display by either operator are reflected on both operators' screens. Thus, by integrating voice communications with remote screen manipulation, another dimension of communications is added, increasing operator effectiveness.

4.2.4 Security monitoring of remote sites

Multimedia can provide control room operators with the capability of security monitoring or remote sites. Both video and audio will be available to the operator from the remote site, eliminating the need for manning of the remote site.

4.3 Possible Full Graphics-MMI influence on control centre techniques

4.3.1 Elimination of operator console screens

Once the installation of projection wallboards becomes more commonplace, their flexibility of display will entice operators to look for more information from them. Eventually, operators may not require individual console screens at all, using the larger screens for all their visual information. Control actions will even be performed on the larger screens.

Also, the amount of information that can be displayed using Full Graphics-MMI via the use of colour, windowing, etc. will reduce the number of console screens required.

4.3.2 Increased control room and field communications

GIS will allow the control room to provide the field operators with detailed equipment site locations

Once on site, portable computers, video cameras, microphones and telephone will provide multimedia communications between the field and control room operators.

As well, all equipment will be identified by a bar code that can be scanned and verified immediately by the control room operator.

4.3.3 Increased emphasis on control room ergonomics

More emphasis will be put on previously neglected control room ergonomics due to two factors:-

Increasing standardisation of the Full Graphics-MMI in terms of hardware (i.e. RISC workstations) and software (e.g. UNIX, X-Windows) means less effort and money will be required to design and provide these facilities. This will leave more time and funds to devote to other areas of concern.

The use of projection displays and large screen displays will require considerable attention to the lighting and layout of the control room beyond what was required for dedicated operator console screens.

4.3.4 Improved decision-making by operators

In comparison to character based graphics, a single picture in Full Graphics can effectively display enormous amounts of information, provided the picture is designed properly. Thus, an operator will be able to get information faster, which will accelerate the decision making process.

Full Graphics will also provide the operators with more detailed analogue displays, allowing them to recognise trends. For example, graphs will not be limited to simple bar charts. Instead, the method of graphical representation of the data will be chosen based on the type of information to be represented. A graph may show data in normal operating condition as a circle, with abnormal conditions distorting the circle into an ellipse. This would show even minor deviations from the normal condition.

Appendix 1

Definitions and descriptions

AM/FM	Automated Mapping/Facilities Management: The ability to display geographic map information on a graphics display and the management of data associated with the plant and equipment shown on the map background.
De-clutter	The ability to control the quantity of detailed information which is displayed in the screen or window. It normally assumes that the original display was created as a number of separate levels, which are switched on and off automatically, linked to the Zoom function. As an operator zooms out, redundant information is removed in order to make the displays more readable (i.e. less cluttered).
Full Graphics	A technique in which each pixel of a display is separately addressable. The display is regarded as a viewport into a much larger global picture.
Pan	The ability to re-locate the viewport anywhere within the global picture on a continuous basis in approximately real time.
Pixel	The smallest separately addressable point on a Graphics Display. A typical graphics display in full graphics applications will have a resolution of 1024 *1200 pixels.
Pop-up window	An image within the viewport that appears in response to a particular action by the user. It normally contains additional information or gives access to additional commands.
Pull-down menu	A list of options that can be requested by the operator. The list is displayed on the screen in such a way that it appears to have been pulled down from the top of the screen or viewport.
VDU	Visual display Unit. A monitor capable of displaying text and possibly graphics, together with an alpha-numeric keyboard.
Windows	Multiple viewports within a single graphics display.
Zoom	The ability to alter the extent of the global picture which is visible on the display, in approximately real time, giving an effect similar to magnification.

Appendix 2

Questionnaire details

There follows a copy of the questionnaire which was submitted to all known manufacturers and suppliers, and to users and consultants who are known to be active in this field. Unfortunately, the number of replies was small, particularly in respect of systems which are installed and commissioned.

A significant number of potential users indicated that full graphics displays would form an important part of future control systems which they were currently planning or specifying. Where these plans had reached the stage of a firm specification and were at least at the Tender stage, these have been included in the analysis in the category 'Ordered', together with an indication of when the order was placed.
Systems which are regarded as 'in operation' were those which were fully commissioned, data transfer or capture is complete, and were in active operational use.

A detailed analysis is included, showing the trends of systems which are actually in use, and, separately, what manufacturers are currently offering as 'state of the art'.

Summary of findings:

Background

The companies that have responded to the questionnaire varied in size from a Maximum Demand of 43000 MW and 67,000 employees to the smallest with a Maximum Demand of 170 MW or 700 employees. Most companies had only one or two control rooms, but one of them had twelve. The number of substations which the companies controlled varied from 36 to 575.

Most of the companies that have systems in production or on order, use them for Production and Transmission control, although some also use them for Distribution and substation control. Two of the responses were from companies that intended to use the systems only for Distribution and substation control. In one case, the company used the new system to complement their existing SCADA system rather than as a replacement for it.

Only three of the responses dealt with systems that are at present in operation. In six cases the systems were ordered and were scheduled for installation by 1992; the remaining responses were from companies who were still discussing precisely how they intended to proceed. The maximum experience with any of the systems was only nine months.

Displays

The systems described make use of between eight and forty-eight colours, although one system can support 1024 colours (only 16 are used). The number of display levels (or de-clutter levels) that were used varied from one to 32, with most systems being nearer the lower end. The number of colours and display levels actually used was, in general, considerably less than the options available

To date, most of the systems that are installed or being installed are either for Distribution Management or for EMS applications. Generally they use 18 to 22 inch monitors with a resolution of 1024 * 1200 pixels. Most control centres will have at least two workstations. Workstations are sometimes based on a single monitor, although most have at least two.

For communicating with the computer system, a variety of techniques are currently in use, with all of them having a conventional alpha-numeric keyboard as the subsidiary rather than the main method of operator dialogue. The growing tendency is to use a mouse, but some systems use such techniques as digitising tablet, tracker ball and special function keyboard.

All the systems are full graphics systems, with about half of them using X-windows; the rest use a variety of proprietary graphics techniques. Most of the display systems consist of a graphics monitor driven by the host computer, although the latest trend is towards intelligent workstations. Most of the software and applications programs are written in C or FORTRAN, although Pascal is also used.

The number of workstations and displays in the systems reported vary considerably in size; The smallest consists of two workstations, each with one display; the largest comprises some 41 workstations with a total of 64 displays. For the operator dialogue, all systems except one have a standard keyboard and special function keys, with one or more additional aids, consisting of mouse, digitising tablet and tracker ball. Not all of the systems use these facilities.

None of the systems had completely replaced the mimic diagram; in most cases it was complemented by the new system. Only two systems made use of projection systems, one of which had six units. A lot of systems would be accompanied by a control room rearrangement.

Most of the replies considered that a strong selling point of the new systems was the windowing techniques. All systems incorporated both Panning and Zooming techniques.

For Panning, most systems employed steps rather than having a completely smooth system. The majority used a stepped zooming system, but some had continuous zoom; one system provided both.

The time to display a new page of information varied from one second to ten seconds, although only one system had a time greater than three seconds. To redraw a screen after a panning or zooming operation there was a greater disparity in the times given. For these operations, the times varied from 1 second to twenty seconds. In this case, six systems specified times of six seconds or less, while three systems gave times of ten seconds or over. Only one system offered a direct hard copy facility (the ability to transfer an exact copy of the screen image to a paper); others offered the ability to output copies of their schematic diagrams directly to a plotter.

In the large majority of cases, the Mimic Board was retained, generally with continuous automatic updating. The purpose of the Mimic Board varied from system to system. In all but two systems, it gave an overview of the electrical network.

The general response to this type of system was positive, although there were a small number of negative comments. In three systems it was used to back up the colour graphics monitors; in three to provide the operators with a comfort or confidence factor, and in one system, because it was traditional to have it.

Analysis of installed systems

Company Reference	1	2	3	4	5	6	7	8	9	10
Company size										
Max Demand MW	11000	3000	672	2600	170	8500	2700	19000	43000	1600
No.of Employees	2300	14000	700	4470	1300	8100	2900	26000	67000	3600
No.of substations	130	198	36	438	200	214	175	114	575	407
Controlled voltages Kv	420-132	400	160-35	345-35	350-70	500-66	345-33	500-70	500-70	275-11
No of Control rooms	12	4	1	1	1	2	2	1	1	4
Graphics system										
Ordered (Year)	91	91	89	92	y	n	n	y	91-2	85
In operation (Year)	n	n	n	n	y	n	n	y	n	y
Purpose										
Production control	y	y	y	y	y	y	y	y	y	y
Transmission control	y	y	y	y	y	y	y	y	y	y
Distribution control				y	y	y	n	n		y
Substation control			y	y	y	y	y	y		y
Displays										
Resolution (pixels x 100)	12-10		12-10	12-10	12-8	12-7	12-10	12-10	10-8	12-10
XWindows used	y				y		y		y	
Colours Available/used	64-30	1024-16	24-8	64-16	64-48	16-16	32-20	8-8	32-32	16-16
Levels Available/used	?-1	4-4	32-1	1-1	64-32	256-?	32-6	4-3	8-8	99-16
Windows Available	4	4	1	4	4	1	5	4	6-8	1
Time to update display(sec)	1	20	1	2-15	1	2-10	1	2	2	2
Language used	C	F,P	F,P	F	C,F	F	F	F	C,F	F
Workplaces										
No.of workplaces	2	15	9	23	3	6	12	26+15	4	14
Displays per workplace	1	2	2-1	3	4	3	2-3	1-3	1	1-3
Wall remains?	n	y	y	y	y	y	n	y	y	y
Projection system?	n	y	n	n	n	y	y	n	n	n

Analysis of Vendor's systems

Company Reference	1	2	3	4	5	6	7	8	9	10
Graphics system										
Purpose										
Produktion control	y		y	y						
Transmission control	y	y	y	y	y	y	y	y	y	y
Distribution control	y	y		y	y	y	y	n	y	y
Substation control	y	y	y	y	y	y	y	y	y	y
Displays										
Resolution	12-10	12-10	12-10	12-10		12-10	12-10	12-10	12-10	
Colours Available/used	?	256-16				64		16	16	
Levels Available/used	?	8						1000/12	1000/12	
Windows available	y	4	y	y	y	y	8	4	n	y
Workstations	y	y	y	y	y	y	y	y	n	y
Software										
Open Systems		y	y	y	y	y		y	y	y
X-Windows		y	y	y	y			y	n	y
GKS				y				y	y	
Object Or'database		y	y	y				y	y	
Modular software	y		y	y		y		y		y

1 July 1991

Man - Machine Interface
using full graphics

QUESTIONNAIRE

CIGRE WG 35-01

LIST OF CONTENTS

1. Introduction
2. Instructions
3. Your company
4. Graphic MMI in your company
5. Experience with full graphichs
6. VDU layout
7. Updating of system
8. Present and future applications
9. General comments

1. INTRODUCTION

1.1 Background

In recent years, the display technology has advanced very fast and the workstations have invaded the control room environment.

This specific display technique with full graphic display functions as man-machine interface in control rooms for power systems is setting new and wider limits for the control room facilities and for the improvement of the quality of information.

In order to collect information on man-machine interface technique using full graphics, a survey has been launched by the CIGRE Study Committee SC 35 through Working Group 01. Up till now WG 01 have asked a group of vendors and consultants about their experience and views on the subject.

To complete the investigation and as a basis for a report, which will be distributed in 1992, WG 35-01 hereby request users and potential users to respond to this question- naire.

Detailed information collected through this questionnaire will be treated as confidential, all information will be published in an anonymous form, and a summary will automatic- ally be forwarded to respondents.

2. INSTRUCTIONS

2.1 Number of systems

The design of the questionnaire is based on the assumption that the persons who reply only represent one full graphic MMI system. If you have more than one system, please make an equivalent number of copies of the questionnaire before filling it in.

2.2 Persons who respond

For our possible follow-up with supplementary questions, please give name of relevant contact person.

2.3 Date of completion

You are kindly requested to return the completed questionnaire to:

Mr. Ture Røes
NESA A/S
Strandvejen 102
DK-2900 Hellerup
Denmark

Telephone: +45 31 62 41 41 / ext 1130
Telefax: +45 31 62 01 50
Telex: 37 500 ifv dk

not later than **16 September 1991.**

3. YOUR COMPANY

Please give general data and requested information about your company activities.

3.1 **Name and country of utility/company:** ....

....

....

....

3.2 **Size of utility/company**

Maximum demand: .... MW

Number of employees: .... persons

Number of substations: ....

Number of control rooms: ....

3.3 **High voltage levels:** .... kV

3.4 **Business area** Y/N

Production: ( )

Transmission: ( )

Distribution: ( )

3.5 **Any supplementary information:**

3.6 **Brief description of state of full graphic MMI-implementation in your control room(s):**

4. GRAPHIC MMI IN YOUR COMPANY

Please note the actual data for systems used or discussed in your company.
Use Y (yes), N (no), actual figures or types.

		Y/N	Specify
4.1	**Purpose**		
.1	Production control:	( )	
.2	Transmission control:	( )	
.3	Distribution control:	( )	
.4	Substation control:	( )	
4.2	**State**		
.1	Discussed:	( )	
.2	Ordered:	( )	
.3	Installed (year):	( )	....
.4	In operation (months):	( )	....
4.3	**Display, colours**		
.1	Monochrome version:	( )	
.2	Colour version:	( )	
.3	Number of implemented colours:		....
.4	Number of colours used:		....
4.4	**Display layers**		
.1	How many display overlays are contained in the system:		....
.2	How many layers are actually used:		....

			Y/N	Specify
4.5	**Resolution**			
	.1	Pixels, width:		....
	.2	Pixels, height:		....
	.3	Size of screen (inches or mm):		....
4.6	**Techniques used**			
	.1	Full graphics:	( )	
	.2	X-windows:	( )	
	.3	GKS:	( )	
	.4	FIGS:	( )	
	.5	Other (Specify):	( )	....
4.7	**Display HW-type (VDU, PC or workstation)**			
	.1	Give display type:		....
4.8	**Display SW**			
	.1	Unix:	( )	
	.2	Other (Specify):		....
4.9	**Applications**			
	.1	Written in C:	( )	
	.2	Written in Pascal:	( )	
	.3	Written in FORTRAN:	( )	
	.4	Written in other (Specify):		....

			Y/N	Specify
4.10	**Operator work place**			
	.1	Number of operator work places:		....
	.2	Number of full graphic displays per work place:		....
	.3	Number of non-graphic display units per work place:		....
4.11	**Operation of work place by**			
	.1	Keyboard:	( )	
	.2	Function keys:	( )	
	.3	Mouse and tablet:	( )	
	.4	Cursor and keys:	( )	
	.5	Cursor and ikons:	( )	
	.6	Other (Specify):		....
4.12	**Active wall board**			
	.1	Will still exist:	( )	
	.2	Is replaced by graphic displays (WS):	( )	
	.3	Is complemented by WS:	( )	
	.4	Is replaced by projection system:	( )	
	.5	Other variations, describe under item 9, 'General comments'		

		Y/N	Specify
4.13	**Projection system**		
	.1 Number of projection units:		....
	.2 Controlled from main computer:	( )	
	.3 Controlled from MMI unit:	( )	
	.4 Other (Specify):		....
4.14	**Control room**		
	.1 Has been rearranged because of full graphic display installation/ projection system installation: If yes, please describe how it has been changed under item 9, 'General comments'	( )	

5. **EXPERIENCE WITH FULL GRAPHICS**

The following questions should be answered according to your experience with systems as indicated under item 4, or system considerations connected to concrete project planning.

			Y/N	Specify
5.1	**Windowing**			
	.1	Is windowing technique considered a strong point in the system:	( )	
	.2	How many windows are typically acceptable at the same time:		....
	.3	Any special considerations which should be remembered:		....
5.2	**Pan**			
	.1	Will your system allow panning, i.e. a continuous movement over the map or network:	( )	....
	.2	Will the panning function work as a stepping from picture to picture with pictures overlapping more or less:	( )	....
	.3	Or will panning be executed like a CAD function, i.e. defining corners of the new picture wanted:	( )	....
	.4	Other techniques (Specify):		....
5.3	**Zoom**			
	.1	Continuous zooming possible:	( )	....
	.2	Stepwise zooming with fixed relations of resolution per step:	( )	....
	.3	Zooming after indication of new picture corners:	( )	....
	.4	Other techniques (Specify):		....

			Y/N	Specify
5.4	**Updating time including real time-data (seconds)**			
	.1	What is the update time for a picture of a completely new part of the network, i.e. loading of picture into the display:		....
	.2	Expected update time after panning to a new part of your network:		....
	.3	Expected update time after zooming in or out:		....
	.4	Please add to this questionnaire a hardcopy of typical pictures according to items 5.4.1 - 5.4.3:		!
	.5	Indicate the operator's response to system update time		
		. positive:	( )	
		. negative:	( )	
		. indifferent:	( )	
		. concrete comments:		....
5.5	**Use of wall board**			
	.1	Will your wall board remain after implementation of full graphic displays:	( )	
	.2	If still kept in place will the board be		
		. updated continuously:	( )	
		. updated manually:	( )	
		. updated automatically by main computer:	( )	
		. manually and automatically updated:	( )	
		. only changed by major changes of network configuration:	( )	

		Y/N	Specify
.3	The purpose of the remaining wall board is to		
	. show actual network coupling:	( )	
	. function as backup for VDU system:	( )	
	. avoid doubt about new system:	( )	
	. give geographic overview:	( )	
	. other reason (Specify):		....
.4	Does your company consider a projection system		
	. cheaper than a mosaic board:	( )	
	. more flexible by network changes:	( )	
	. stable solution with minor service/adjustment:	( )	
	. other strong points (Specify):		....
	. having some weak points (Specify):		....
.5	If your company will keep some sort of wall board in place even though the network/map can be displayed on colour displays, is the reason for this:		
	. that many persons must see exactly the same picture at the same time:	( )	
	. that the operators are of the opinion that your map/network cannot be displayed in reasonable details on a colour VDU:	( )	
	. that a major change in working conditions should await some years of experience with the new techniques:	( )	
	. other reasons (Specify):		....

6. VDU LAYOUT

		Y/N	Specify
.1	Have pictures been developed		
	. by users:	( )	
	. by specialists, etc.:	( )	....
	. according to some sort of standard:	( )	....
.2	Has your company established		
	. an internal set of guidelines for picture design and functions:	( )	
	. some manufacture standard:	( )	
	. a general standard:	( )	
.3	Preferred design of pictures		
	. network geographically oriented:	( )	
	. network schematically arranged:	( )	
	. stations detailed:	( )	
	. stations as one-line diagrams:	( )	
	. power stations as process units with flow, etc. shown:	( )	
	. production and forecasts shown as		
	- bar graphs:	( )	
	- figures:	( )	
	. pie charts		
	. three dimensional		
	- combinations:	( )	
	- curves:	( )	

	Y/N	Specify
. alarms		
- number of system priorities:		....
- priorities used:		....
- shown as text line:	( )	
- shown as ikons:	( )	
- shown as trends (moderate to urgent state of alarms):	( )	
- special functions should be described briefly under item 9, 'General comments'		

.4 Time for developing a good display by using vendor display generator and linking to the database:
(choose one)

0-2 hours	( )
2-4 hours	( )
4-8 hours	( )
>8 hours	( )

7. UPDATING OF SYSTEM

		Y/N	Specify
.1	Category of personnel who will do picture creation and correction		
	. operators in general:	( )	
	. experienced user:	( )	
	. system manager:	( )	
	. engineering section:	( )	
	. other (Specify):		....
.2	Category of personnel who will do database generation and corrections		
	. user:	( )	
	. engineering section:	( )	
	. system manager:	( )	
	. other (Specify):		....
.3	Corrections are made		
	. on-line:	( )	
	. off-line:	( )	

8. **PRESENT AND FUTURE APPLICATIONS**

		Use Y/N	Possibilities
.1	Do you use the system or see possibilities or trends of a wider use of full graphic display functions as interface to related jobs. If other possibilities, please give examples.		
	. generation, control:	( )	....
	. generation , unit commitment:	( )	....
	. generation, economic dispatch:	( )	....
	. generation, study cases:	( )	....
	. network planning:	( )	....
	. production planning:	( )	....
	. training:	( )	....
	. management (technical):	( )	....
	. description of database and display updating	( )	....
	. maintenance:	( )	....
	. communication network:	( )	....
	. instructions for complicated procedures (re-establishing of net, etc.):	( )	....
	. energy management:	( )	....
	. mapping:	( )	....
	. engineering:	( )	....
	. telecontrol, supervisory:	( )	....
	. telecontrol, station one-line:	( )	....
	. telecontrol, alarms:	( )	....
	. telecontrol, maps:	( )	....

Use	Y/N	Possibilities
. artificial intelligence:	( )	....
. video surveillance:	( )	....
. forecasting:	( )	....
. simulation:	( )	....
. weather radar:	( )	....
. other possibilities:		....

.2 Has your company implemented any of the graphic functions mentioned under item 8.1. (   )
If yes, please describe them under item 9, 'General comments'

.3 Is your company considering any of the graphic functions mentioned. (   )
If yes, please describe them under item 9, 'General comments'

9. GENERAL COMMENTS

21 rue d'Artois - F-75008 PARIS