AG03-8711 E

Application Guide
September 1986
Supersedes:
NT 330-105E

Microcomputer-based control equipment at Starfors transmission substation

This document describes the design of a microcomputer-based control equipment for Starfors transmission substation.

The principles of the microcomputer-based control equipment were developed jointly by ASEA and the Swedish State Power Board (SSPB). SSPB is the largest power supplier in Sweden and is the owner of most power transmission equipment at the 200 kV and 400 kV voltage levels and of 50% of all electricity production. One outcome of collaboration with a power supply company is that it has been possible to base the principles on well-founded requirements in terms of operation, running, maintenance and reliability.

The microcomputer equipment has been arranged in a manner which gives effective integration of functions while it remains easy to modify functions and to expand the station. The hardware is made up of units from the Asea Master general purpose electronic and computer system.

A general description of the microcomputer-based control equipment is given in pamphlet A03-8710 E.

Contents

Ordering - Delivery

In January 1982, due to the successful collaboration during the development stage, a contract between SSPB and ASEA was signed for the delivery of microcomputer-based control equipment. The equipment is to be installed at the Starfors 220/70 kV substation. The substation is located in Central Sweden and its purpose is to increase the power supply to the region and to reduce transmission losses. After comprehensive testing of software and hardware the substation will be commissioned during the autumn of 1983. After this the substation will be run on a commercial basis like any other substation.

Scope of the substation

As the diagram in Fig. 1 shows, the arrangement of the substation is simple, with an incoming 220 kV line, 220/70 kV transformer and two outgoing 70 kV lines.

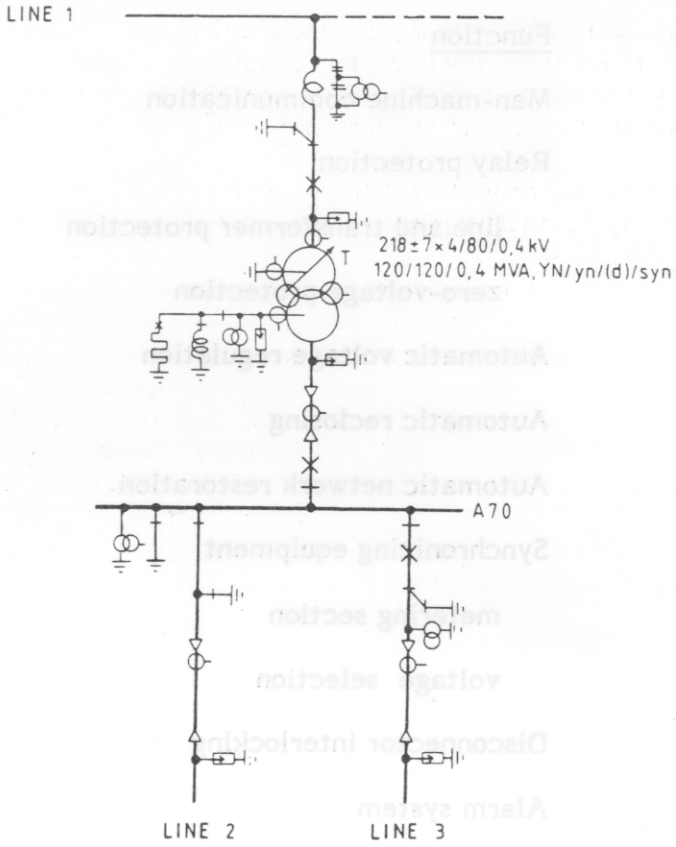

Fig. 1 Single-line diagram for the Starfors substation

Since the substation is associated with the national grid, it will be equipped with a large number of functions. These are listed in the table below.

Function	Implementation
Man-machine communication	▨
Relay protection	
line and transformer protection	□
zero-voltage protection	▨
Automatic voltage regulation	▨
Automatic reclosing	▨
Automatic network restoration	▨
Synchronizing equipment	
metering section	□
voltage selection	▨
Disconnector interlocking	▨
Alarm system	▨
Event recording	▨
Disturbance recording	□
Back-up alarm	□
Energy metering	
invoicing	◧
statistics	▨
Remote control	◧

▨ microcomputer-based equipment

□ relay-based equipment

Table 1 Scope of functions at the Starfors substation

Control equipment

The computer system is made up of units from the Asea Master microcomputer system . The units are arranged as a two level hierarchical structure according to the principles set out in pamphlet NT 33-101 E. From the upper (substation) level control and monitoring for the entire station are coordinated. From the lower (unit) level individual control and monitoring is performed in a number of dedicated control units for individual lines, transformers, etc.

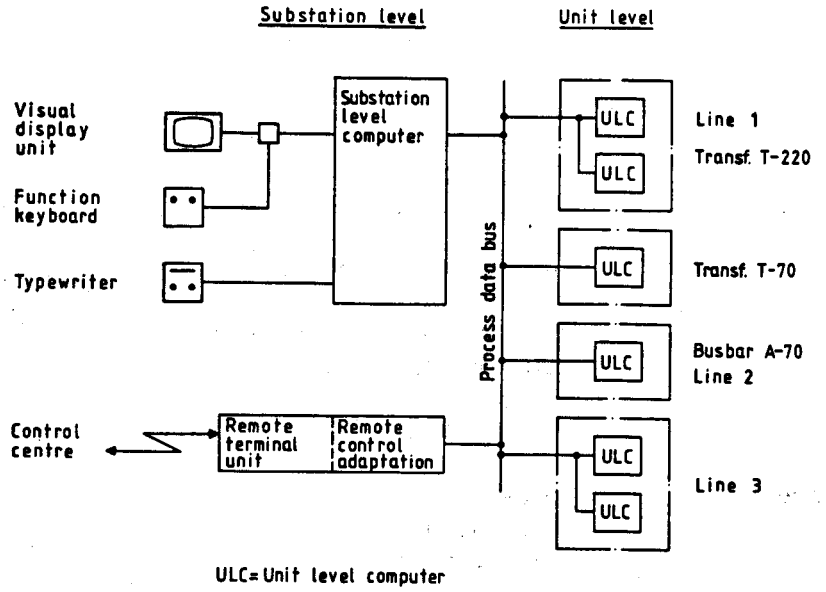

Fig. 2 Scope of computer system

Unit level

The functions that only affect the associated unit are placed on the unit level. For line 3 this means that the equipment shown in Fig. 3 is required.

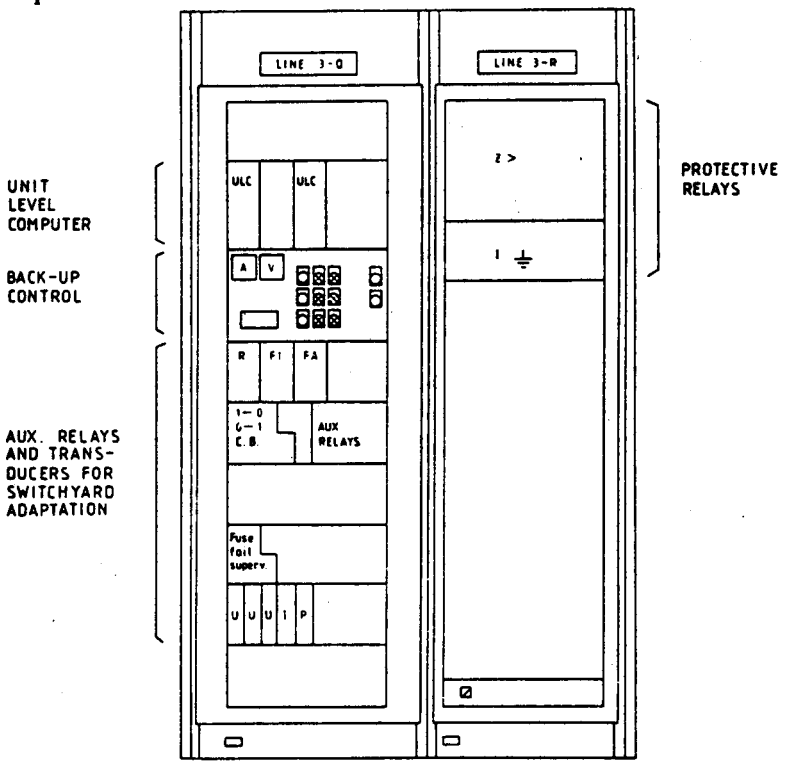

Fig. 3 Equipment for line 3

These functions take place in the unit level computers:

- acquisition of signals from the switchgear
- acquisition of relay protection indications
- acquisition of measured values from transducers
- time-tagging of events
- monitoring of switchgear positions
- operation of circuit-breakers and disconnectors ordered from substation level or control centre
- automatic reclosing
- presentation of alarms under back-up control

Circuit breakers and disconnectors can be operated from the back-up control panel, which is operable independently of the computer system. This operation facility is used only when an operational change has to be made when the computer system is out of service.

Station level

Most of the substation level functions are integrated in the substation level computer. Examples of such functions are the man-machine communication system, sequential event recording, automatic voltage regulation etc. The various functions are implemented in the form of programs which are modular to simplify maintenance and future extensions.

The description of the substation level below deals with the man-machine communication system and alarm handling for the Starfors substation. A more comprehensive description of the substation level is given in pamphlet A03-8710 E.

Man-machine communication

The man-machine communication system on the substation level is made up of:

- local/remote switch
- video display unit (VDU)
- function keyboard
- typewriter
- acoustic alarm

The local/remote switch is used to determine whether the substation is to be controlled from the control centre, substation level or from the back-up control panels.

The video display unit is used to display indications and events that occur in the power system or the computer system. The information has been grouped into the following displays:

Substation diagram replaces the former main control panel. It shows the operating status of the substation and gives current, voltage and power readings.

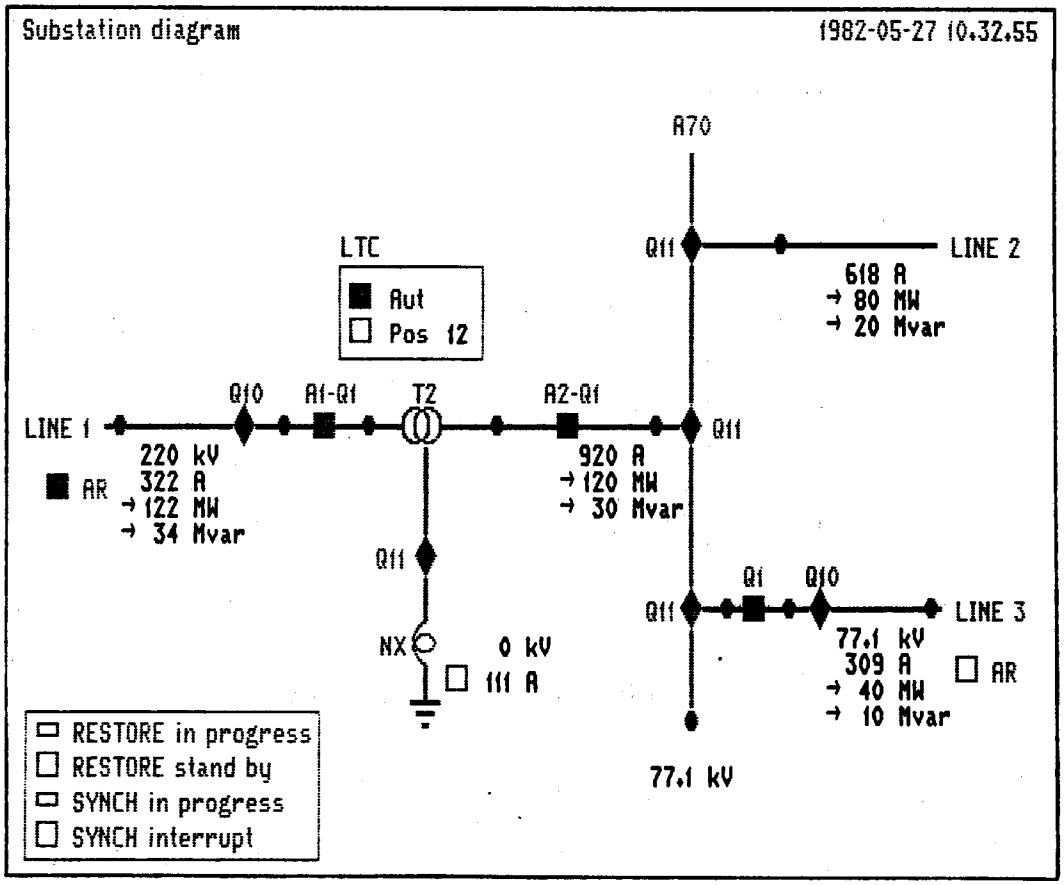

Fig. 4 Substation diagram

Automatic control diagram showing the various automatic systems of the substation.

Alarm list providing a current evaluation of the substation alarm signals. It includes unacknowledged alarms and persistent alarms.

Sequential event list containing events (relay protection indications, etc) for subsequent analysis of a disturbance in the power system.

Control equipment diagram showing the structure of the computer system.

Report directory, from which it is possible to order printout of daily reports and weekly reports of energy and voltage values.

The **function keyboard** is used:

- to choose which display is to be shown on the VDU
- to operate high-voltage switchgear and automatic systems
- to acknowledge the acoustic alarm and to acknowledge displayed alarms
- to order printouts on the typewriter

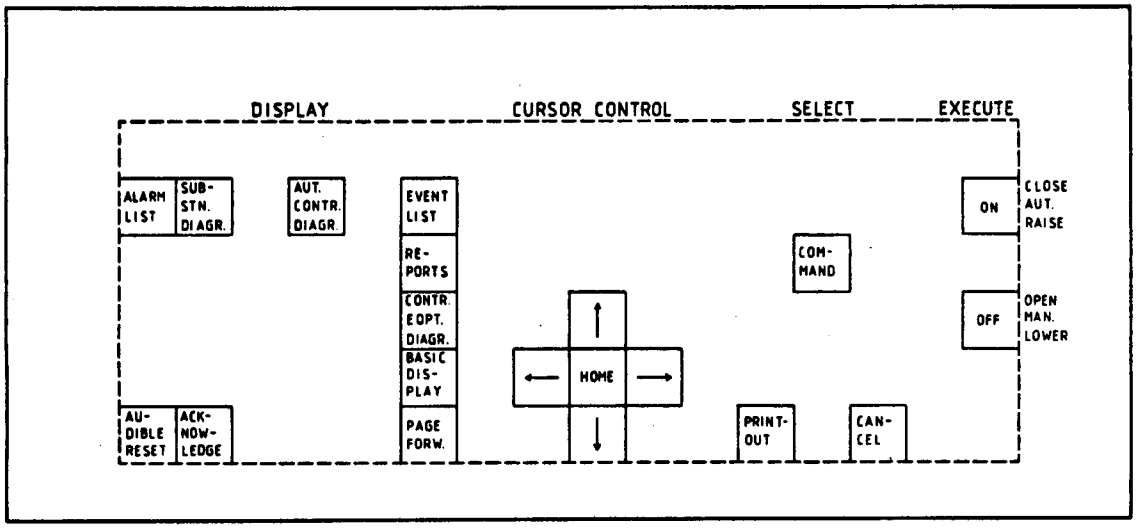

Fig. 5 Function keyboard

The keyboard is divided into four sections which are used from left to right.

1 In the first section, "Display ", the operator selects the display that is to appear on the VDU.

2 The keys in the second section, "Cursor control", may be used to move the cursor to the item to be operated.

3 In the third section, "Select", the operator selects the item to be operated; the computer system then checks that operation is possible.

4 The item can be operated "On" or "Off" by means of the fourth section, "Execute". The same keys are used for the tap changer, but in this case they mean "Raise" and "Lower" respectively.

Events in the power system and the computer system are printed out on the **typewriter** as they occur. The typewriter is also used to print out reports ordered from the report directory display.

The **acoustic alarm** is initiated if a fault occurs when the substation is manned. The acoustic alarm is acknowledged from the keyboard.

A mimic diagram has been introduced to give a clearer picture of the operating status of the substation when the substation is being operated in the "back-up control" mode. The positions of the high-voltage switchgear are shown on the mimic diagram by means of LED crosses. The mimic diagram operates independently of the computer system.

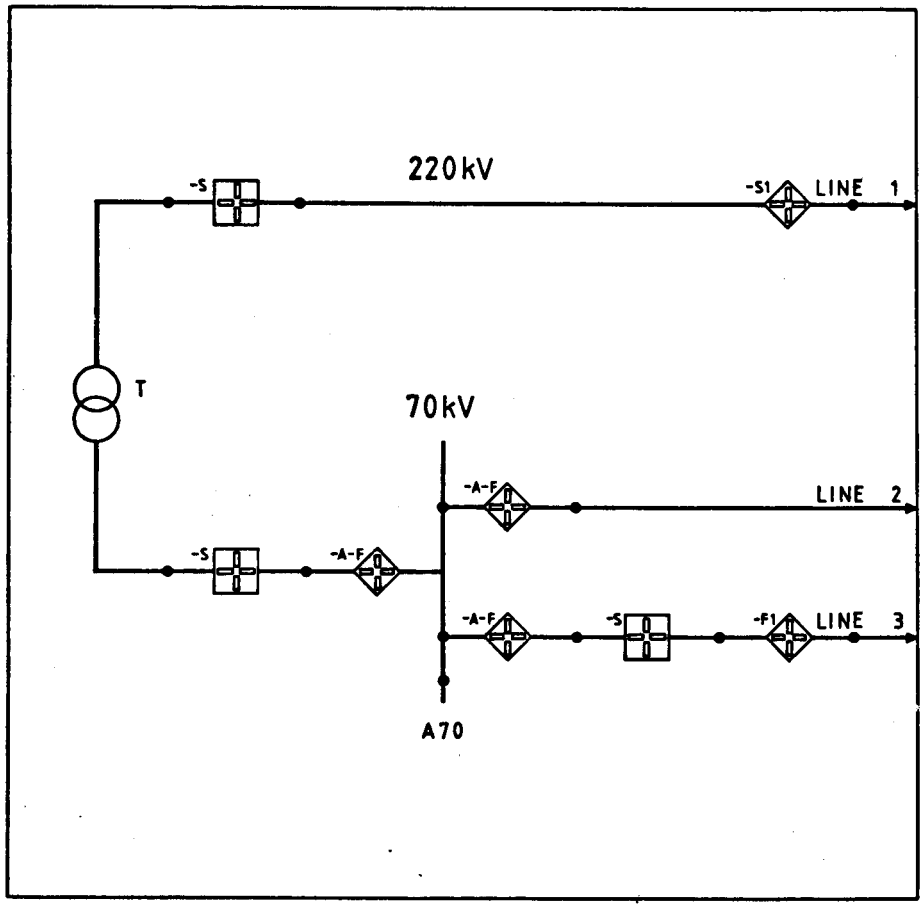

Fig. 6 Mimic diagram

Alarms

It is extremely important that the operating personnel are informed when a fault occurs. Power components and control equipment must therefore be monitored. An important feature of the computer system is its ability to discover when a fault has occurred. The faults that occur are combined in the substation level computer and printed out in the alarm list. If the substation is in the "remote control" mode the alarms are transmitted to the control centre.

Certain faults in the control equipment may make it impossible to transmit alarms to the control centre. Examples of such faults are:

- a fault in the transmission link between the substation and the control centre
- a fault in the remote terminal unit
- a fault in the substation level computer

It is therefore important not to become entirely dependent on this equipment. Hence a basic principle is, that the substation should be able to maintain an operating mode with an intact protection system if a fault develops in any of the above. This is achieved by providing the units at unit level with, among other things, a complete protection system, back-up control, fault indication and automatic reclosing.

Obviously equipment can be duplicated to increase the availability for control from the control centre, but this increases the cost.

At the Starfors substation the requirements have been reduced to the following: if there is a fault which prevents data reaching the operator at the control centre, the operator shall nevertheless be informed as to whether there is, at the same time, a serious fault in the substation that may affect the power system. In such a case the substation must be rapidly manned. If not, correction of the fault can be postponed until the next routine visit to the substation.

The substation is therefore equipped with a simple back-up alarm system which is started in the event of a fault in the normal transmission link to the control centre (see Fig. 7). The back-up alarm system receives information from the units at unit level in terms of urgent alarm, less urgent alarm or no alarm. The back-up alarm system is connected via a telephone line to a simple receiver which may be situated in the control centre. This simple equipment can provide the operating personnel with sufficient information to determine whether the substation requires to be manned immediately or if the fault can be attended to on the next routine visit.

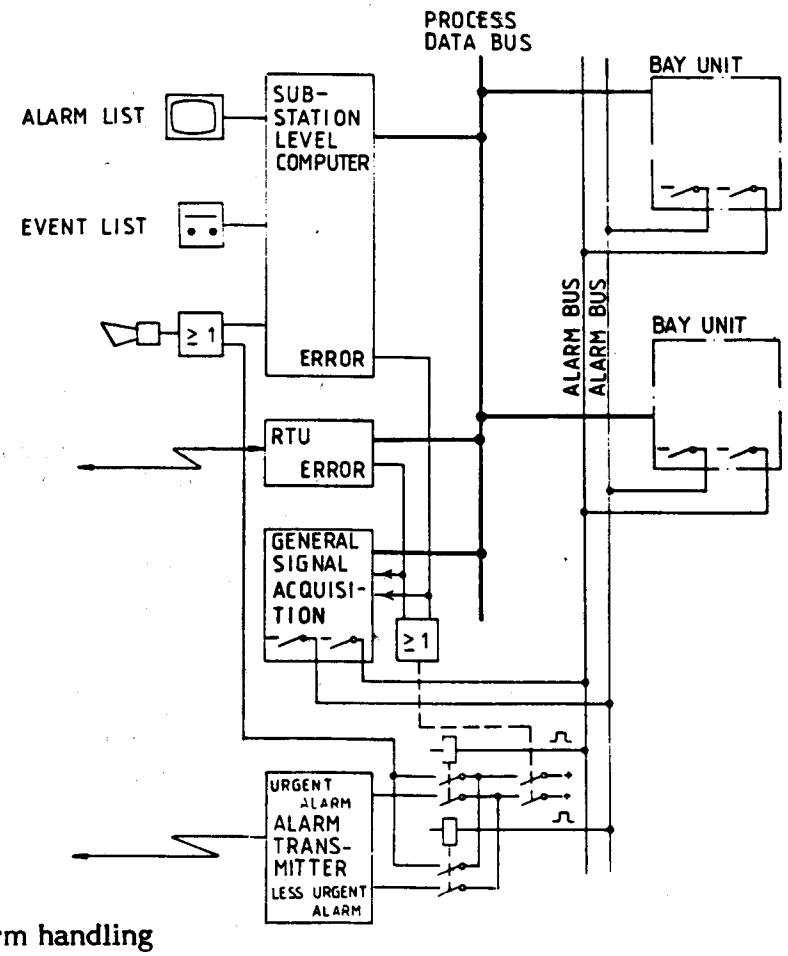

Fig. 7 Alarm handling

Control room layout

Fig. 8 shows the layout of the control room. The unit level equipment for each line is housed in two cubicles which are supplied assembled and tested. The unit level equipment for the transformer is housed in three cubicles.

The substation computer is located adjacent to the cubicle that contains the local/remote switch and the mimic diagram.

The VDU, function keyboard and typewriter are arranged as a work station.

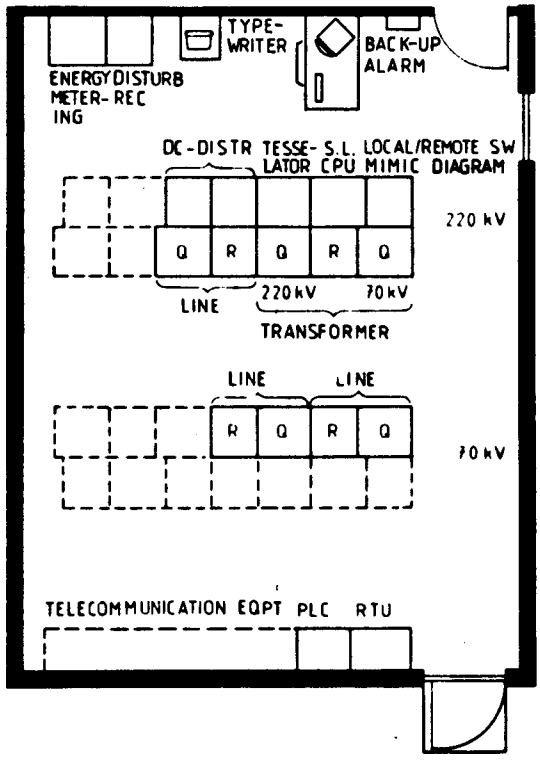

Fig. 8 Control room layout

Maintenance of the computer system

The maintenance costs of control equipment account for a significant portion of the life cycle cost of the equipment. It is therfore essential to fully utilize the facilities offered in order to reduce these costs when introducing microcomputer technology. This means that new approaches to maintenance and new aids must be produced.

In the proposed maintenance approach the work of maintenance is divided into two levels:

- An A-level, involving personnel located at the substation or in the district. The characteristics of these personnel from the maintenance point of view are:
  - that they have had brief training in the relevant computer system
  - that they have access to simple fault-tracing aids
  - that they shall be capable of isolating faults and correcting the majority of faults (90%).

- o A B-level, involving centrally located personnel. The charactistics of these personnel from the maintenance point of view are:
  - that they have a proper special training in the relevant computer system
  - that they have access to advanced fault-tracing aids
  - that they shall be capable of isolating and correcting the majority (90%) of all faults that could not be corrected by A-level personnel
  - that they carry out modifications and extensions to the computer system

For maintenance to operate in this way there must be routines, aids and documents designed for the two maintenance levels.

The following aids are used when correcting faults at the A-level:

- o the VDU system of the substation (mainly the alarm list)
- o LED indications on the front panels of the printed circuit boards
- o hand-held terminal for troubleshooting in software and hardware
- o troubleshooting documentation

For troubleshooting on level B the following are used:

- o level A aids (as listed above)
- o aids for PC-programming and advanced troubleshooting

The ability of the microcomputer to show where a fault has occurred is used for troubleshooting. Faults that originate from other equipment are acquired via digital inputs, whilst internal faults are detected in software and hardware tests. The various faults are displayed on the VDU in the alarm list.

Certain internal faults in the computer system may make it impossible to transmit fault condition information to the VDU system. The faults are therefore indicated by means of light-emitting diodes (LEDs) on the front panels of the circuit boards, as a back-up. Certain indications are used to show which circuit board is faulty.

A hand-held terminal, which plugs in to the unit containing the program in question, is used to study the signals in a particular program.

A powerful portable aid with integral display screen is used for software modifications and for advanced fault-tracing.

Design work

The introduction of computers has led to changes in design work. The relay systems previously used now have to be converted into computer programs.

A group of designers, including personnel from customer and supplier, and responsible for producing the various computer programs, was set up as a speedy means of achieving correct conversion of these systems.

The work was mainly divided into the following sections:

- specification
- programming
- testing the standard software
- testing the system to be delivered

This design work has resulted in a number of standard programs which have been thoroughly tested on an in-house machine. It will be possible to use these programs unchanged in future installations.

Scope of the computer system

The computer equipment consists of units from the **Asea Master** system and includes:

Substation level computer

Asea MasterTwo, based on a 16-bit VLSI processor (MC 68000). The **MasterTwo** can be supplied with both PROM and RAM memories and has a 2 Mbyte address capability. Communication units for both asynchronous and synchronous serial communication are available for the system. The system software can handle demanding real-time processing and is equipped with an effective database system. A modern process control language (PC language) or PASCAL is used as the programming language.

Unit level computer

Asea MasterOne, which is a compact distributed control unit with its own microprocessor (MC 6803). MasterOne has a 64 kbyte address capability and has resources for asynchronous serial communication and process signal interfacing, and can perform its own calculations. The programming language used is PC.

Communication between substation level computer and unit level computer

Data is carried between the MasterTwo and the MasterOne units on the ASEA process data bus, the **PD bus,** which is an asynchronous serial communication bus.

The PD bus is optimized for short messages and high security. Several MasterOne and MasterTwo units can be connected to the same bus in a multidrop configuration.

Man-machine interface

The man-machine interface consists of the ASEA **TESSELATOR** graphic colour VDU system, a 19" monitor, a function keyboard and a typewriter.

Maintenance aids

Asea MasterAid 111, a hand-held terminal mainly intended for troubleshooting. It can be plugged in to the various computer units for such purposes as the reading of error codes from the testing and diagnostic functions incorporated in the system.

Asea MasterAid 213, a portable aid for PC-programming, Including an integral display screen, an alphanumeric keyboard and two floppy disc units.