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(71) Applicant *(for all designated States except US)*: ENEL - SOCIETÀ PER AZIONI [IT/IT]; Via G.B. Martini, 3, I-00198 Rome (IT).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: COMELLINI, Enrico [IT/IT]; Via di San Godenzo, 182, I-00189 Rome (IT). GARGIULI, Raul [IT/IT]; Via Domenico Vietri, 24, I-00149 Rome (IT).

(74) Agents: BAZZICHELLI, Alfredo et al.; Società Italiana Brevetti S.p.A., Piazza di Pietra, 39, I-00187 Rome (IT).

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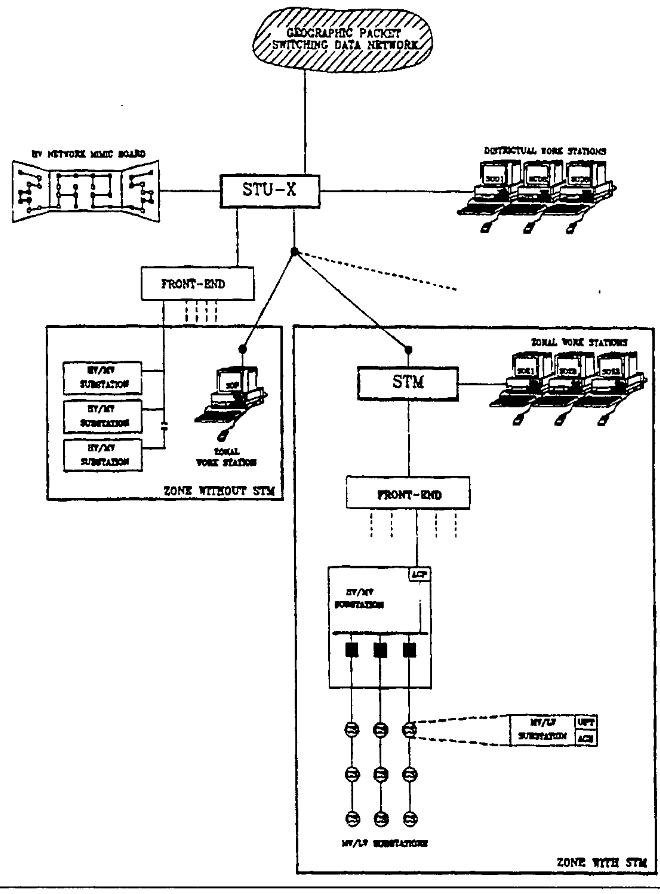
(57) Abstract

A system for the remote control of the electricity distribution network and the telereading of the electricity, gas, water and other services meters of the customers connected to the same network. More specifically a system which uses centralized and distributed intelligence to manage the information and carrier currents at relatively high frequencies over the wires of the electricity networks to transmit the information. The carrier current system is implemented according to an original method, which, unlike the traditional one, does not utilize high frequency traps and by passes, at the network nodes. This method allows the use of the power distribution network without the expensive changes required by the traditional solution. This result is obtained by forecasting the messages over the Medium Voltage (MV) and the Low Voltage (LV) radial networks as they are configurated for the distribution of the electricity and by properly addressing the various substations and the customer meters. Because the MV and LV electricity network configuration is subject to change as a consequence of intentionaly made switching operations or as a consequence of automatic tripping of the switchgears following a fault, the method of properly addressing and routing the messages to their final destinations requires that the state of the network is very frequently updated. This function is performed by the system subject of this invention and the updating of the state of the network, a very important information in itself, has to be seen as an added value for the system.



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DISTRIBUTION AUTOMATION SYSTEM USING MEDIUM AND LOW VOLTAGE DISTRIBUTION POWER LINES AS TWO-WAY DATA TRANSMISSION MEDIA

DESCRIPTION

The present invention refers to a system for the remote control of the electricity distribution network and the telereading of the electricity, gas, water and other services meters of the customers connected to the same network.

More specifically the present invention refers to a system which uses centralized and distributed intelligence to manage the information and carrier currents at relatively high frequencies over the wires of the electricity networks to transmit the information.

The carrier currents system is implemented according to an original method, which, unlike the traditional one, does not utilize high frequency traps and by passes, at the network nodes. This method allows the use of the power distribution network without the expensive changes required by the traditional solution.

This result is obtained by forecasting the messages over the Medium Voltage (MV) and the Low Voltage (LV) radial networks as they are configurated for the distribution of the electricity and by properly addressing the various substations and the customer meters.

Because the MV and LV electricity network configuration is subject to change as a consequence of intentionally made switching operations or as a consequence of automatic tripping of switchgears following a fault, the method of properly addressing and routing the messages to their final destinations requires that the state of the network is very frequently updated.

This function is performed by the system subject of this invention and the updating of the state of the network, a very important information in itself, has to be seen as an added value for the system.

According to the present invention, the system mentioned above, can provide, one by one or in an integrated way, the following functions:

- Supervision of the High Voltage Network and remote control of the Primary Substations;

- Supervision of the Medium Voltage Network and remote control of the secondary substations;

- Remote reading of the meters and automation of other commercial functions for the MV and LV customers;

These, and other characteristics, aims and advantages of the present invention will be more clearly seen from the following detailed description, to be considered in conjunction with the enclosed drawings, and the enclosed claims.

As regards the drawings:

Figure 1 shows the architecture of the system according to the present invention;

figure 2 is a table giving the meaning of the symbols used in figure 1 and in the subsequent figures;

figure 3 shows a diagram for routing the messages;

figure 4 shows a diagram of the high frequency coupling device for the injection/pickup of carrier-current signals on the MV network;

figure 5 shows a the architecture of the ACP apparatus;

figure 6 shows the architecture of the ACS apparatus;

figure 7 shows the architecture of the Remote Terminal Unit (UPT);

figure 8 shows the architecture of the Peripheral Electronic Unit (UEP) which is installed inside the metering apparatus for domestic LV users;

figure 9 shows the Multifunction Portable Terminal (TEM);

figure 10 shows the block diagram of the

Multifunction Portable Terminal (TEM);

figure 11 shows a LV network diagram as it appears on screen in an STM graphic workstation;

figure 12 shows the structure of the message on the MV network according to the used protocol;

figure 13 shows an example of the "store and forward" procedure on a LV line;

figure 14 shows a map of the remote controlled HV/MV substations within a certain distribution zone;

figure 15 shows the topological diagram of a MV distribution network;

figure 16 shows the diagram of a MV feeder;

figure 17 shows the sub-diagram of a MV feeder section;

figure 18 shows a typical HV/MV Substation Diagram;

figure 19 shows a diagram of a secondary substation with one bus-bar;

figure 20 shows a diagram of a secondary substation with three bus-bars;

figures 21 and 21bis show an example of the automatic sectionalizing procedure on an overhead MV feeder;

figure 22 shows an example of the automatic sectionalizing procedure on a MV underground feeder;

figure 23 shows a diagram of the pulse generator device installed inside the metering apparatus;

figure 24 shows the metering apparatus and the electronic units required by the system for the various categories of users defined as a function of their subscribed power demand;

figure 25 and figure 26 show two types of electric metering apparatus;

figures 27a and 27b show the insertion of the electronic unit into the metering apparatus in the case of an individual installation and in the case of the installation over a centralized board;

figure 28 shows the structure of centralized board for residential low voltage customers;

figures 29, 30, 31 show different types of metering apparatus;

figure 32 shows the connection of a metering apparatus through current transformers for an LV customer;

figure 33 shows an SF6 insulated apparatus installed at the MV customer connection and containing current and voltage transformers, an earthing device and equipped with the carrier current coupling device;

1. GENERAL SYSTEM ARCHITECTURE

System architecture as shown in fig. 1 is divided into the following subsystems:

STU-x for management of the HV (high voltage) network and the Primary Substations in a certain territorial unit (District).

STM for management of: MV (Medium Voltage) network, secondary substations and users in each territorial sub-unit (Zone) into which the territory controlled by STU-x is divided;

STU-x is at the highest level in the hierarchy and is capable of managing up to 200 Primary Substations (HV/MV transformation substations): therefore it can supervise and control an HV network of notable proportions.

It can interface on the one hand with other STU-x systems and/or with remote Host Computers, by means of packet switching geographical networks, and on the other hand with one or more STM systems from the component territorial sub-units, by dedicated Point-to-point channels.

If one or more zones are not provided with STM it is possible for them to be provided with a Peripheral Work Station (SOP) allowing the operator, in the local control center, to work on the network he is in charge of.

STM, as well as giving remote control of the MV network, also provides for all functions connected with customer service automation in the Zone, and it is available in three sizes, according to the dimensions of the network to be managed:

- A-type STM for small MV networks;
- B-type STM for medium sized MV networks;
- C-type STM for large MV networks;

Both the STU-x and STM subsystems are organized on Ethernet type Local Area Networks; the vital components of each system, including the computer, are doubled, and there are special procedures to switch from the faulty component to the healthy one.

The FRONT-END Computers (FEC) use the same Hardware base, but can adopt different types of protocol and manage communication with the field autonomously.

If the territorial sub-unit (Zone) is provided with STM, the information relating to the Zonal Primary Substations is acquired directly by the FECs of STU-x (Fig.1).

The information from the Secondary Substations is acquired by the FECs of STM. This information comes from the Primary Substation Apparatus (ACP), and can be divided into two main categories:

a) Information relating to the subsystem for the automation of the MV network, coming from the Remote Terminal Units (UPT) in the secondary substations;

b) Information relating to the subsystem for Customer Service Automation, coming directly from the metering devices for MV users, or from the Secondary Substation apparatus (ACS) for LV users.

The work stations (Fig. 1) installed at District (SOD) and Zone (SOP) level are practically identical to each other, and are high definition graphic stations.

From figure 1 it is evident that the single sub-systems can be used separately, according to the territorial organization of the electric company and according to the applications required; the following is therefore possible:

* remote control of the HV network over a vast territory using the STU-x alone;

* remote control of the Primary substations and the MV network over a more restricted territory using the STM alone;

* customer service automation using STM alone and the software strictly necessary for this operation;

* implementation of all the functions given in the above points, by integration of a STU-x with a series of STMs.

<u>The telecommunications sub-system</u>

Communication between the Primary Substations and the Control Center is carried out through standard vectors, and so it is possible to use radio links, dedicated telephone lines, carrier-current signalling on HV lines, etc.; <u>in this way, each Zone, is connected to its own primary substation.</u>

Connection of each Primary Substation to its own secondary substations and connection between the LV meters and the secondary substation by which they are fed, is carried out by a line carrier transmission system, on the same MV and LV distribution networks.

Application of the line carrier transmission system to the MV and LV networks requires some technical solutions that make it differ strongly from the classical method used on HV lines.

In effect, due to the extremely high number of nodes in the MV and LV networks, make practically impossible the adoption of high frequencies traps and by-passes, but the HF signal is injected into each MV bus-bar in a Primary Substation and onto every LV bus-bar in each secondary substation, so that the signal spreads through the whole of the electrical network fed by these bars.

This solutions means that the impedance of the transmission circuit cannot be matched easily to the continually varying impedance of the communication support. The decay in performance that results from this lack of matching is prevented by the ability of the intermediate stations to re-transmit the messages, using a "Store and Forward" procedure.

The non-existence of High Frequency by-pass on the switching elements means that the interruption of a feeder caused by a fault produces a break in the communication link at that point in the system. The solution to this problem, which is briefly described in the following paragraphs, consists in providing the Remote Terminal Units (UPT) with a certain amount of autonomy, so that they implementing on them a logic that allows automatic re-closure of the switches in the substations to be reenergized, as soon as the faulty section has been isolated.

For the same reasons, any variation in network connection produces a change in the configuration of the Telecommunications System which, in order to route messages, has to refer to a real time updated Data Base, containing the status of electrical connections in the network.

It must be noted that the above does not form what could be defined a "negative characteristic". It is, in fact, a novel and innovative form of use of what was considered a negative aspect, that is to say a fault in carrier-current signalling systems when considered in general.

As a matter of fact, up to now the line carrier systems, which are well known from a conceptual and operative point of view and also on a commercial hardware level, were designed to operate by "imitating" the "on-the-air" radio communication systems.

As will be seen from the following, one of the main aspects of the present invention makes advantageous use of what was up to now considered a limitation in line carrier transmission systems.

With reference to figure 3, routing of the various messages starting from the STM subsystem, according to the present invention, will now be described in greater detail.

The subsystem (STM) for distribution automation in one of the territorial sub-units mentioned above is managed by a control center (100). This center, by means of the FRONT-END computers (101) communicates using dedicated multi-point lines with the HV/MV substations in the territory covered.

Once one of these installations is reached, the message is delivered to the ACP apparatus (102), from which the line carrier system, according to the present invention, departs.

The ACP (102) has a series of independent output channels which, by suitable coupling devices (103), allow injection/pick-up of the carrier-current signal on each medium voltage bus-bar (104) in the substation.

A series of lines departs from each Primary Substation MV bus-bar, with the interposition of MV circuit-breaker (105), and each of these lines feeds a series of MV/LV substations (106) connected in cascade.

Once one of these substations has been reached, the signal is picked up by a coupler (107) and sent to the ACS apparatus (108) or sent directly to a medium voltage customer metering apparatus (109) if the substation supplies a user of this kind.

The ACS (108) connects with the low voltage (LV) supply bus-bar by a capacitative coupler that allows the messages to reach the low voltage meters (111) installed in the user premises. In certain cases (remote controlled MV/LV substations) the ACS is connected to the UPT apparatus (110), which allows remote signals to be sent and remote commands destined for the switches in that secondary substation, to be performed.

Naturally, as underlined above, in order to route the signals correctly it is necessary to know instant by instant the electrical connection status of the network, that is to say the open or closed state of all the switching devices situated in the various substations, both Primary and secondary.

The type of modulation used is narrow-band (FSK), and the transmission frequencies are the following:

approx. 72 kHz for the MV network

approx. 82 kHz for the LV network

both within the range of 9-95 kHz, assigned by CENELEC to electric utilities.

The modem used, which is of the single-chip type, is the same for both the MV and the LV network.

The frequencies indicated above do not pass beyond the distribution transformers (both HV/MV and MV/LV) and, generally speaking, do not pass the open switches. As a consequence of this, and of the fact that the ENEL MV and LV networks are radially operated, the signals are injected onto the secondary winding of each HV/MV and MV/LV transformer. There are, therefore, the same number of independent transmission routes as there are HV/MV transformers on the MV network, and as there are MV/LV transformers on the LV network.

The chosen frequencies do not penetrate into the power factor correction capacitor banks present in the plants, and these therefore have no effect on signal attenuation.

Signal coupling is capacitive, as this is more effective than the corresponding inductive solution.

With regard to the propagation mode, the phase-phase mode is used in the MV network, and the phase-neutral mode is used in the LV network.

The following are therefore used:

- a capacitive phase-phase coupling device on the MV network (figure 4)

- a capacitive phase-neutral coupling device on the LV network.

The solution chosen for the MV network does not influence operation of the directional earth protections in the HV/MV substations, and minimizes crosstalk at open switches.

From the construction point of view, the MV coupling device is confined inside a small metal oil filled box, and is connected to the line by means of air or gas insulated bushings, for installation on an air or gas insulated cell, respectively.

Transmission power is rather low (~1W) both on the MV and on the LV network.

As signal attenuation, noise level and coupling impedance may vary greatly over a period of time due to variations in the electrical loads and configuration of the network, the "store and forward" function has been provided in the peripheral units to re-transmit the signals and reach the most distant points even under the hardest conditions.

Furthermore, with reference to the LV networks, which are the ones most frequently influenced by electrical loads, the used procedures are tolerant with delays of several hours in the transmission of signals; this, for customer service automation, makes it possible to avoid transmission during the least favourable hours of the day (hours of maximum load).

The transmission rates are the following:

1200 bit/sec. on the MV network

600 bit/sec. on the LV network.

These rates, even when taking into account the "store and forward" procedure and the re-transmission of incorrect messages, can ensure the following performance:

- acquisition of signals from 100 remote controlled MV/LV substations, in less than one minute;

- acquisition of consumption data from 10,000 meters, in less than four hours.

These values correspond to the average number of MV/LV transformer stations and MV and LV users, supplied by a Primary Substation, so the performance indicated above ensures good performances.

In addition to the processing resources at the control center, the system, according to the present invention, also uses the peripheral apparatus described below.

ACP

The ACP, or Primary Substation Apparatus (figure 5), situated in each HV/MV substation, is the communication interface between the FEC installed in the control center and the peripheral apparatus connected to the Medium Voltage network (ACS, UEPM, UPT).

The hardware architecture of the apparatus is modular and uses a System bus to interconnect cards, thus allowing sizing that is aimed at the specific needs of each site.

The fundamental blocks of ACP are:

a) Processing unit (CPU, memory and accessory circuits):

b) Telegraphic modem to FECS;

c) Interface to the Portable terminal;

d) MV network RX/TX modules;

e) Synchronization unit with MV zero crossing.

The ACP can connect with:

- FEC Apparatus through a bi-directional full-duplex communications channel with standard HDLC-NRM protocol in multipoint slave mode;

- ACS apparatus by means of a certain number of channels, each one of which is coupled to a Primary Substation MV bus-bar by means of capacitive coupler. Each channel is bi-directional half-duplex and can manage the traffic in parallel with the others on the various substation bus-bars. The protocol is specialized multipoint HDLC-MT type, with the ACP acting as Master. All the messages sent on the MV bus-bars are synchronized with the zero crossing of the alternate current at 50 Hz, that is to say there is a positive zero-crossing indicator supplying the start of the message.

- Portable terminal, by means of an asynchronous serial interface with optical connection.

The ACP node is only assigned tasks connected with communication, and in particular the following functions:

- Management of HDLC-NRM slave connection protocol to and from FECS;

- Management of HDLC-MT master connection protocol to and from the peripheral apparatus in the secondary substations (MV network);

- Management of synchronism for transmission of messages at zero-crossing;

- Management of standard ISO/IEC connection protocol to and from the non-resident portable terminal;

- Management of routing for messages from FECS towards a specific section of MV bus-bar according to the peripheral to which it is destined;

- Management of priority levels both for centrifugal and centripetal messages;

- Determination of the relay stations for each end node;

- Determination of the level of signal received by MV nodes and communication of the latter to the control center;

- Diagnosis of inconsistencies and incongruences in the peripheral devices;

- Remote loading of routing tables by the central system;

- Management of data structures for diagnostics and communication statistics;

ACS

The ACS, or Secondary Substation Apparatus (fig. 6), installed in the MV/LV substations, is a slave node of the communications network on the medium voltage lines and the Master node for the Low Voltage communications network.

The Hardware is characterized by a high level of integration with sharing of functions between the various units, which takes into consideration not only functional aspects but also industrialization aspects.

The functional blocks making up the ACS are the following (fig. 6):

a) CPU and Power-fail management circuits;

b) Static RAM memory;

c) FLASH_EPROM memory for the application programs code;

d) EPROM memory for Bootstrap programs and those for management of portable terminal loading;

e) EEPROM memory for semi-permanent ACS data (address, routing tables, etc.);

f) A/D converter for measurement of network voltage;

g) Real Time Clock for management of time/date with Back-up capacitor to guarantee operation of the clock for 48 hours in the absence of power supply;

h) MV Multiplex to share the MV transceiver with the UPT;

i) LV Multiplex to share the single serial channel with the three LV transceivers, each one connected to one phase and neutral;

j) MV transceiver;

k) LV transceiver;

l) LV couplers;

m) Dual-input power supply (220 V AC - T phase, 24V DC);

n) Block for processing of the zero crossing on the three phases of the LV network, starting from the signal for the T phase of the power supply.

The ACS can connect with:

- The ACP by means of the MV network, to which both are connected by a capacitative coupler; communication can be direct or through a number of ACS repeater units.

- The Electronic units in the LV metering groups (UE-BT) through the LV network - the LV transceivers, one for each phase, can only be used separately according to the phase involved;

- The Portable Terminal by means of an asynchronous serial interface with optical coupling of the same kind as that used by the ACP.

- The UPT or Remote Terminal Unit by a standard RS232 interface; this connection has the sole aim of allowing the UPT to use the MV transceiver for communication with the ACP.

The ACS node is assigned tasks connected with communication, and in particular the following functions:

- Management of HDLC-MT slave connection protocol to and from the ACP;

- Management of synchronism for transmission of messages at zero-crossing;

- Management of communications protocols on the LV network, in order to guarantee communication with the UE-BT in all the types of dialogue foreseen;

- Management of standard ISO/IEC connection protocol to and from the non-resident portable terminal;

- Management of dialogue, on RS232 interface, with the UPT apparatus;

- Determination of the relay stations for each end node;

- Cyclic verification of the connection status of the LV network, with notification of any anomalies to the center;

- Acquisition of newly installed UE-BT;

- Remote loading of routing tables processed by the central system;

- Management of data structures for LV diagnostics and communication statistics;

- Direction of User Terminal updates in the basic cycle;

- Direction of User Terminal updates in the daily cycle;

- Daily control of the dependent UEs and collection of consumption;

- Management of non-periodic remote management operations requested by the center;

UPT

The UPT or Remote Terminal Unit (fig. 7) is only present in remote controlled secondary substations, where, in addition to its normal functions of actuating commands and transmitting remote signals, it is also used to apply a series of automatic rules that allow a faulty section of MV line to be identified and sectionalized.

The Hardware is characterized by a high level of integration, the functions being shared between the various units like for the ACS apparatus.

The architecture can be divided into two main sections, each one managed by a separate bus: the processing section and the section for interface with the field.

In greater detail, the functional blocks forming the UPT are the following (fig. 8):

a) CPU and support circuits;

b) Static RAM memory;

c) FLASH_EPROM memory for the application programs;

d) EPROM memory for Bootstrap programs and those for management of portable terminal loading;

e) EEPROM memory for semi-permanent ACS data (address, routing tables, etc.);

f) Real Time Clock for management of timing;

g) System Watch Dog (WD);

h) Controller for 2 serial channels (connection with ACS and with the portable terminal);

i) RS232 interface for connection with ACS;

j) RS232 interface and opto-electrical converter for connection with the Portable Terminal;

k) Connection interface between the bus of the processing unit and the bus for dialogue with the field;

l) Signals interface;

m) Commands interface;

n) Power supply (24V DC);

The UPT can connect with:

- The ACP by means of the MV network to which both are connected by a capacitative coupler; communication can be direct or through a number of ACS repeater units.

- The ACS by means of a standard RS232 interface; this connection has the sole aim of allowing the UPT to use the MV transceiver for communication with the ACP.

- Another UPT by means of the MV network during identification of the faulty section of underground lines (with RG).

- The Portable Terminal by means of an asynchronous serial interface with optical coupling like that used by the ACP and by the ACS.

The main functions carried out by the UPT are the following:

- Remote control of the installation (actuation of commands on switches, production of status information, pre-processing and transmission of elementary signals from the field, etc.);

- Identification of Faulty Section (group of rules and procedures which are applied automatically by the apparatus to allow identification of the faulty sections of MV line);

- dialogue with the center by means of the ACS in HDLC-MT protocol;

- HW/SW diagnosis of the apparatus and service functions through the portable terminal.

UEP

The UEP or Peripheral Electronic Unit associated to the meter for each MV and/or LV user, performs a series of communication and data processing functions.

The functions and different types of electronic unit will be illustrated in the following; the block diagram of a UEP for single-phase LV user is given as an illustration (fig. 8).

The Hardware architecture shows the following basic blocks:

a) Processing Unit (CPU, memory and accessory circuits);

b) Opto-electronic transducer connected to the impulse emitting device housed inside the new power meters;

c) Tripping device for the thermo-magnetic switch;

d) Transceiver coupled to the LV line upstream of the meter;

e) Liquid Crystal display for user;

f) Power supply connected to the LV line upstream of the meter.

The UEP can connect with the following:

- The ACS by means of the LV network and HDLC-BT protocol;

- Another UEP, again by means of the LV network and HDLC-BT protocol;

- A user terminal associated to the UEP by means of the user's own LV power supply plant;

- A Portable Terminal by means of the LV network and HDLC-BT protocol.

Within the architecture described above, the UEP performs the following functions:

- Basic timing management with clock/calendar functions;
- Management of tariff programs capable of allowing different rates according to the time of day, the season, the power used and of mobile peak load;
- Count of the "quanta" of energy measured by the Ferraris meter;
- Processing of data for the quality of the service and any attempts at fraud;
- Management of procedures for initialization of the operating parameters;
- Management of procedures for bi-directional dialogue with other UEPs, with the ACS, with the Multiple function Portable Terminal;
- Management of procedures for dialogue with its own user terminal;
- Management of commands for tripping the thermo-magnetic circuit-breaker;
- Management of procedures for data displaying;
- Management of procedures for self-diagnosis and safeguard of processed data;

User Terminal

The communications function also comprises any dialogue with an optional electronic device that the user may install in his home, and which has the function of displaying information, sent directly by the Electrical Company, relating to energy consumption and, in the more sophisticated version, of performing load optimization activities.

The procedures for dialogue between each UEP and its user terminal will be examined later in the present text.

The System also provides a Multi-function Portable Terminal (TEM), using which it is possible to connect to all the peripheral apparatus mentioned above.

The TEM (figures 9 and 10) is made up of a metal case containing on its inside:

- Personal Computer of a Note-book type;
- 1 transceiver for the MV network;
- 3 transceivers for the LV network;
- 1 asynchronous serial interface with optical coupler;
- 1 X.28 interface for telephone lines;
- 1 set of connection cables.

The personal computer is provided with suitable software packages for management of all types of protocol used by the System according to the present invention. Interactive procedures developed ad hoc allow the TEM to perform the following activities:

1) Programming and testing of the following apparatus: ACP, ACS, UPT and electronic units associated to the Medium Voltage power meters (UEPM) by means of asynchronous serial connection with optical coupler;

2) Programming and testing of the electronic units of Low Voltage meters by means of the modems for the LV network;

3) Dialogue according to the protocol on the MV network with the apparatus indicated in point 1, by means of MV modem;

4) Dialogue according to the protocol on the LV network with the apparatus indicated in point 2, by means of LV modems;

5) Dialogue with ACP and with all the nodes in the network (both MV and LV) that are hierarchic dependent on it, in a manner similar to that used between the FECS apparatus and the Control Center;

6) Dialogue on X.28 network with the Central System by means of a suitable interface.

PROTOCOL

The communications protocol adopted is derived from the standard HDLC (NRM), to which the modifications necessary for the following have been introduced:

- addressing an extremely high number of "End-nodes";

- managing the "Store and Forward" process.

The dialogue is managed autonomously by the ACPs on the MV network and by the ACSs on the LV network, and takes place in parallel on each independent communication island. More specifically, it is possible to identify:

- independent communication islands on the MV network, made up of all the lines connected to the same LV bus-bar in the Primary Substation. On each of these islands the ACP manages dialogue with the ACSs and with the UEPs of MV users in parallel; in particular the ACSs in each island are interrogated cyclically to check their connection status.

- independent communication islands on the LV network made up of all the "Sections" connected to the same LV bus-bar in the secondary substation. On each of these, in parallel, the ACS interrogates the UEPs cyclically to check their connection status.

The addressing methods will now be illustrated.

Above all, as regards remote management of users, it is well to explain the method of addressing the LV metering devices.

While the MV network is represented in a classical manner using nodes and branches, the LV network is represented in "Sections" (figure 11); as the section is a part of the LV network that cannot be further sub-divided by switches. Basically speaking, the section can be defined as a part of the LV network which is divided from the rest of the network by a certain number of switches, and which does not contain any other switch inside.

As a number of LV metering devices are connected to each Section, the address for one of these is made up of two sub-fields:

- the section number, called the "main address"

- the number of the meter within the section, known as the "sub-address".

This address is stored within the meter's electronic unit when it is activated.

The addressing method given above offers the following advantages.

a) As the network is radially operated, each section is fed at all times by a specific transformer, and therefore all the metering devices within the section are connected to the same transformer. Consequently, it is not necessary to interrogate all the electronic units to ensure that the section is actually connected, but it is sufficient to interrogate just one. If this responds, the section, and therefore all the meters in that section, are connected; if it does not respond, they are not connected. In this way, updating of the network connection status is very quick.

b) By reserving, within the section, the number 1 (numbers 2 and 3 are used as a reserve) to address a meter in a particularly advantageous position for transmission, that is to say near the main conductor, if possible at the center of the section, it is possible to use this meter (known as the "Section Master") as a relay for re-transmission of messages to the other metering devices in the same section or to the Master of another section.

Bearing in mind the usual length of sections in the LV network, it can therefore be stated that:

- all the meters in one section can be reached by a message transmitted by the Master of that section;

- the Master of a specific section can be reached by messages transmitted from the Masters of adjacent sections.

c) In order to manage all the activities required for customer service automation, the ACS memory does not contain any information relating to the meters, but only a small amount of information relating to the LV network, which can be fed from the substation in which the ACS is installed, more specifically:

- the list of sections that can be fed from that substation;

- the number of meters that are connected to each of these sections;

- a table expressing the possible connections between the above mentioned sections (that is to say the way in which these sections can be connected to each other and to the adjacent MV/LV substations).

In this way it is possible to avoid the problems relating to storage and updating of the large amount of data that would result from providing the ACS with the data for meters, as is normally the case in prior art solutions.

d) Another important advantage obtained using this addressing system is the management, by the Section Master, of data transmission from each meter to the respective electronic device with which the user may be provided.

The routing method will now be illustrated.

Every message transmitted by the center must contain, as well as the address corresponding with its final destination, an indication of the route it has to follow.

Bearing in mind the fact that the MV and LV networks are radially operated, this route is unique and is defined by the HV/MV substation and by the MV/LV substation (in the case of LV users) feeding the user under consideration (or the substation under consideration, in the case of messages for remote control of the network) at the time of data transmission.

Routing also includes the address of certain intermediate MV nodes and the masters of certain intermediate LV sections, to be used as transmission relays in the "Store and Forward" procedure.

An example of relay procedure performed on a LV feeder is the following.

The format of the LV message has the structure shown in figure 12; attention should be focussed bear on the following fields:

- IND (address): address of the station to which the message is destined;
- CTL (control): provides information on the type of message and is made up of the sub-fields:

T= NORM = No Repetition
SR = Message to repeat
RCP = Message for repetition control

N = Number of repeters
D = Communication rules

- REP (repeat): contains a variable number of addresses relating to the relay stations and the final destination;
- INF (information field): contains the application message destined for the final destination.

With reference to figure 13, which shows the hypothetical dispatch of a message by the ACS to UE using two relay stations R1 and R2, let us analyze the sequence of outgoing and returning messages on the LV line.

A) The ACS receives a request for communication with the UE node; from the routing table the relay procedure manager sees that direct communication is not possible, and that it is necessary to use relay stations R1 and R2. It therefore prepares a centrifugal message with a final address equal to the UE node, sends it to R1 and reverts to reception mode with the address R1 (the ACS has no address within the

LV network for which it is MASTER), setting a suitable Time-out.

B) R1 receives the message and recognizes it as being destined for the UE via R2; at this point it re-formats the message, transmits it towards R2 and reverts to reception mode with the address R2, setting a shorter time-out to that set by the master node.

C) R2 receives the message from R1, recognizes the final destination, re-formats the message and sends it to the UE node. It then listens in with a suitable time-out (lower that set by the master), with the address of UE.

D) The UE recongizes the message as personal to itself and sends the response to the Master with its own address (UE) as destination.

E) R2, which was awaiting a centripetal message with the address UE, receives the message, cancels the reception timer, re-transmits the message with its own address (R2) as destination, and then reverts to standby with its own normal network address (R2).

F) R1, which was awaiting a centripetal message with the address R2, receives the message, cancels the reception timer, re-transmits the message with its own address (R1) as destination, and then reverts to standby with its own normal network address (R1).

G) ACS, which was awaiting a centripetal message with the address R1, receives the message, cancels the reception timer, picks up the contents of the field INF and passes it to the application program as if it would have been originated from the node interrogated (UE).

It should be noted that, thanks to a status information present on the intermediate relay stations, and that is to say:

that each relay station is in reception mode with the address of the rélay station downstream, thus knowing that it awaits a reply from a slave node and that once reply has been received it can relay it using its own station address;

the messages travelling in a centripetal direction can have a normal message format with the REP field empty, resulting in an improvement of overall performance.

The various time-outs in reception are calculated by the intermediate nodes according to the communications rules contained in the sub-field D of CTL.

Any relay errors are managed by generation of an RCP message. This message, generated by the relay station for which the reception time-out triggers, has the address of the generator node in the field REP and is transmitted in a centripetal direction in the same way described above.

From the above, it can be seen that routing of the message is strictly dependent on an up-to-date knowledge of the connection status of the two MV and LV networks; this information is found in the STM sub-system and is obtained by the following main steps.

- Storage of the structural configuration in the STM data base, by means of information from another data base resident in a Host computer and containing information relating to network structure, information which is stored at the time of construction and updated at the time of any alteration works.
- Updating of the status of MV line switches by the activity carried out by the STM itself to manage the MV network, also bearing in mind the cyclic interrogation activity performed by the ACP in the Primary Substation on the MV nodes fed by the latter.
- Updating of the status of LV line switches by means of the cyclic interrogation activities performed by the ACS in each MV/LV substation, on the masters in the sections fed by the latter.

The background activity performed by the ACS devices will now be illustrated.

Each ACS device, during the day, performs a cyclic interrogation directed exclusively to the Masters of the sections fed by the MV/LV transformer within the same substation (section of the supplied LV network), or connected to the preceding sections by a switch that is normally open (section outside the periphery of supplied network).

When an interrogation message is sent by the ACS to the master of a known section, during the above background activity, there are two possibilities:

A1) The "master" responds to the ACS, thus confirming that the section is still connected to that transformer. In this case the ACS sends a new message to the "Master" of the section to start a data updating procedure towards electronic device within the user's home.

This procedure assigns a clearly defined amount of time to each meter in the section to send certain data from its UEP to the respective electronic device that may be installed with the user.

At the end of this procedure (the duration of which is known to the ACS on the basis of the number of users connected to the section), the ACS proceeds to interrogate the master of another section.

A2) The "Master" does not respond, thus permitting the ACS to note that the section is no longer connected to that transformer. In this case the ACS records this information and reverts to "Alarm State" to allow the ACP to record this information and pass it on to the STM in order to update the network connection status.

When an interrogation is sent by the ACS to the master of a known section, by the above background activity, as a section situated at the external periphery of the supplied network, there are two possibilities:

B1) the master does not respond to the ACS, thus confirming that the section is not connected to the transformer.

B2) The master does respond, thus allowing the ACS to note that the section, which was previously disconnected, is now connected to the substation in which the ACS is installed.

Whereas in the former case (B1) the ACS proceeds to interrogate the "Master" of another section, in the latter case (B2) the ACS performs the same operations described in the point A1 to allow transfer of information from each UEP to the respective user device and performs the operations described in point A2 to update the working configuration of the STM. Furthermore, the ACS performs the synchronization of the clocks in the meters within the section, which, for cost reasons, are not provided with a back-up power supply and which therefore loses synchronization when the LV section is transferred from the network supplied by one transformer to the network supplied by another one (this transfer operation, in order to avoid parallel working of the two transformers, requires the section to be deenergized for a short period).

The sub-system for Automation and Remote Control of the MV network will now be illustrated, allowing the following functions:

- Management of network diagrams,
- Network supervision and control,
- Automatic procedures to identify faulty feeder sections and re-supply the healthy ones.

The above functions are carried out using technologically advanced instruments, such as graphic workstations, plotters, colour printers.

The man-machine interaction procedures make use of entirely graphic environment procedures and real-time windows systems to guide the operator through the operations possible at each specific time, and to give instant visualization of changements in progress on the network.

All operations are performed by the operator exclusively using the Mouse, which enables the choice of objects and commands in the on-screen Menus.

The network diagram is managed entirely on-screen by several levels of visualization and the use of "Panning" commands for the positioning on the screen of the desired portion of the diagram.

The symbols used to represent the electrical elements are not the usual ones, but an "ad hoc" series of symbols is used in order to give greater information and to use better the space available on screen.

These symbols are illustrated in figure 2.

More specifically, the MV network is managed by means of the following diagrams:

General network diagram (figure 14). This schematic diagram, which is contained in a single video page, gives a compact illustration of the whole network to be remote controlled, with a simple representation of all the Primary Substations in the Zone. Starting from this page, the operator can select one Primary Substation and request visualization of the topological diagram for the MV network around the substation selected.

Topological network diagram (figure 15). This schematic diagram shows all the secondary substations that are remote controlled, with their respective connections. It is generally an extremely large diagram, which cannot be shown in a single video page, but thanks to the "panning" it is possible to move through it in a continuous manner, visualizing any part of the chart. The topological diagram is the main working base for operation of the network. From this diagram it is possible to operate on the network requesting visualization of line and substation diagrams on overlying windows and so on.

MV feeder diagram (figure 16). This diagram, which is obtained from the preceding one by highlighting the portion of network electrically connected to a specific MV circuit-breaker, is fundamental for feeder boundary changements, network adjustment, manual recovery of service following a fault or an unavailability period. At each point at which it is possible to reenergize a feeder power the directrix, all the information necessary for resupply actions is given. Furthermore, by a suitable compacting algorithm, it is always possible to obtain un-deformed visualization of the whole feeder line, even when the latter is greater than the screen size on the topological diagram.

Feeder section diagram (figure 17): As only remote controlled substations are shown on the topological diagram, it is necessary to have a further level of detail, which can be selected from the topological level. From this schematic diagram it is possible to update information on all the non-remote controlled secondary substations within a section.

The aim of this diagram is to allow manual updating of the information relating to the status of switches that are not remote controlled.

If ACS devices are installed in the substations within a section for remote management of users, thanks to the interrogation of these ACSs by the ACP it is possible to highlight any incongruities between the status of switches deriving by manual updating of the diagram and the connection status of the network deriving from the communication subsystem.

Primary Substation diagram (figure 18): a window containing the typical schematic diagram of a primary substation with the HV/MV transformers, the bus-bars fed by them, and the connected MV feeders.

Secondary substation diagram (figures 19 and 20): by selecting the proper symbol on one of the preceding diagrams, a detailed schematic diagram of that substation can be obtained. This schematic diagram shows all the information relating to the substation itself, and it is possible to send remote commands or perform manual settings of the status of switches or breakers that are not remote controlled.

As well as wiring diagrams, alphanumeric pages are also available, underlining alarm situations and variations in status (as compared with the status considered normal). From these pages it is possible to obtain the diagram of the corresponding electrical element directly, merely by selecting an alarm.

The graphic configuration of any element within the network at any hierarchic level, as well as being simple and quick for the operator to create, involves the creation and automatic updating of the relative structure in the data base in a manner that is totally transparent for the operator, thus making subsequent analytical description of the element itself much easier.

Because of the great frequency of interventions on and changements of the medium voltage network, particular care has been taken to improve the simplicity of procedure, the ease of access to information and the speed with which alterations are carried out.

Changements of network diagram are thus performed "on line", that is to say without interrupting the operation of the System. This is possible as the operations for configuration and modification of the network Data Base are normally carried out on a temporary copy of the data base and then, once congruency tests have been performed, the changements are propagated within the System.

The supervision and control procedures for the distribution network will now be illustrated.

To enable network management from a work station, the latter must be in a "network operation" mode; in this condition there is a reciprocal exclusion mechanism that prevents two stations from operating simultaneously on the same electrical element. This mechanism is activated in two ways:

- The dynamic block: automatically assigning the exclusive ability to operate on an electrical element to the first workstation selecting the command; the block operates from the moment in which the command is selected until it is completed or cancelled.

- Working attribution: assigning the exclusive ability to operate on the whole feeder to a specific workstation. Attribution of a feeder may be determined statically during configuration, or it may be established during normal operation.

The alarms and variations in status that relate to both the MV network and the Primary Substations, are routed to the various workstations, by which they are acquired automatically or manually according to the working attribution; they are then printed on the "Service Protocol" and filed in the mass storage.

By selecting a specific alarm from the alarm pages, the operator can access the diagram for the corresponding electrical element, and then perform whatever adjustment he desires.

In addition to the remote control of circuit-breakers in the Primary Substations and of load breaking switches in the secondary substations, the operator can perform the following:

- request print-outs (in graphic or table form),
- search the data base,
- search the back-up files containing past operating data.

The automatic procedures will now be illustrated for identification of faulty feeder sections line and re-energizing of healthy ones.

In order to guarantee rapid service restoration following any faulty that may occur, including those occurring at times in which the Zone control Center is not manned, STM provides a series of automatic procedures aimed at identification and isolation of the faulty section of line between two remote controlled substations, the re-energizing of the section of the network upstream of the faulty section, and the possible re-energizing of the network downstream of the latter.

As the telecommunications system does not allow exchange of information with the MT circuit-breaker open, the remote terminal unit devices (UPT) have been designed with a high degree of autonomy (automatic rules for opening and closing the switches), giving them the ability to identify and isolate a faulty section of line autonomously.

As the rules for opening the switch are activated on the basis of a lack of voltage on the line and on the bus-bar in a secondary substation, any failure in power supply to a Primary Substation MV bus-bar, should it continue for longer than the time limit set for activation of the above rules, causes the unnecessary opening of all the switches in the remote controlled substations powered by that MV bus-bar.

In order to overcome this problem, the STM is provided with an automatic procedure which, following a loss of voltage on a Primary Substation MV bus-bar, sends a message disabling the automatic rules to all the UPTs involved within the necessary time limit. When the voltage returns to normal, the STM automatically restores the initial status.

In order to perform functions relating to identification of the faulty section correctly, the remote controlled secondary substations must be suitably equipped with voltage detectors (RV) and, in urban underground networks, with devices to sense the passage of fault current (RG).

The RGs to be installed on each cable terminal are made up of a toroidal probe, to be installed around the cable itself, capable of picking up the passage of homopolar currents (caused by phase to earth faults) of an intensity exceeding a certain predetermined level (typically 60 Amp.), and three "maximum current" probes, one for each phase, capable of picking up the passage of short-circuit currents exceeding a certain predetermined level (typically 600 Amp.); this information is passed through small cables and optical fibers to the electronic circuits which, in case of malfunction, cause an optical and an electrical signal (closing of a contact) to be emitted.

For this reason, two different MV fault management procedures have been implemented: one being employed mainly for overhead networks and using RV only, the other employed mainly for underground cable networks and using RG as well as RV.

<u>Procedure for sectionalizing faulty feeder sections</u>

Method of operation of the UPT.

The UPT essentially gives a series of rules for opening and a series of rules for closing the switches. The opening rules have the aim of isolating the malfunction, whereas the closing rules serve to re-energizing the bus-bar in the secondary substation, thus restoring communication.

Each switch is associated to a specific group of rules, which are univocally identified by the type of switch (incoming, outgoing, boundary) and by the type of network, overhead (without RG) or cable (with RG).

The following table illustrates the structure of the various groups according also to the type of switch with which they are associated.

GROUP	RULE		IMS	NETWORK TYPE
	OPENING	CLOSING		
A	Rav_0, Rav_1	Rcv_0	Generic	OVERHEAD
C	Rav_0, Rav_1	Rcv_1	Border	(no RG)
D	Rag_0,Rag_1,Rag_2	Rcg_0	Generic	CABLE
E	Rag_0	Rcg_1	Border	(with RG)

Given that the following terms have the following meanings:

- IMSi, generic motorized load breaking MV line switch
- RVLi, voltage detector associated with the MV line originating at IMSi (RVLi=voltage present on i-th line; $\overline{RVLi}$=current voltage absent on i-th line)
- RVS, voltage detector associated with the MV bus-bar to which IMSi relates (RVS=voltage present in bus-bar; $\overline{RVS}$=voltage absent in bus-bar)
- RGi, fault current detector associated with the MV line from IMSi (RGi = fault current recorded; $\overline{RGi}$ = fault current not recorded)
- Tavn, Tcvn Tagn, Tcgn, times indicating perduration of a condition
- *, AND logic operator.

The following is a description of the rules that the UPT must apply to single switch, to enable them to move autonomously.

<u>Rules for UPT without RG</u>

The **opening rules** that apply for UPT without RG are the following:

Rav0 = $\overline{RVLi}$ * $\overline{RVS}$ * Tav0 ——> open IMSi

Rav1 = $\overline{RVLi}$ * $\overline{RVS}$ * beta ——>

- if the IMS in question was closed with an autonomous command, it is opened first and then all the other IMSs on the bus-bar are opened. A group of rules Z (blockage of all IMS) is associated to all IMSs;

- if the IMS in question was closed with a remote command, it is opened and the group of rules Z (blockage of that IMS) is associated to it.

The condition beta occurs when the IMSi passes from the open state to the closed state in the presence of line or bar voltage, and the condition of lack of line or bar voltage occurs within Tav1 seconds.

The condition beta resets after a local or remote comand closing the IMSi.

The **closing rules** that apply for UPT without RG are the following:

$Rcv0 = RVLi * \overline{RVS} * Tcv0 * delta$,,,,> close IMSi

$Rcv1 = RVLi * \overline{RVS} * Tcv1 * delta$,,,,> close IMSi

The condition delta occurs when all the IMS on the bus-bar are open.

One of the following **groups of rules** can be associated to each IMS in an UPT without RG:

- group "A", made up of rules Rav0, Rav1 and Rcv0
- group "C", made up of rules Rav0, Rav1 and Rcv1
- group "Z", made up no rules (IMS block).

<u>Rules valid for UPTs with RG</u>

The **opening rules** that apply for UPTs with RG are the following:

$Rag0 = \overline{RVLi} * \overline{RVS} * Tag0$,,,,> open IMSi

$Rag1 = \overline{RVLi} * \overline{RVS} * RGi * alpha$,,,,>

- opening of the IMSi and association of the group of rules "Z" to it.

The condition alpha implies that one of the following conditions has been met:

- the UPT receives no reply to the fault interrogation message sent to another UPT;

- the IMS whose RG has sensed the fault has no UPT associated with it.

$$Rag2 = \overline{RVLi} * \overline{RVS} * RGi * gamma \;,,,,>$$

- opening of all the IMS on the bus-bar starting from the one associated to the RG that sensed the fault current, and association of group "Z" to them.

The condition gamma occurs when:

- the RG of all the IMSs, with the exception of the i-th IMS, have sensed the fault current;
- the UPT has transmmitted the message responding to the interrogation received from the preceding UPT.

The **closing rules** that apply for UPT with RG are the following:

$$Rcg0 = RVLi * \overline{RVS} * Tcg0 * delta \;,,,,> \text{close IMSi}$$
$$Rcg1 = RVLi * \overline{RVS} * Tcg1 * delta \;,,,,> \text{close IMSi}$$

The condition delta occurs when all the IMS on the bus-bar are open.

One of the following **groups of rules** can be associated to each IMS in an UPT with RG:

- group "D", made up of rules Rag0, Rag1, Rag2 and Rcg0
- group "E", made up of rules Rag0 and Rcg1
- group "Z", made up of no rules.

For each line IMS in a secondary substation, the configuration message must be sent to the respective UPT. This configuration message contains: the group of automatic rules to be applied, the address of the UPT downstream. Furthermore, the values of the opening and closing time constants must be configured for each UPT.

<u>Startup of the procedure</u>

When final tripping of the MV line circuit-breaker takes place, due to the intervention of one or more protections, STM starts a timer T1, following which it commands the MV circuit-breaker to close. If this operation, which simulates slow re-closing, causes further tripping, then the procedure for sectionalizing faulty section starts.

Sectionalizing faulty feeder section procedure - overhead lines (without RG)

After the time interval T2 from the last trip, during which the UPT opens all the IMSs (application of opening rule Rav1), STM commands closure of the MV circuit-breaker in the Primary Substation.

At this point it is better to differentiate between 4 types of faults, according to their location:

First section fault. The closure of the MV circuit-breaker causes instantaneous tripping of the latter; the System emits the diagnostic "Fault on first section" and terminates the procedure (if possible the automatic re-supply procedure is started).

Fault on the bus-bar of the first substation on the feeder. Closing of the MV circuit-breaker, in this case, gives positive results; STM positions itself to await automatic closure of the IMS entering the first substation (Rcv0).

When this takes place, the consequent tripping of the circuit-breaker will allow the STM to diagnose a "Fault on first substation and, after having waited for T1 seconds, during which time the IMS opens and blocks, to reenergize first section.

Fault on an intermediate section. Closure of the MV circuit-breaker, in this case, has positive results; STM positions itself to await automatic closure of the IMS entering the first substation. When this takes place, connection between the system and the UPT resident within it is restored and the STM starts to re-close the first of the IMS on output from the substation; if no other remote controlled substation is connected to it, the procedure continues to re-close the other IMS adjacent to it on the bus-bar, until another remote controlled secondary substation is re-energized.

At this point the central System once more reverts to standby to await automatic closure of the IMS inputting to the substation. When closure has taken place and after the subsequent recovery of communications between the system and its respective UPT, STM starts a new substation IMS closure cycle using remote commands. At the moment in which a faulty section is fed anew, the MV circuit-breaker trips, and the IMS performing the closing on fault opens and blocks. After T1 seconds STM re-closes the circuit-breaker and renergizes the feeder up to the section immediately upstream of the faulty one. At this point the System, by interrogating the UPT in the substation on which it was operating before the trip and by picking up the open and blocked status of the last IMS handled, emits the diagnostic relating to the faulty section. Then the automatic procedure goes on to re-energize any branches upstream of the fault that may still be without power. (If possible the automatic resupplying procedure is started).

Secondary substation bus-bar fault. The return of voltage on the line supplying a substation causes automatic closure (rule Rcv0) of the IMS inputting to the faulty bus-bar, causing the main circuit-breaker to trip. The IMS in question opens automatically and reverts to block status. After T1 seconds from the trip, STM commands closure of the MV circuit-breaker, reenergizing the feeder and restoring connection between the system and the UPT immediately upstream of the substation in which the fault has occurred.

By interrogating the latter (the UPT upstream of the fault), STM recognizes that the IMS connecting the substation to the one downstream is closed as usual, so that it is not a section fault, which would have cause opening and block of the IMS, but a fault in the downstream substation bus-bar. STM emits the diagnostic relating to the faulty secondary substation bus-bar and the procedure goes on to re-energize any branches that may have been left without power. (If possible the automatic re-supply procedure is started).

For the above, with the exclusion of "The first section fault" and "First substation fault", when the main circuit-breaker trips for closing on fault, STM does not immediately discriminate between a section fault and a substation fault; this will, only be possible after having interrogated the last UPT with which dialogue took place (the UPT upstream of the fault).

In general, an IMS opens and blocks only if the fault is detected within Tav1 seconds from its closure. This characteristic allows the exact location of the fault to be identified (line or bar).

Furthermore, the command to re-close, which is emitted by STM subsequent to the last trip, prevents a transitory or semi-permanent fault that may occur on the feeder during the identification phase, from being mistaken for the permanent fault that has started the procedure.

In fact if, when service is resumed, the STM finds no IMS in block mode, that is to say if no fault has been identified, the procedure continues by feeding the other sections. Naturally the above error would occur in the case of a transitory malfunction occurring within the time Tav1, which, however, is fairly short.
It will now be illustrated an example of procedure for a permanent fault on section "c" of figure 21.

Figure 21a shows a schematic diagram of the overhead network under consideration, energized under normal working conditions by substation CP1 through a MV circuit-breaker I1.

*- The group of rules associated to each IMS is indicated beside the graphic symbol, and causes them to behave as illustrated above.

1) When a fault occurs on section "c", the circuit-breaker I1 opens then performs a rapid re-closure; the fault remains and the trip becomes final.

2) After T1 seconds, STM commands another re-closure, and when this results negative starts the procedure for sectionalizing the faulty section.

3) After a period of time T2 to ensure opening of all the IMS on the feeder (fig.21b), STM sends a command to close I1 and awaits the result of it.

4) As the first section of line is healthy, the remote closing command is performed correctly and the System waits for the IMS entering CAB1 to close automatically (applying rule Rcv0).

5) After the required time has passed, the IMS results closed and transmission connection restored; STM starts to talk to UPT1 and thus acquires the actual closed status of the switch moved (Fig.21c).

6) STM commands closure of the first IMS in output (IMS2) and awaits performance of the remote command.

7) The System interrogates the UPT again to check that the manoeuvre has been performed successfully.

8) Having checked that IMS2 moves correctly, STM sends the command closing the next switch IMS3 and awaits execution of the remote command.

9) The System interrogates the UPT again to check that the manoeuvre has been performed successfully, then, as IMS3 covers a remote controlled substation, the system starts a timer to await closure of the ingoing switch in CAB2.

10) Afterwards, STM interrogates the UPT in CAB2 to check that the incomming IMS has been closed and to command closure of the outgoing one.

11) Having checked that IMS1 moves correctly, the command closing IMS2 (in CAB2) is emitted, and STM begins to await the result of the remote command (Fig.21d).

12) Consequent closure on the faulty section causes: tripping of circuit-breaker I1 and opening and blocking of IMS2 in CAB2. Folling this event a timer

T1 starts (Fig.21e).

13) When timer T1 runs out, because of IMS2 in CAB2 is open and blocked, STM can re-close I1.

14) Following positive closure of I1, STM interrogates the UPT of CAB2 again on the present status of the switches. Having picked up the open and block of IMS2, the STM emits the diagnostic "Fault on line C" and returns to CAB1 to close IMS4 which is still open.

15) Having emitted the command closing IMS4 of CAB1, the process awaits closure of the IMS entering CAB5 (Fig.21f).

16) Once correct closure of IMS1 in CAB5 has been checked, STM emits the command closing IMS2.

17) Once closure of IMS2 in CAB5 has been checked, STM awaits closure of IMS1 of CAB6, and when this has occurred also closes IMS2 using a remote command.

18) The process terminates, or the process for re-energizing CAB3 is started if the required conditions have been met.

<u>Sectionalizing faulty feeder section procedure - underground cable (with RG)</u>

On start-up of the procedure, with no voltage on the line, a waiting time is set up, during which the UPTs interrogate each other in cascade to identify the fault and open the IMS isolating it.

At the end of this time, the STM commands closure of the main switch and re-energizes the working sections of the feeder (unless the malfunction is in section I of the line).

Generally speaking, three types of fault can be distinguished:

<u>Fault on first section</u>. Closure of the MV circuit-breaker causes instantaneous tripping of the latter; the System emits the diagnostic "Fault on first section" and terminates the procedure (if possible the automatic re-supply procedure is started).

Fault on an intermediate section. Closure of the MV main switch, in this case, has a positive effect, and allows the STM to communicate with the UPTs and therefore to emit the signal indicating the section in which the malfunction has occurred. In fact, the interrogation sequence sent to the UPTs regarding the status of the various IMSs will underline a situation in which one switch is found to be open, whereas the same switch was not open just before the fault occurred. STM therefore emits a diagnostic identifying the fault on the section downstream of the above switch.

Secondary substation bus-bar fault. On service restoration, STM starts to dialogue in cascade with the feeder UPTs. One UPT does not respond, in spite of the fact that the IMS feeding it in the preceding remote controlled substation is closed. The system signals the presence of the fault on the bus-bars of the substation corresponding to the un-reachable UPT.

As an example, the procedure will be illustrated for a permanent fault on line "c" of figure 22.

Figure 22a shows the network under consideration, supplied under normal conditions by substation CP1 through the MV circuit-breaker I1.

The group of rultes associated with each IMS is indicated beside the graphic symbol, and causes them to behave as illustrated above.

1) When the malfunction occurs on line "c", the fault detectors RG1 and RG2 of CAB1, RG1 and RG2 of CAB2 switch to "On", then the line protections cause the circuit-breaker I1 to trip, opening the line.

2) STM starts a timer with a duration T1, following which the circuit-breaker will be re-closed (Fig. 22b).

3) After a time Tin from loss of voltage, UPT1, which knows itself to be the first on the feeder, sends an interrogation message GI to the UPT downstream of

the outgoing line on which the RG is in "on" state (UPT2).

4) UPT2, having received the interrogation message, responds with RGR, thus confirming the "On" status of one of its RGs. After sending the message RGR to UPT1, UPT2 in turn sends an RGI to UPT3.

5) UPT3, which has no RG in "On", does not respond (or else the fault prevents transit of messages on the section).

6) UPT2, upon failing to receive a response, understands that the fault is on the section downstream of its own IMS2, opens it and sets it to blocked mode (Fig. 22c).

7) After timer T1 has passed, STM re-closes I1 and the line is re-energized up to CAB2. Return of voltage for a sufficiently long period of time produces "Reset" of the RGs in the re-energized substations (Fig. 22d). By interrogating UPT2, STM picks up the open and blocked status of IMS2 and diagnostics a fault in section "c".

Automatic re-supply procedure

If the structure of the electrical network and the current capacity of the conductors allows it, once the section or substation that is faulty has been isolated, a procedure for re-supply of the healthy sections downstream of the fault can be started.

This is possible because the IMS (normally open), which is the boundary between the feeder containing the fault and that adjacent to it, is provided with an automatic rule that causes it to close if there is a loss of voltage lasting for a determined period of time.

When this interval of time (which is calculated in such a way as to ensure completion of the procedure for sectionalizing of the faulty section described above) has passed, closure of this IMS re-establishes data connection with the boundary substation and the consequent ability of the STM to re-energize all the working section of line downstream of the fault by an iterative process.

In effect, the remaining IMS on the bus-bar of the boundary substation are re-closed by means of remote commands. Those in input into the next substation, which close again thanks to one of the automatic rules, in turn restore connection to the respective UPT and allow the procedure to be repeated up to the section or substation immediately preceding the malfunction.

The subsystem for remote management of Medium Voltage and Low Voltage users will now be illustrated.

The subsystem in question allows remote management of both LV and MV users, thus making it possible to carry out a series of operations that would normally be carried out on site by specialized staff.

With this aim, new metering units provided with the electronics required to support this application, have to be installed for all MV and LV users.

These metering units, at least for the present, use conventional electro-mechanical technology (Ferraris meter) for measurement of energy and only use electronic digital technology for the additional functions, which are therefore performed by an electronic device, closely connected to the meter. This hybrid solution has the advantage, with respect to a fully electronic solution, of preserving measurement of overall energy consumption in case of failure of the electronic device.

On the other hand the solution chosen is open to the future introduction of electronic meters, once these have reached a level of reliability and cost comparable with those of the Ferraris meters.

The solution used in our "Integrated Metering Apparatus" integrates all the necessary components in a single case, which is completely closed and sealed and made of plastic reinforced with fiberglass.

With reference to the two main categories into which users are divided, these components are the following:

* For mass users, that is to say domestic and residential LV users:

- a meter for measurement of active energy

- a thermomagnetic circuit breaker to protect the upstream circuit (and to limit the maximum demand below the contractual value when the electronic unit is not installed in the meter)

- an electronic unit for data processing and communication.

* For large LV users and for all MV users:

- two meters, to measure active and reactive energy

- one electronic unit for data processing and communication.

The electronic units.

For transmission of the consumption data indicated on the Ferraris meter to the electronic unit inside, each meter is provided with the following (figure 16):

- one sector wheel to generate the count pulses;

- two optical fibers to transport light from one end of an optical connector to the sector wheel, and from the latter to the other end of the optical connector;

- an optical connector, installed on the surface of the case, towards the corresponding connector on the electronic unit.

The sector wheel is mechanically connected to the shaft of the meter and its perimeter is divided into a certain number of sectors, alternately filled in or empty, so that they are either completely transparent or completely opaque under incident light.

One end of each optical fiber is fixed in correspondence with the edge of the wheel, in a face-to-face configuration, whereas the other end is connected to the connector.

The light beam, generated by a photo-electric emitter installed in the electronic unit, is carried to the edge of the sector wheel through one of the two optical fibers, either passing through or not passing through the wheel, according to the position of the sectors.

When the light beam crosses the wheel, it is picked up by the other optical fiber, which carries it to the other end of the connector and from there to a photo-receiver, likewise installed in the electronic unit next to the photo-emitter.

In this way light pulses are produced, each one of which corresponds to a clearly defined amount of energy made independent by the constant of the meter in an appropriate design of the activating mechanism and of the sector wheel.

Thanks to the system described above, only passive, highly reliable elements are installed within the casing of the meter, while active elements are positioned inside the electronic unit.

The categories of user in an electric utility, the various types of Integrated Metering Apparatus and the corresponding electronic units are illustrated in figure 17 according to the subscribed demand.

The main categories into which users of a generic electric utility can be divided are the following:

- domestic and residential LV users with a subscribed demand not exceeding 15 kW: this category makes up the majority of the utility's users.
- large LV users with a subscribed demand over 15 kW and MV users.

Domestic and commercial LV users.

The following types of Integrated Meters have been developed:

- single-phase users: GMY (figure 18)
- three-phase users: GTY (figure 19)

The thermo-magnetic circuit-breakers installed inside the GMY and GTY are original products, designed to satisfy the following needs:

- limitation of the power available to the user by means of the thermal relay of the circuit-breaker when the apparatus operates without an electronic unit (in this case the apparatus must be chosen according to the power subscribed;

- elimination of intervention by the thermal relay once the electronic unit has been installed, and activation of the trip pulse emitted by the electronic unit when the power level exceeds the set value (in this case the apparatus no longer refers to the power level subscribed by the user).

- As stated above, this value can be changed from a remote center following variation of the contract, emergency in the supply, etc.;

- activation of a continuous trip signal emitted by the unit, which prevents the user from closing the circuit-breaker, should supply cease or should there be an excessive delay in payment.

With reference to the latter two functions, the circuit-breaker has been provided with a tripping coil which allows it to be controlled by the electronic unit. The electronic unit is the same both for the GMY and for the GTY, but it has been made in two different versions called UEP and UEPR (reduced UEP).

The UEP is used in an Integrated Metering Apparatus when the latter is installed inside the user's premises, whereas the UEPR is used in an Integrated Metering Apparatus when the latter is installed on a central board (on the same panel, which is usually situated on the ground floor of the building, it is possible to install up to 24 meters). In case of installation in a central board, the functions of the electronic unit are grouped in a single unit (UEPC) which performs these functions for all the apparatus on the board. The photo-emitter and the photo-receiver for generation and pick-up of the optical signals and the final relay to trip the circuit-breaker are the only components inside the UEPR, which is thus an extremely low-cost unit. Consequently, the overall cost of application of the automatic system, when the apparatus are installed on a central board, is much lower than in case of single installations. Figures 20A and 20B show how an UEP or an UEPR can be inserted from the back of a GMY, and how the GMY itself can be installed on the central board. Figure 21 shows a central board with an UEPC serving all the metering apparatus on the board.

As regards large "Low and Medium Voltage" users, the following Integrated Metering Apparatus have also been developed:

- GTWD for LV users with a subscribed demand between 15 and 30 kW (direct connection)
- GTWS for LV users with a subscribed demand between 30 and 250 kW (in this case current transformers are necessary for connection);
- GTWM for MV users (in this case current transformers and voltage transformers are necessary for connection).

These apparatus are illustrated in figures 22, 23 and 24, respectively; although their cases differ in certain points, they are obtained from the same mold.

The current transformers required for the GTWS apparatus are the same for the whole range of use, from 30 to 250 kW; they are housed in the case illustrated in figure 25, on which the apparatus is installed by means of plug connectors.

The above case houses four current transformers (TA) instead of the three that are strictly necessary (one TA is also inserted on the neutral conductor) in order to detect any fault that can be detected from the imbalance of the four secondary currents.

The voltage and current transformers required for the GTWM apparatus use a single voltage ratio and four current ratios, and can be used to cover the whole field of use of the apparatus on ENEL's MV networks, with nominal voltages between 10 and 20 kV.

The current and voltage transformers can be installed in two different types of housing: the first is an air-insulated compartment, the second is an SF6-insulated box (figure 26).

The air-insulated compartment comprises the coupling device for transmission of high-frequency signals from the electronic unit to the MV network, whereas in the SF6-insulated box this device is inserted externally by a plug connection, to allow easy replacement in case of malfunction.

For the MV users, three current transformers are used instead of the two that are strictly necessary, in order to detect malfunctions using a device that is sensitive to imbalance in the three secondary currents; malfunctions of voltage transformers, on the other hand, are detected by comparing the peak values of the two voltages measured.

In case of fault in a measuring transformer, an alarm is immediately sent to the center by means of the electronic unit.

The electronic units used in these apparatus are the following:

- UEPB both for GTWD and GTWS;
- UEPM for GTWM.

As in neither of these cases does ENEL own a switch in the supply board, the electronic units are able, in an emergency, to send a trip signal to the user's switch.

The available functions will now be illustrated as an example.

By means of the sub-system for customer service automation it is possible to perform the following operations from a remote location:

Remote reading of metering apparatus. Once a day, starting for example at 00.00, each ACS interrupts its background activity described above, and starts a new polling procedure consisting in the reading of data recorded by all the meters fed by a transformer, in order to acquire the following:

- diagnostic information on the meters themselves;
- data consumption from meters for which the invoicing period has terminated at midnight of the previous day;

The messages from the LV meters are temporarily stored in the ACS, from which they are then picked up by means of another procedure, parallel to the first one, carried out by the ACP on the ACS under it; the ACP in turn sends the data to the Central system. The latter retains the data with which it is concerned and, by means of the packet switching network, sends those relating to consumption to the Host Computer in the commercial department for invoicing.

Application of time of day tariffs: by means of the new meters it is possible to apply time of day tariffs to all users, both LV and MV, and to carry out remote modification of the structure and parameters of these tariffs.

Modulation of the power level available to the user: by means of a suitable parameter K, which can vary between 0 and 1, it is possible to modify the power level available to the user, reducing it to a vital minimum level in emergency power supply situations, or even to zero if payments are in arrears or upon termination of contract.

Remote modification of contractual parameters: all contractual parameters, and in particular the set value of power can be modified from a distance.

The above procedures are performed by the System in the following manners.

When the Host Computer dedicated to commercial procedures receives a request from a user that involves modification of certain pre-set values within the meter (variation of power supply level, termination of contract, etc.), it sends this request to the Distribution Automation System, where the changements are performed.

The latter converts the user identification code used by the Host Computer into the actual address used by the Distribution Automation System, then it adds the routing data on the basis of information continually updated by the STM.

The message is sent to the meter, which confirms correct acquisition of the request; in exceptional cases on the LV network, the message might require a number of attempts before reaching destination, or it might even be delayed by several hours in order to await better conditions for transmission.

Thus, immediate acquisition of the command cannot always be guaranteed; for this reason the procedure allows an execution time to be associated to each command. This time normally is chosen sufficiently far from the time of transmission.

Communication between the LV meters and the MV/LV substation causes a flow of signals which propagates on the wires and can be received inside the user's home through a special "User Terminal" (TU).

The communication protocol, together with the cyclic sequential polling, allows the channel to be shared by all the transmitters, that is by all the LV meters supplied by the same substation.

In this way the information relating to one user can be refreshed at an acceptable rate for practical use.

An adequate choice of data creates a powerful interface that can have an important role in load control and in energy saving in a program for automation of the home or building.

The flow of information from the electric utilities is shown in a manner that is easily comprehensible to the user, and can be used for fairly sophisticated control of the load performed by the home Automation system. Furthermore, as the connection is potentially bidirectional, these services can be further extended.

It must be noted that construction details relating to the metering groups and the necessary structures are described in detail in the Italian patent application No. 47576A/90, filed on 26 January 1990 in the name ENEL - Ente Nazionale per l'Energia Elettrica.

CLAIMS

1. A system, making use of high frequency carrier currents over the medium voltage and the low voltage electricity distribution networks, according to a method characterised in that:

- the choice of the frequencies and the transmitted power has been made in such a way that the signal does not overcome the transformers and the open switches, so as to confine itself within the range of each radially operated MV and LV distribution networks;

- the signal is injected or picked up in the HV/MV and MV/LV substations through capacitive couplings implemented in various ways on the bus-bars or on the transformers;

- no high frequency traps and by-passes are required, which makes it possible to use the existing networks without any substantial change or modification;

- the messages can be routed to their final destination on the MV network through intermediate substations and on the LV network through intermediate customer meters which receive and retransmit the messages, thus reducing the length of the transmission spans and hence improving the quality of the transmission (store and forward procedure).

2. A system according to claim 1, wherein use is made of a method of addressing and routing the messages to their final destinations which allows the concentration of all the customer data in the central intelligence of the system, thus avoiding the installation and updating of large data bases in the distributed intelligence; this being achieved by the implementation of a system where:

i) the intelligent apparatus installed in the MV/LV substations (ACS) contains only the information regarding the physical structure of the LV network defined by the set of sections which may be fed by the substation and by the possible interconnections among them, this section being a part of an LV line which does not include any switching device, so that all the customers connected to the same section are fed at any moment by the same substation;

ii) the operating address of the LV customer meters is given by a code composed of the address of the section and of the progressive number of the meter within the section;

iii) the ACS makes a cyclic interrogation of one meter per each section (the meter having the progressive number one) and on this basis is able of knowing and updating in the central intelligence of the system the state of the connections of the LV network;

iv) the intelligent apparatus installed in the HV/MV substations (ACP) contains the information regarding the physical structure of the MV network which may be fed by the substation, performing in respect of the MV network in a way which is analogous to the one above described in respect of ACS;

whereby on the basis of the cyclic activity performed by all ACSs in the MV/LV substations and by all ACPs in the HV/MV substations, the central intelligence of the system knows at any moment the state of connection of the networks and is therefore able to establish the route to any node of the system, both substations and MV and LV customer meters.

3. A system according to claims 1 and 2, characterised in that means are provided by which it is able to give to the central intelligence of the system and hence to display to the operator the real time situation of the connections in the MV and LV networks including the sections of the LV networks which are out of service.

4. A system according to claims 1 and 2, characterised in that means are provided to render it capable of performing the automatic separation of the parts of the MV network which are affected by a fault, in

a way which is not sensible to the loss of the data transmission link on the faulty line, the system being arranged so that it can be implemented into two different ways:

- the first one needs only voltage detectors on the terminals of the MV lines in the MV nodes, but requires one further very short outage to select the faulty section, before the final restoration of the service;

- the second one needs both voltage and fault-current detectors on the MV line terminals in the MV nodes but does not require any further interruption before the restoration of the service;

the same system also being able to perform, in an automatic way not sensible to the temporary loss of the data transmission link, a sequence of switching operations on the MV network, leading to a different configuration of the network fed by the various HV/MV substations.

5. Electricity metering apparatus useful as terminals of the system in correspondence of the customers, of various types according to the supplied voltage, the type of connection (direct or through measuring transformers, three-phase or single phase), and the maximum power demand subscribed by the customer; this being valid both for the hybrid solution where the traditional functions are accomplished by an electronic unit inserted into the meter case, and for the entirely electronic solution where also the measuring functions are performed by electronic means, so that the arrangement is in no way limited to the hybrid solution but may be equally applied to entirely electronic metering apparatus;

the LV metering apparatus being optionally equipped with a circuit breaker located in the same case as the meter; the circuit breaker being linked with the electronic unit from which it can receive a tripping command.

6. A system arranged to perform the following

functions related to the management of the metering apparatus of the customers as described in the previous claim:

i) remote reading of consumption data also related to multi-rate tariffs;

ii) remote modifications of the characteristics of the multi-rate tariffs;

iii) automatic recording and transmission to the centre of data related to the quality of service and characteristics of supply, such as number and duration of outages, maximum power supplied in a certain period;

iv) energy balance between the energy supplied at various points of the system such as by the HV/MV transformers or the MV/LV transformers and the energy sold to the customers supplied by the same points of the system, this method having the capability to be used to detect losses and electricity frauds;

v) identification of the supplying phase for single phase consumers;

in the case of metering apparatus also being equipped with a circuit breaker which can receive a tripping command from the electronic unit, the further following functions being performed as follows:

I) modulation of power available to the user according to the different hours of the day or seasons in the year, to take account of the different availability of power;

II) remote cut off of the supply in case of termination of contract;

III) remote cut off of the supply or reduction to a vital minimum in case of payments in arrears;

IV) reduction or cut off of the power available to the user during periods of emergency as a consequence of faults on the electric system.

7. A system according to claims 1 and 2 built over the electricity networks, to perform also network control functions and remote reading of meters for the benefit of

other Utilities such as water, gas, district heating and similar centralized supplies of goods.

8. A user terminal to be installed in the customer premises which gives to the user the data relevant for optimizing its demand and other data regarding its commercial transactions with the Utilities; this terminal for domestic users being adapted to be installed inside the TV set and arranged to make use of the CRT of the set to display the data.

9. A gas insulated apparatus containing measuring transformers and an earth device for use at the point of connection of the MV customer to the network, wherein:

the power cables arriving from the Utility, those departing towards the user as well as the coupling device under claim 11 are plugged into the apparatus;

redundancies being built in the apparatus, so that a fault on any component can be immediately detected and the relative information transmitted to the centre, via the transmission system described according to the above claims; this leading to advantages which are related to reduced space, ease of installation and hence the reduced time required for the installation, the high reliability and security towards any possible error of insertion and towards the electricity frauds.

10. An apparatus containing current measuring transformers for use at the point of connection to the network of the LV customer, with relatively high value of subscribed power, wherein:

the power cables arriving from the Utility go through the apparatus in appropriate channels and then are connected to the user's cables; inside the apparatus, in correspondence of the channels, toroidal type current measuring transformers are placed, and the metering apparatus as described under claim 6 is directly plugged onto the front of this apparatus so that the two together constitute a robust set;

four current transformers being included in the apparatus, on each phase and on the neutral conductor, so that a fault on any transformer can be immediately detected and the relative information transmitted to the centre, via the transmission system described under the above claims; the advantages being related to the reduced space, the easy installation and hence the reduced time required for the installation, the high reliability and security towards any possible error of insertion and towards the electricity frauds.

11. A capacitive coupling device used to inject and pick up the signal on the MV lines, composed of a capacitor, a tuning reactance and a transformer, all immersed in oil and placed inside an insulated case, the device being arranged so that it may be plugged into the apparatus described under claim 9 or into an MV/LV transformer suitably equipped with sockets.

12. The ACP apparatus, which is the intelligent node of the data transmission system in the HV/MV substations, performs functions of surveillance over the MV network and is the link between the centre and the MV and LV networks fed by the HV/MV substation.

13. The ACS apparatus, which is the intelligent node of the data transmission system in the MV/LV substations, and that is arranged to perform functions of surveillance over the LV network and constituting the link between the ACP under the above claim and the LV customer meters fed by the MV/LV substation.

14. The remote terminal unit (UPT), which is the intelligent interface in the MV/LV substations between the data transmission system and the MV switchgears to which is connected by a standard cabling system, and that further than originating the opening and closing commands, it implements also a set of rules, recorded in its memory, which complement the orders coming from the center, so allowing the operation of the electric system during the loss of the communication link caused by a fault.

15. The multi-function portable terminal (TEM), which is the intelligent interface between the operator and all the apparatus and units of the system (ACPs, ACSs, UPTs, UEPs, the coupling device and the central units) for their initialization, testing, manual data collection, so that the same terminal is the key of access to whatever part of the system; they are of economical, organizational and practical nature.

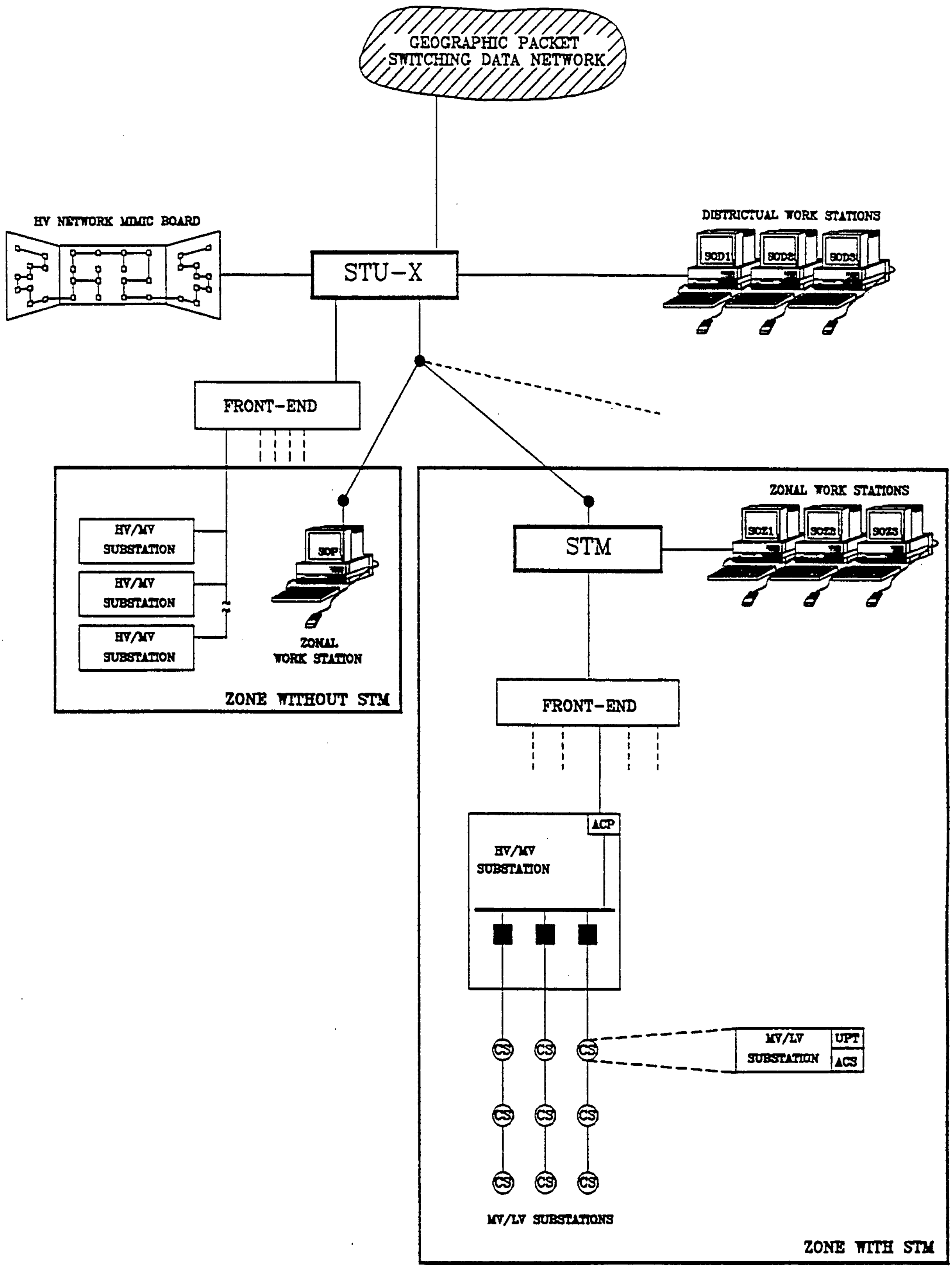

GEOGRAPHIC PACKET SWITCHING DATA NETWORK
HV NETWORK MIMIC BOARD
STU-X
DISTRICTUAL WORK STATIONS
SOD1
SOD2
SOD3
FRONT-END
HV/MV SUBSTATION
HV/MV SUBSTATION
HV/MV SUBSTATION
SOP
ZONAL WORK STATION
ZONE WITHOUT STM
STM
ZONAL WORK STATIONS
SOZ1
SOZ2
SOZ3
FRONT-END
ACP
HV/MV SUBSTATION
CS
MV/LV SUBSTATION
UPT
ACS
MV/LV SUBSTATIONS
ZONE WITH STM

FIG. 1

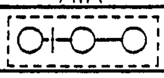
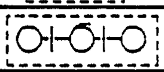
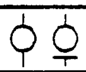
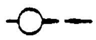
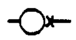
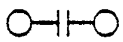
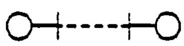
SYMBOLS	MEANINGS
○ (bold)	REMOTE CONTROLLED MV/LV SUBSTATION
○	NOT REMOTE CONTROLLED MV/LV SUBSTATION
□ ■	REMOTE CONTROLLED CIRCUIT-BREAKER (OPEN, CLOSED)
	NOT REMOTE CONTROLLED CIRCUIT-BREAKER (OPEN, CLOSED)
[I]	NOT AVAILABLE CIRCUIT BREAKER (PERMANENTLY)
[X]	NOT AVAILABLE CIRCUIT BREAKER (TEMPORARILY)
	TRANSFER CIRCUIT-BREAKER
	CIRCUIT-BREAKER IS NOT IN NORMAL STATE (RED COLOURED)
	OVERLOADED FEEDER BAY (BLINKING OF FEEDER NAME)
	MV/LV SUBSTATION WITH 3 BUSBARS AND A CLOSED BUSBAR COUPLER SWITCH
	MV/LV SUBSTATION WITH 2 BUSBARS AND CLOSED BUSBAR COUPLER SWITCH
	MV/LV SUBSTATION WITH 3 BUSBAR AND COUPLING AUTOTRANSFORMER
■	ANOMALY ON A SUBSTATION OR ON A FEEDER SECTION
Ⓟ	TEMPORARY MV/LV SUBSTATION
	POLE MOUNTED SWITCH (CLOSED/OPEN)
	THE CLOSED RIGHT SWITCH IS NOT IN NORMAL STATE
	THE OPEN RIGHT SWITCH IS NOT IN NORMAL STATE
	THE STATE (OPEN/CLOSED) OF THE SWITCH IS NOT KNOWN
	ALARM (BLINKING OF THE ELEMENT)
———	ENERGIZED FEEDER SECTION
	DEENERGIZED FEEDER SECTION
-·-·-·-·-	DATA FROM THE FIELD ARE NOT MATCHED WITH THE STATUS OF THE FEEDER
	FEEDER SECTION HAS BEEN DISCONNECTED IN ONE POINT
	FEEDER SECTION HAS BEEN DISCONNECTED IN SEVERAL POINTS
	FEEDER SECTION HAS BEEN DISCONNECTED AT ONE END
	BRANCH POINT
	END NODE

FIG. 2

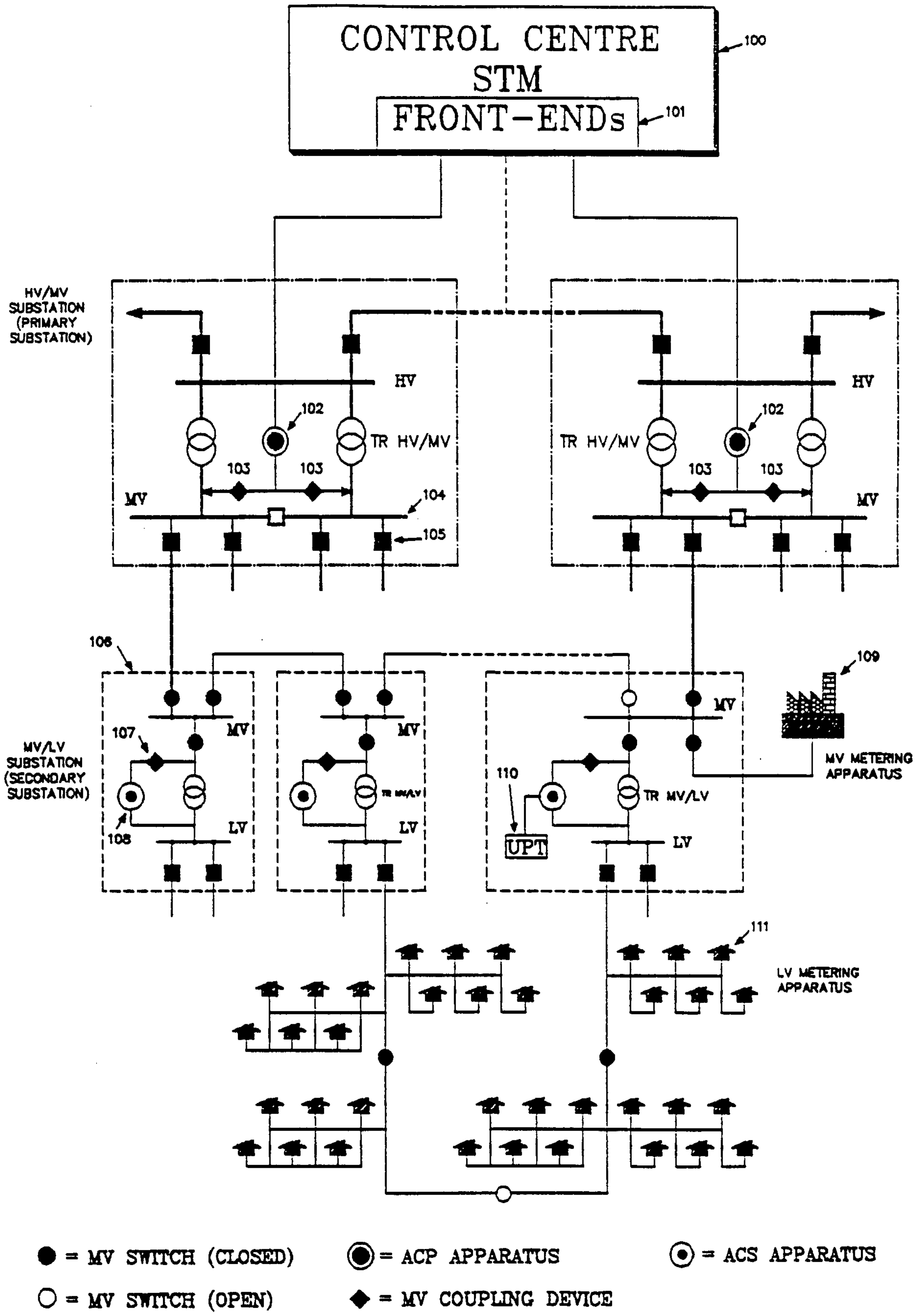
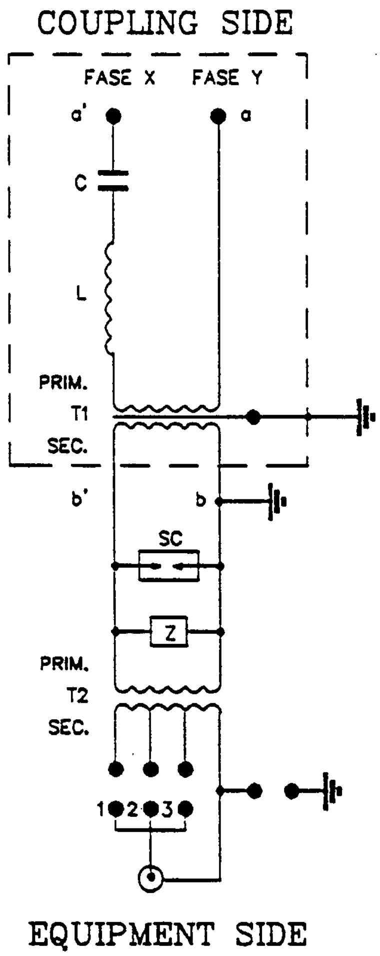

CONTROL CENTRE
STM
FRONT-ENDs
100
101
HV/MV SUBSTATION (PRIMARY SUBSTATION)
HV
102
TR HV/MV
103
103
MV
104
105
106
MV/LV SUBSTATION (SECONDARY SUBSTATION)
107
108
MV
LV
TR MV/LV
110
UPT
109
MV METERING APPARATUS
111
LV METERING APPARATUS
● = MV SWITCH (CLOSED)
○ = MV SWITCH (OPEN)
= ACP APPARATUS
◆ = MV COUPLING DEVICE
= ACS APPARATUS

FIG. 3



C : COUPLING CAPACITOR
L : TUNING COIL
T1 : COUPLING TRANSFORMER
SC : LIGHTING ARRESTER
Z : BALANCE IMPEDENCE
T2 : IMPEDENCE TRANSFORMER

FIG. 4

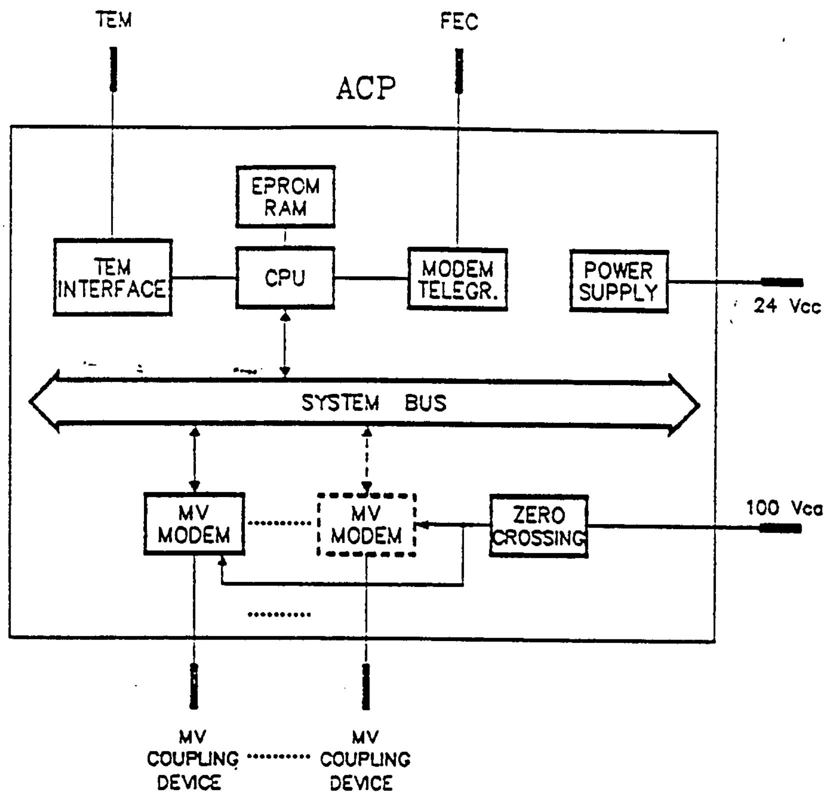

TEM
FEC
ACP
EPROM RAM
TEM INTERFACE
CPU
MODEM TELEGR.
POWER SUPPLY
24 Vcc
SYSTEM BUS
MV MODEM
MV MODEM
ZERO CROSSING
100 Vca
MV COUPLING DEVICE
MV COUPLING DEVICE

FIG. 5

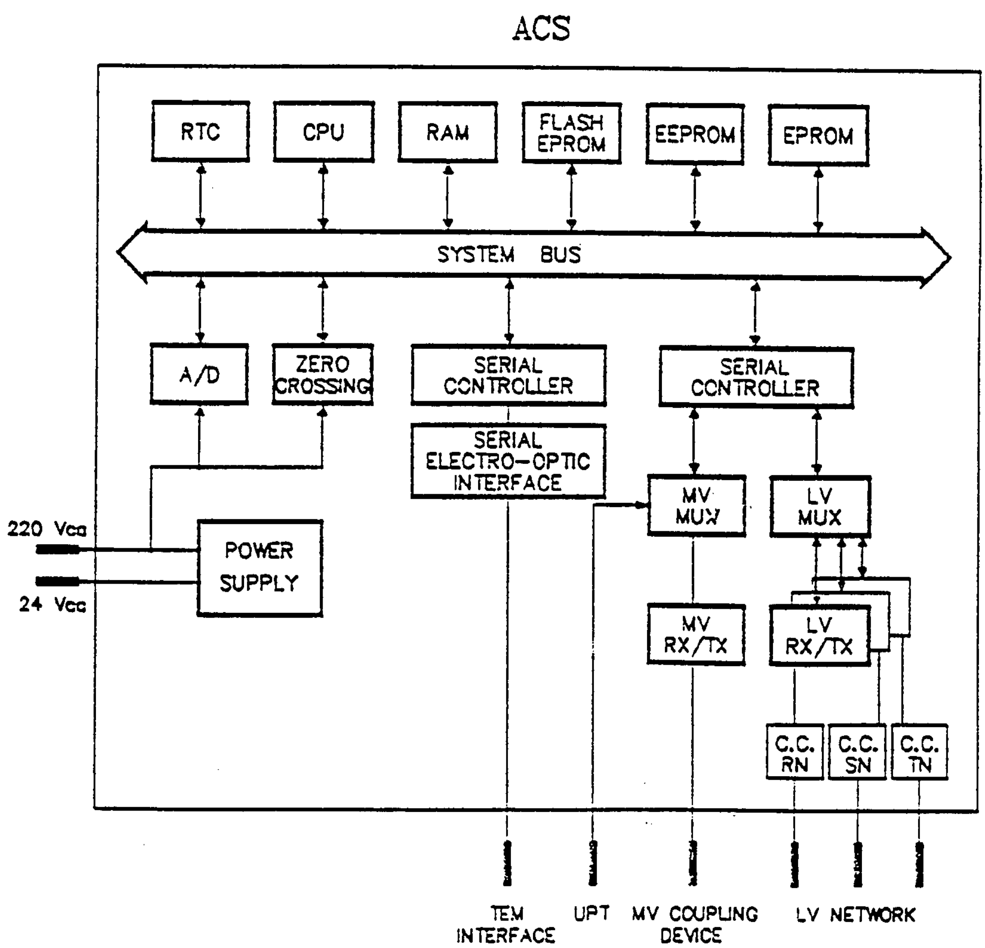

ACS
RTC
CPU
RAM
FLASH EPROM
EEPROM
EPROM
SYSTEM BUS
A/D
ZERO CROSSING
SERIAL CONTROLLER
SERIAL CONTROLLER
SERIAL ELECTRO-OPTIC INTERFACE
MV MUX
LV MUX
220 Vca
24 Vcc
POWER SUPPLY
MV RX/TX
LV RX/TX
C.C. RN
C.C. SN
C.C. TN
TEM INTERFACE
UPT
MV COUPLING DEVICE
LV NETWORK

FIG. 6

UPT

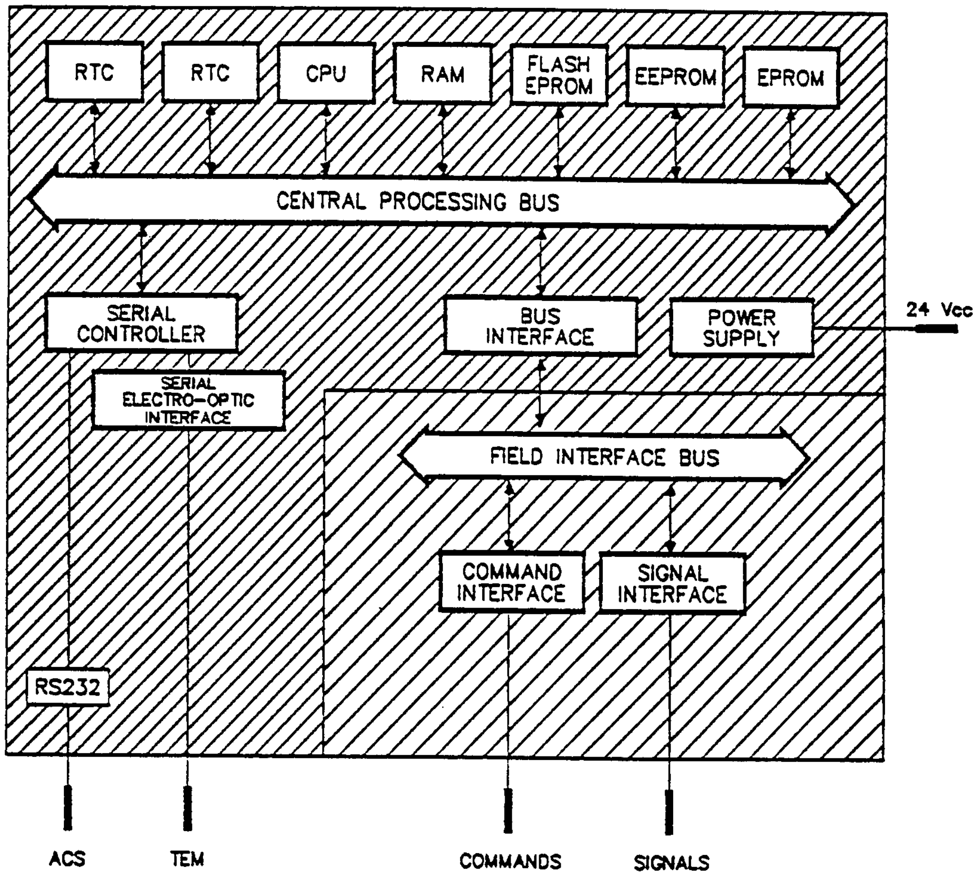

RTC
RTC
CPU
RAM
FLASH EPROM
EEPROM
EPROM
CENTRAL PROCESSING BUS
SERIAL CONTROLLER
BUS INTERFACE
POWER SUPPLY
24 Vcc
SERIAL ELECTRO-OPTIC INTERFACE
FIELD INTERFACE BUS
COMMAND INTERFACE
SIGNAL INTERFACE
RS232
ACS
TEM
COMMANDS
SIGNALS

FIG. 7

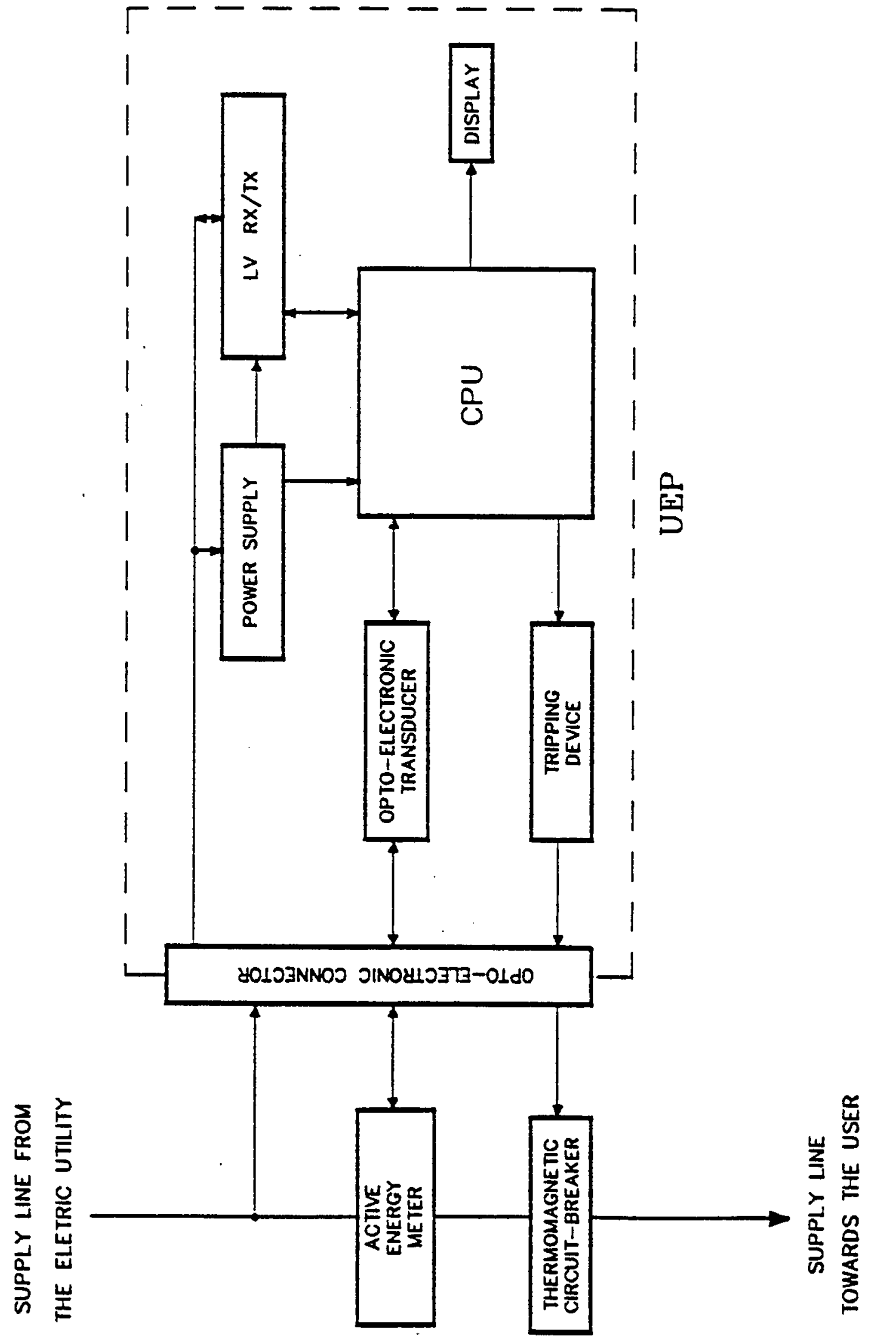

SUPPLY LINE FROM
THE ELETRIC UTILITY
ACTIVE
ENERGY
METER
THERMOMAGNETIC
CIRCUIT–BREAKER
SUPPLY LINE
TOWARDS THE USER
OPTO–ELECTRONIC CONNECTOR
POWER SUPPLY
LV RX/TX
CPU
DISPLAY
OPTO–ELECTRONIC
TRANSDUCER
TRIPPING
DEVICE
UEP

FIG. 8

TEM

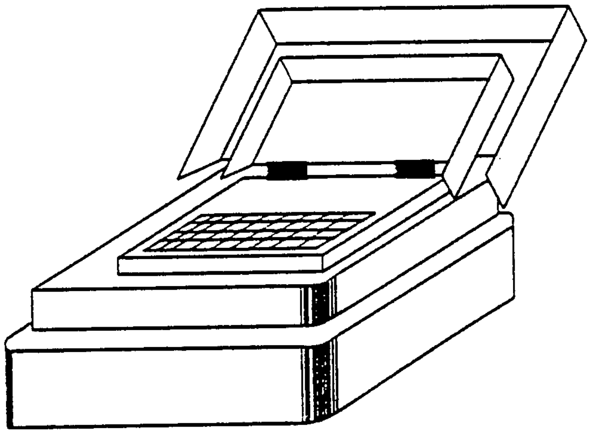


FIG. 9

TEM

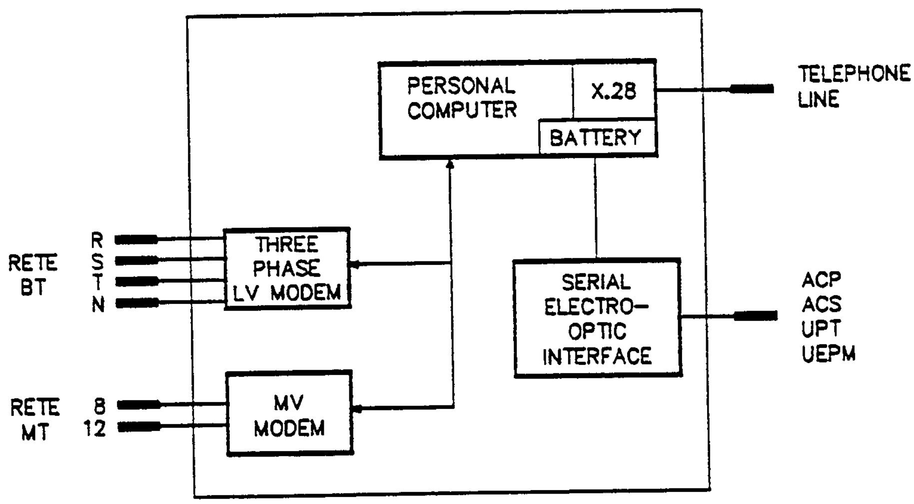


FIG. 10

LV NETWORK DIAGRAM

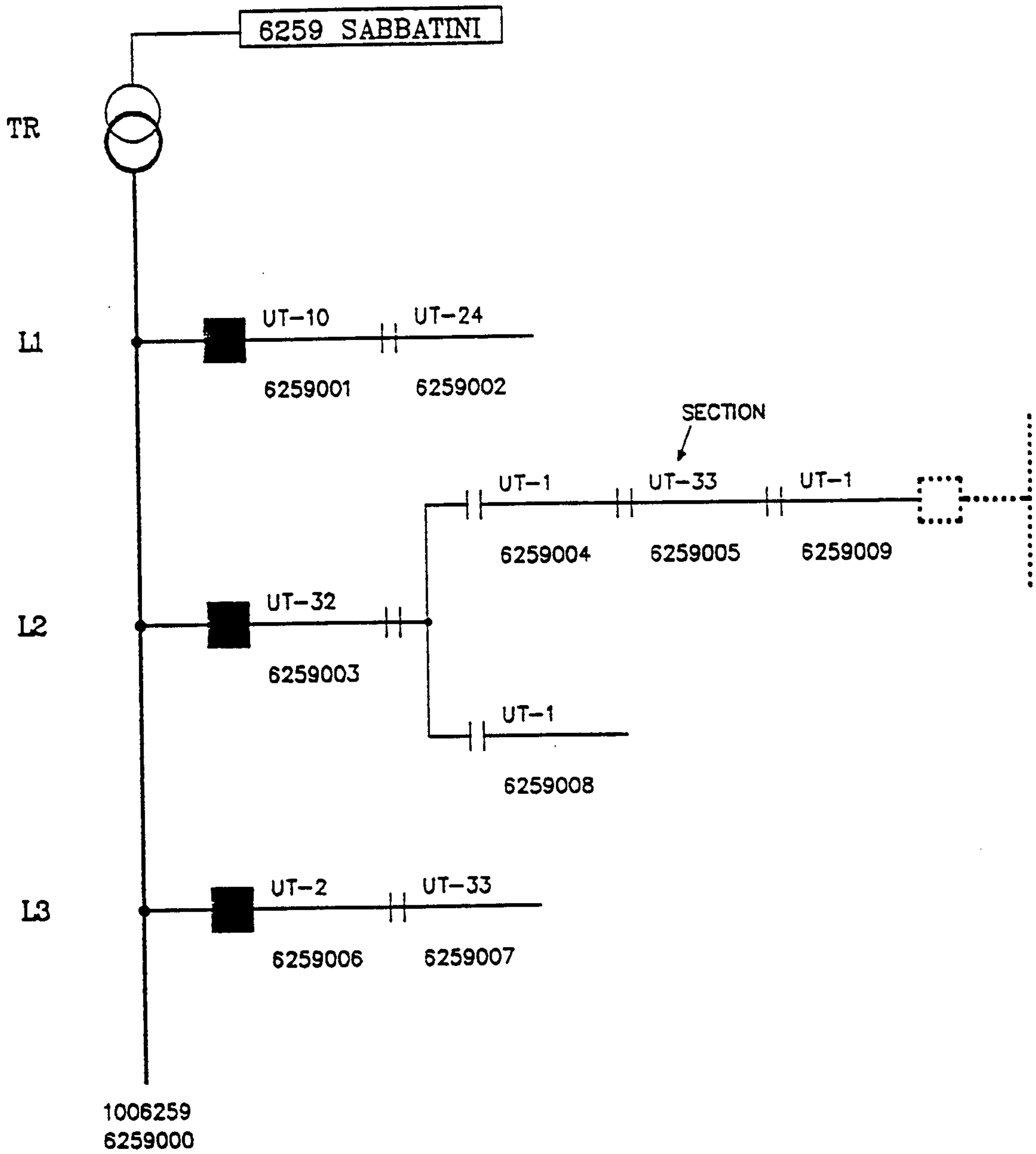
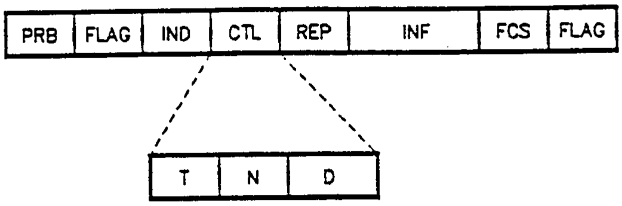


FIG. 11



PRB : PREAMBLE
FLAG: FLAG
IND : ADDRESS
CTL : CONTROL
REP : RELAYING PARAMETERS
INF : INFO
FCS : FRAME CHECKING SEQUENCE

FIG. 12

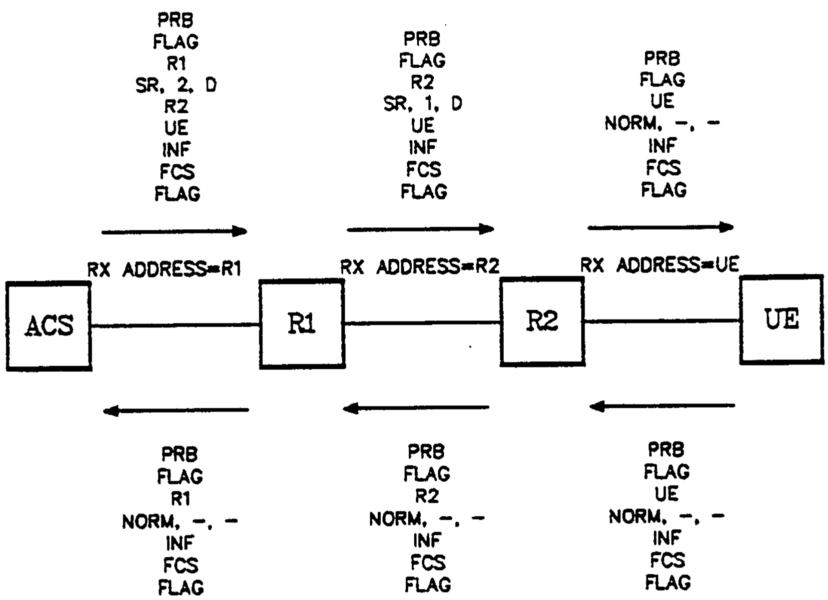


FIG. 13

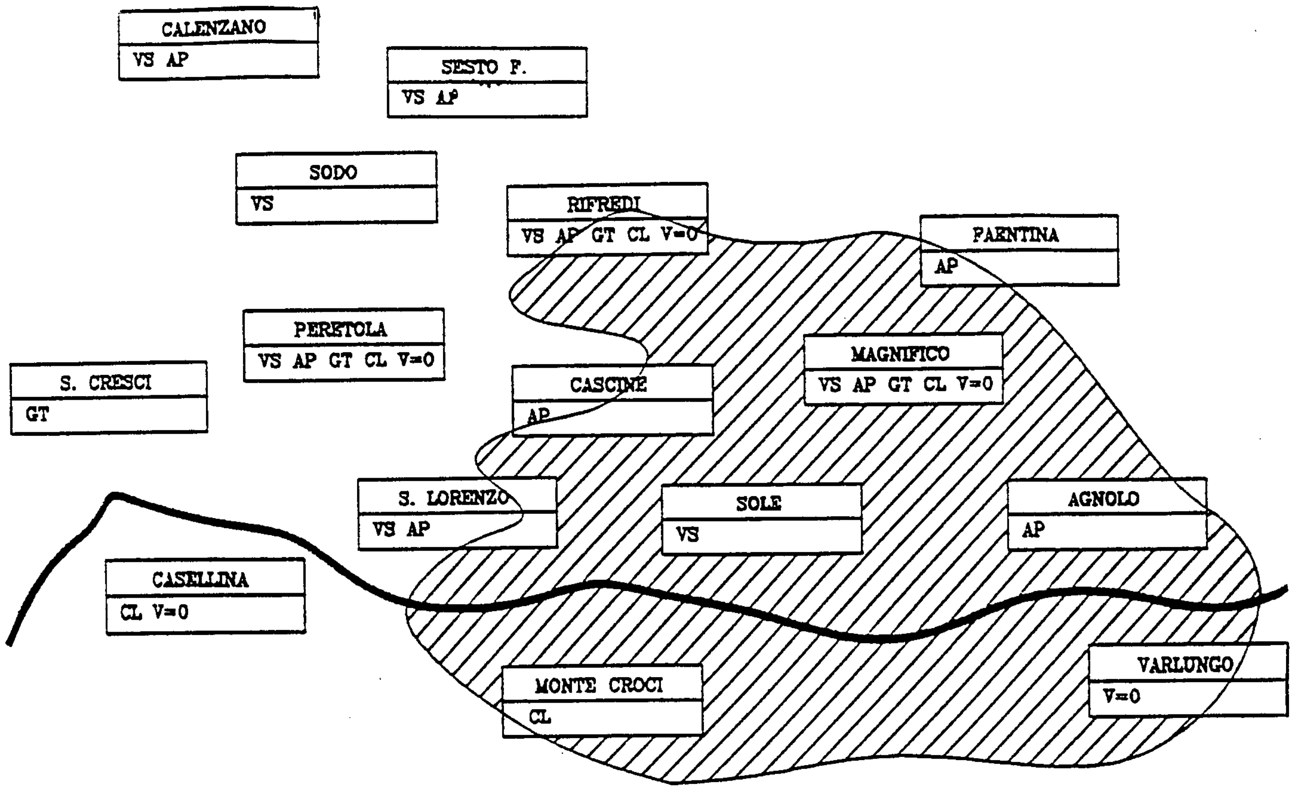

CALENZANO
VS AP
SESTO F.
VS AP
SODO
VS
RIFREDI
VS AP GT CL V=0
FAENTINA
AP
PERETOLA
VS AP GT CL V=0
MAGNIFICO
VS AP GT CL V=0
S. CRESCI
GT
CASCINE
AP
S. LORENZO
VS AP
SOLE
VS
AGNOLO
AP
CASELLINA
CL V=0
MONTE CROCI
CL
VARLUNGO
V=0

FIG. 14

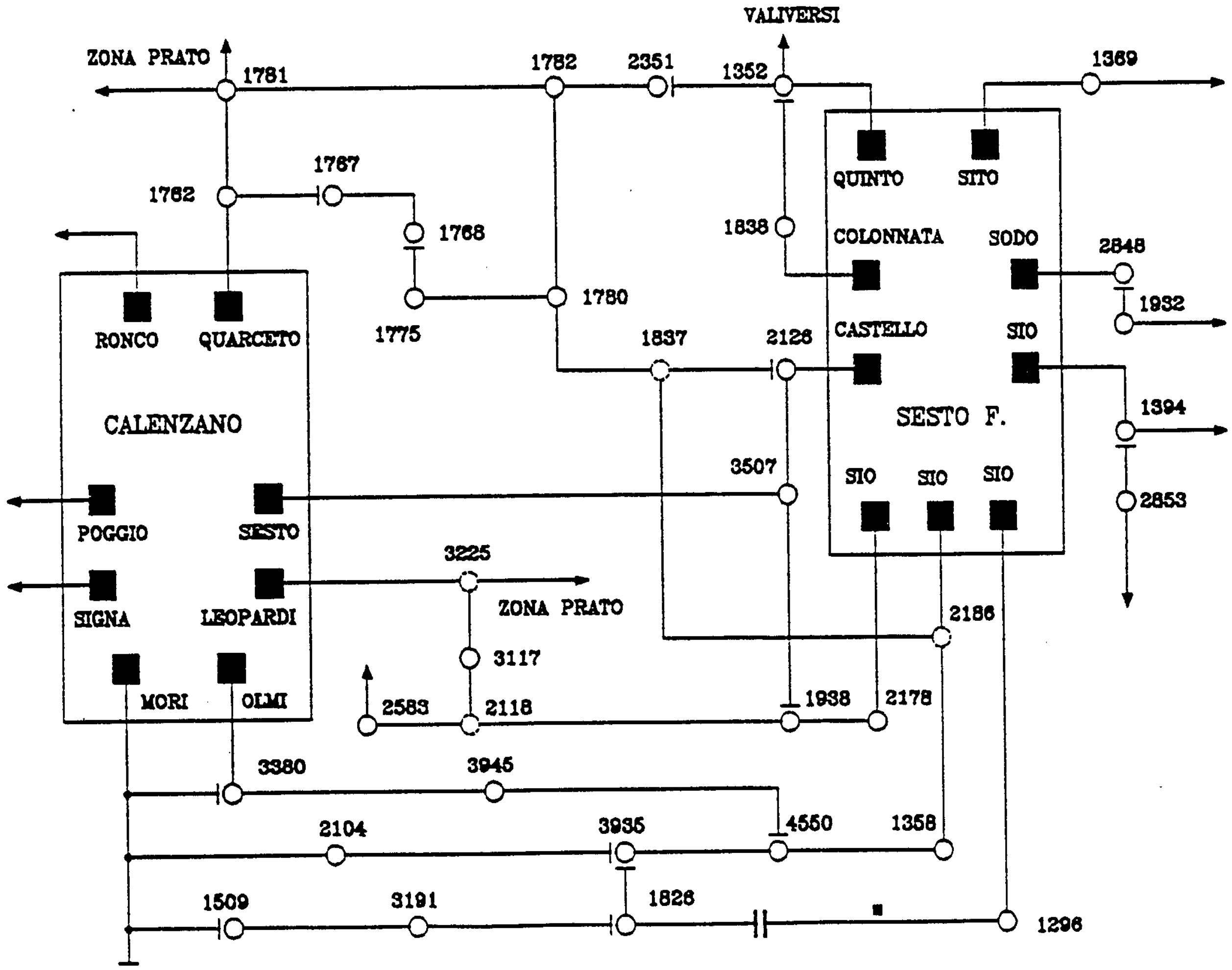

ZONA PRATO
VALIVERSI
1781
1782
2351
1352
1369
1767
1762
1768
1838
2848
1932
1775
1780
1837
2126
1394
2853
3507
3225
3117
2583
2118
1938
2178
2186
3380
3945
4550
1358
2104
3935
1509
3191
1826
1296
RONCO
QUARCETO
CALENZANO
POGGIO
SESTO
SIGNA
LEOPARDI
MORI
OLMI
ZONA PRATO
QUINTO
SITO
COLONNATA
SODO
CASTELLO
SIO
SESTO F.
SIO
SIO
SIO

FIG. 15

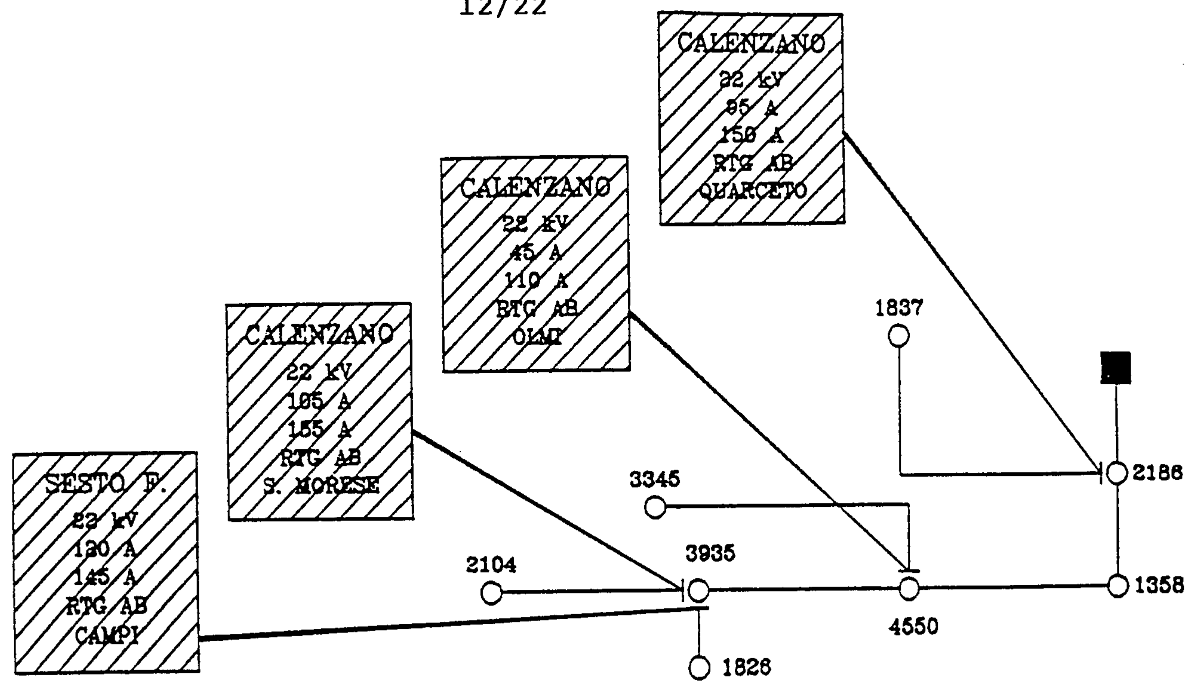

CALENZANO
22 kV
95 A
150 A
RTG AB
QUARCETO
CALENZANO
22 kV
45 A
110 A
RTG AB
OLMI
CALENZANO
22 kV
105 A
155 A
RTG AB
S. MORESE
SESTO F.
22 kV
130 A
145 A
RTG AB
CAMPI
1837
2186
3345
2104
3935
4550
1358
1826

FIG. 16

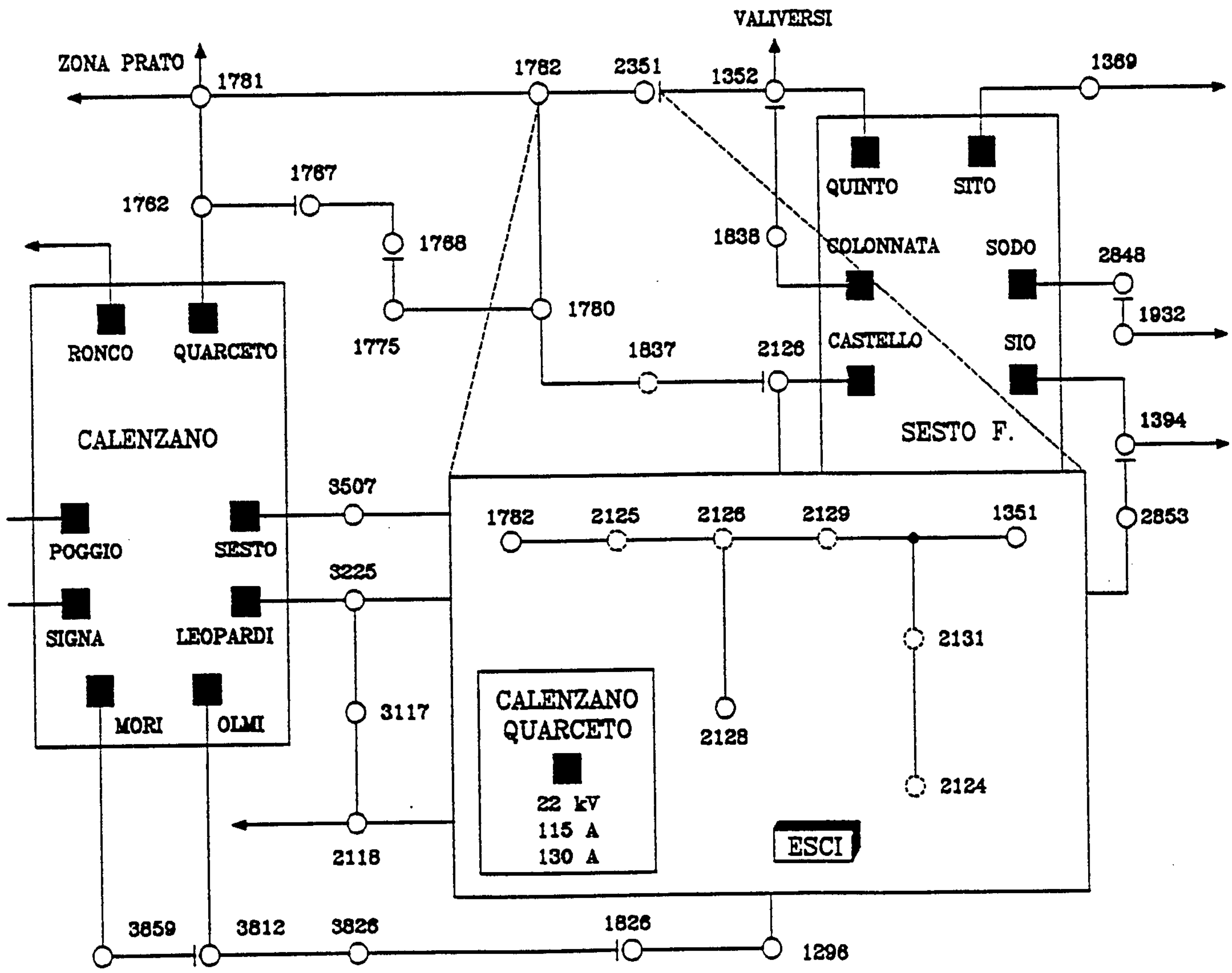
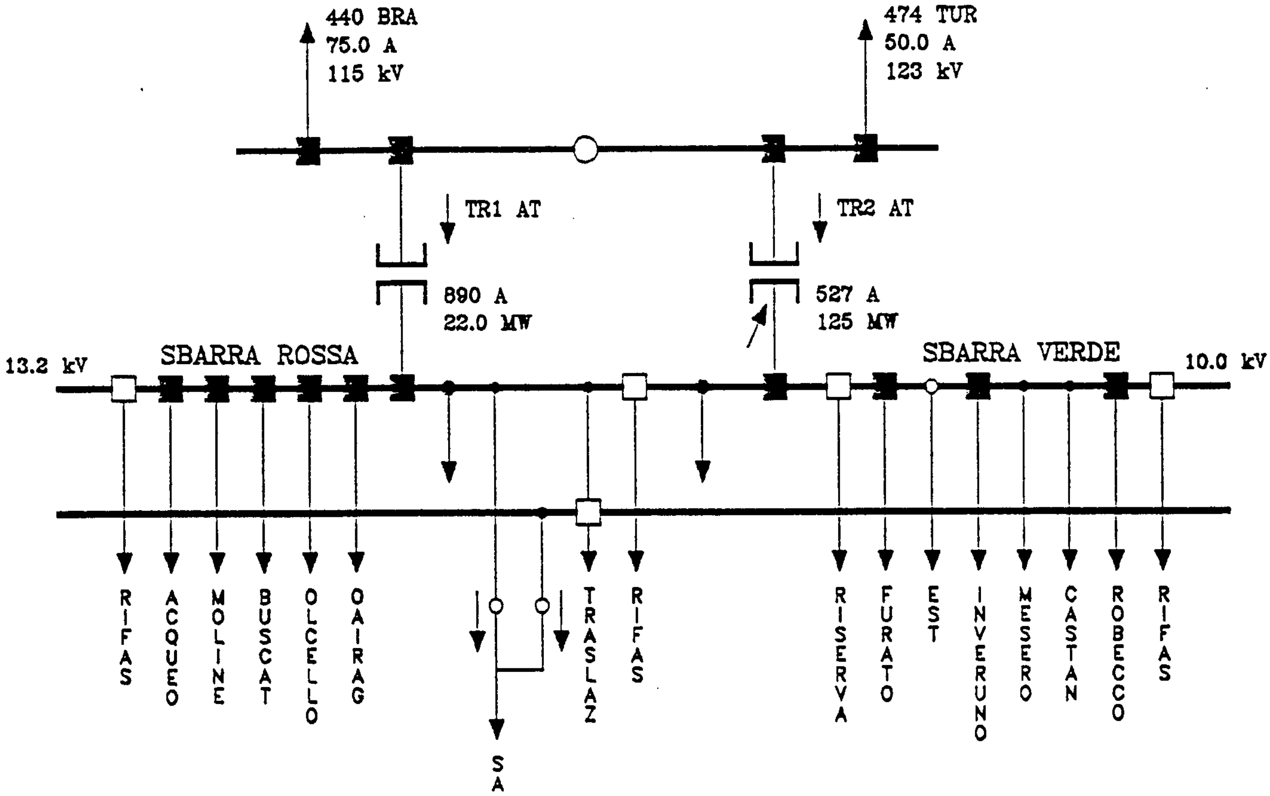

VALIVERSI
ZONA PRATO
1781
1782
2351
1352
1369
1767
1762
1768
1838
QUINTO
SITO
COLONNATA
SODO
2848
1932
RONCO
QUARCETO
1775
1780
1837
2126
CASTELLO
SIO
1394
CALENZANO
SESTO F.
3507
2853
POGGIO
SESTO
1782
2125
2126
2129
1351
3225
SIGNA
LEOPARDI
2131
3117
MORI
OLMI
CALENZANO
QUARCETO
22 kV
115 A
130 A
2128
2124
ESCI
2118
3859
3812
3826
1826
1296

FIG. 17



440 BRA
75.0 A
115 kV
474 TUR
50.0 A
123 kV
TR1 AT
TR2 AT
890 A
22.0 MW
527 A
125 MW
13.2 kV
SBARRA ROSSA
SBARRA VERDE
10.0 kV
RIFAS
ACQUEO
MOLINE
BUSCAT
OLCELLO
OAIRAG
SA
TRASLAZ
RIFAS
RISERVA
FURATO
EST
INVERUNO
MESERO
CASTAN
ROBECCO
RIFAS

FIG. 18

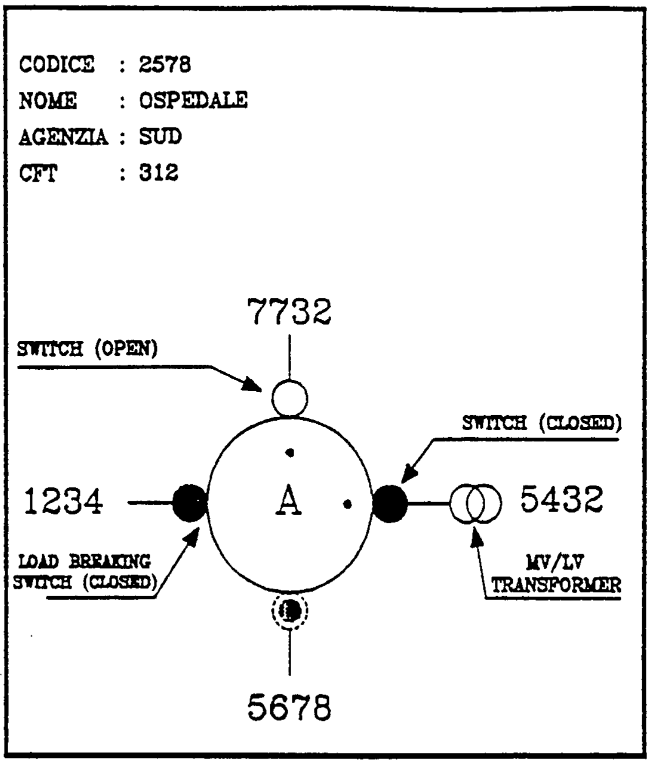

CODICE : 2578
NOME : OSPEDALE
AGENZIA : SUD
CFT : 312
7732
SWITCH (OPEN)
SWITCH (CLOSED)
1234
A
5432
LOAD BREAKING SWITCH (CLOSED)
MV/LV TRANSFORMER
5678

FIG. 19

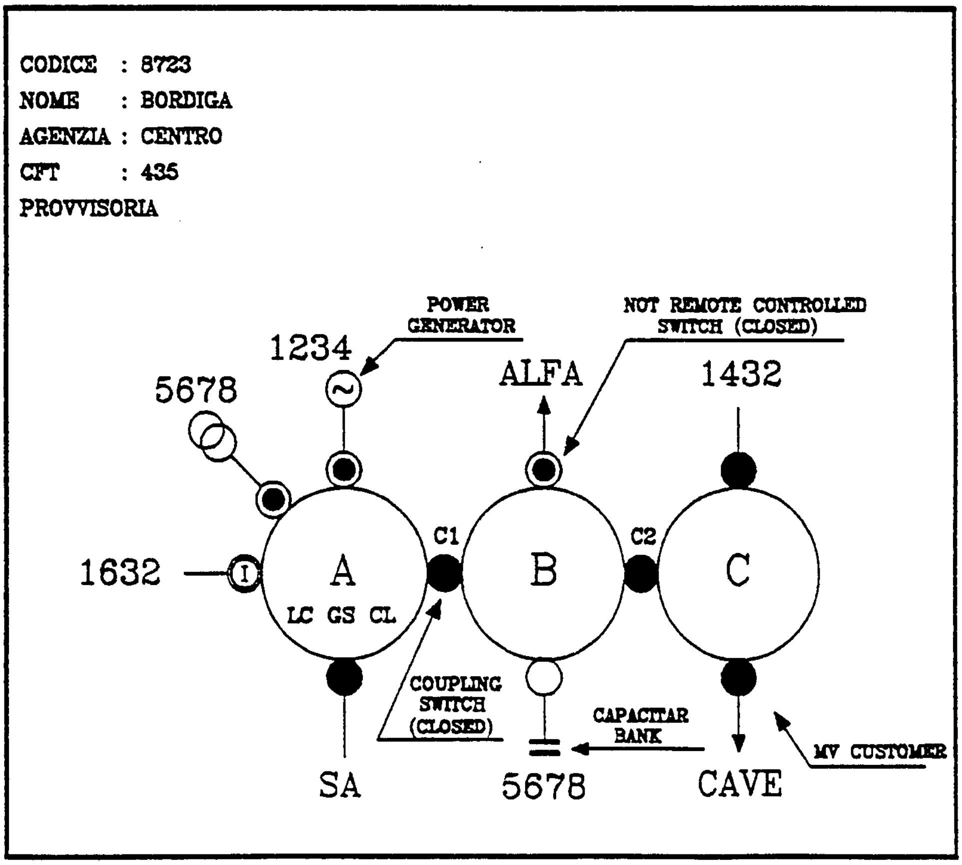

CODICE : 8723
NOME : BORDIGA
AGENZIA : CENTRO
CFT : 435
PROVVISORIA
POWER GENERATOR
NOT REMOTE CONTROLLED SWITCH (CLOSED)
1234
5678
ALFA
1432
1632
A
LC GS CL
C1
B
C2
C
COUPLING SWITCH (CLOSED)
CAPACITAR BANK
MV CUSTOMER
SA
5678
CAVE

FIG. 20

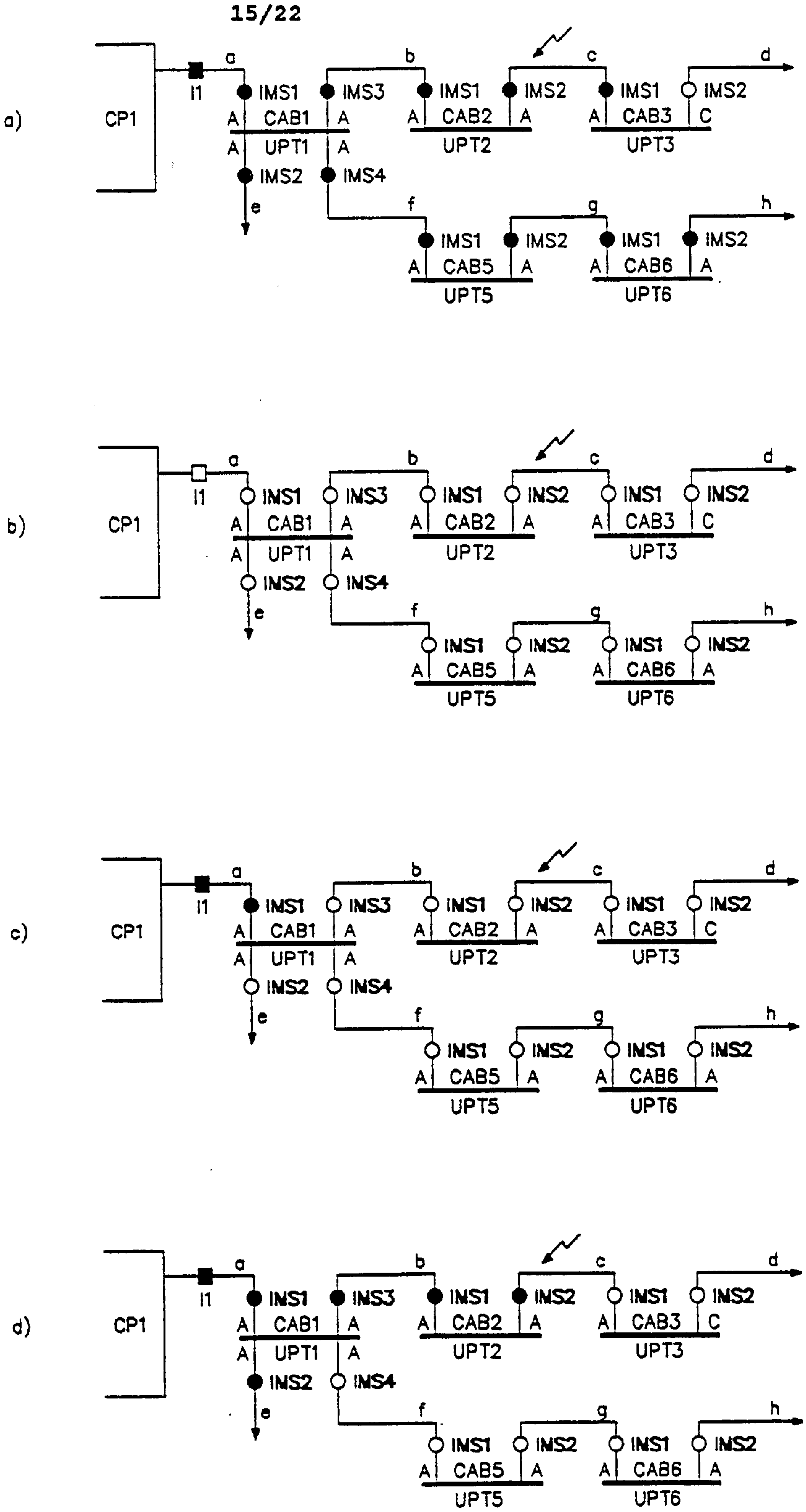

a)
CP1
I1
a
b
c
d
e
f
g
h
IMS1 IMS3 IMS1 IMS2 IMS1 IMS2
A CAB1 A
A UPT1 A
IMS2 IMS4
A CAB2 A
UPT2
A CAB3 C
UPT3
IMS1 IMS2 IMS1 IMS2
A CAB5 A
UPT5
A CAB6 A
UPT6
b)
CP1
I1
INS1 INS3 INS1 INS2 INS1 INS2
A CAB1 A
A UPT1 A
INS2 INS4
A CAB2 A
UPT2
A CAB3 C
UPT3
INS1 INS2 INS1 INS2
A CAB5 A
UPT5
A CAB6 A
UPT6
c)
CP1
I1
INS1 INS3 INS1 INS2 INS1 INS2
A CAB1 A
A UPT1 A
INS2 INS4
A CAB2 A
UPT2
A CAB3 C
UPT3
INS1 INS2 INS1 INS2
A CAB5 A
UPT5
A CAB6 A
UPT6
d)
CP1
I1
INS1 INS3 INS1 INS2 INS1 INS2
A CAB1 A
A UPT1 A
INS2 INS4
A CAB2 A
UPT2
A CAB3 C
UPT3
INS1 INS2 INS1 INS2
A CAB5 A
UPT5
A CAB6 A
UPT6

FIG. 21

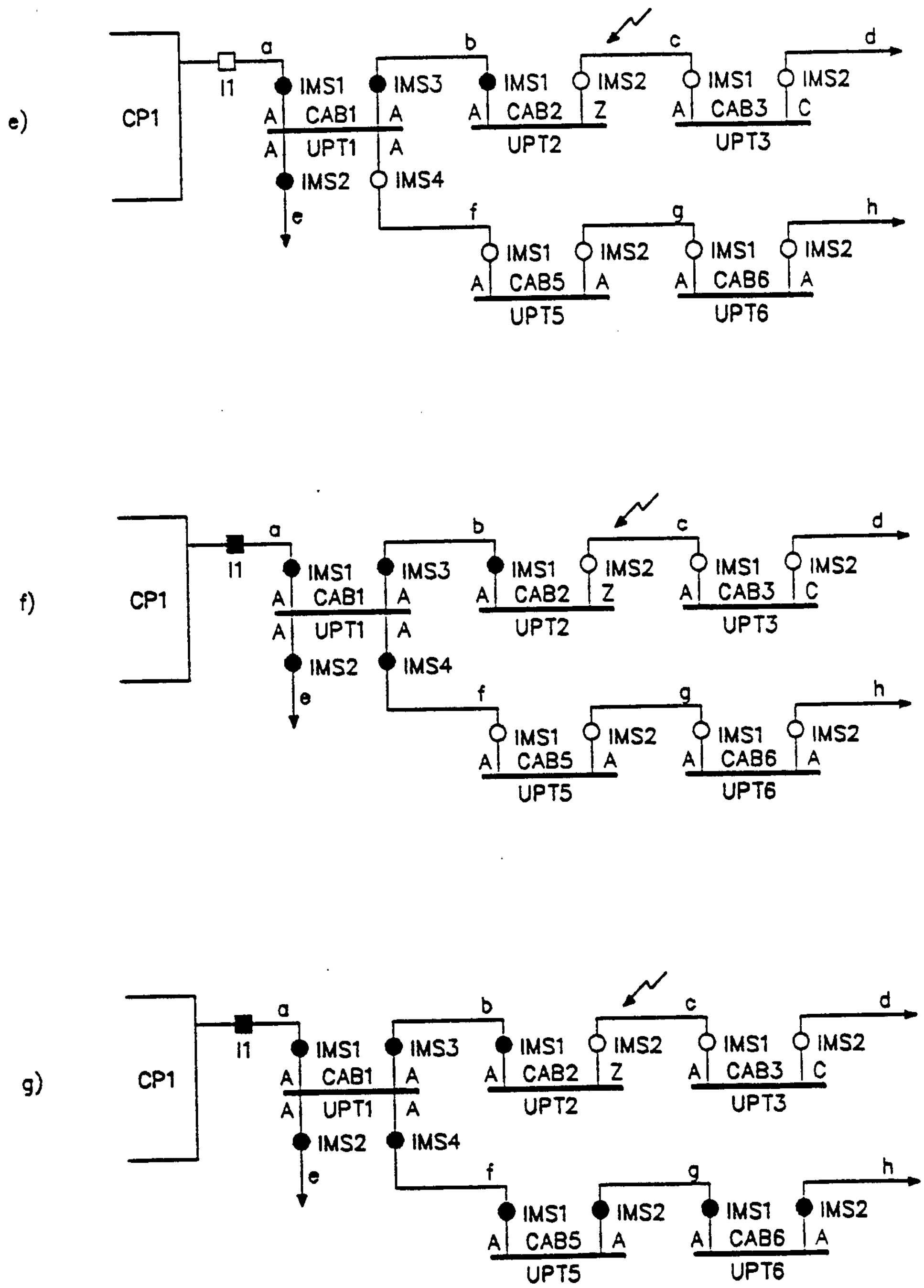

e)
CP1
I1
a
b
c
d
IMS1
IMS3
IMS1
IMS2
IMS1
IMS2
A CAB1 A
A CAB2 Z
A CAB3 C
A UPT1 A
UPT2
UPT3
IMS2
IMS4
e
f
g
h
IMS1
IMS2
IMS1
IMS2
A CAB5 A
A CAB6 A
UPT5
UPT6
f)
CP1
g)
CP1

FIG. 21bis

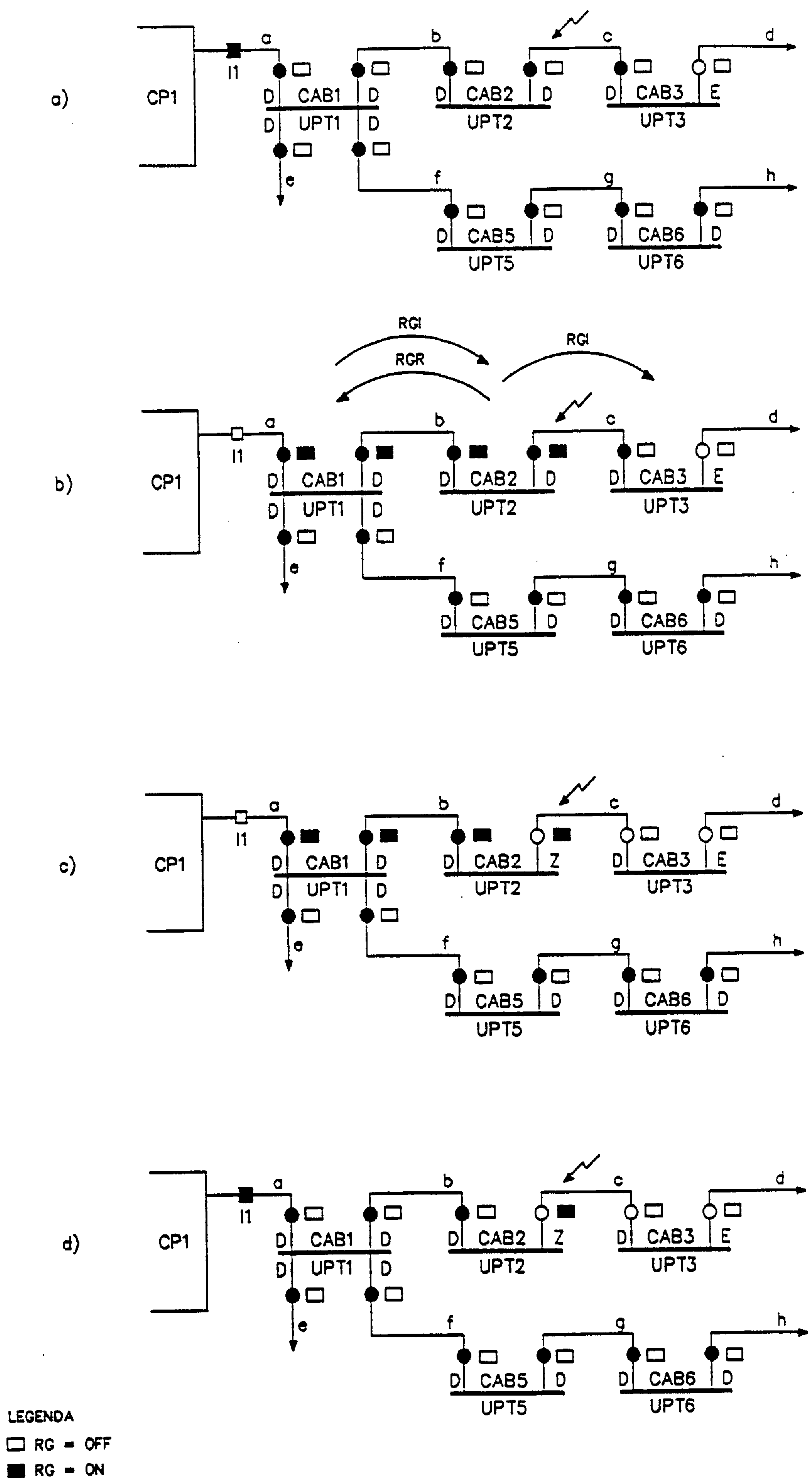

a)
CP1
I1
a
b
c
d
CAB1
UPT1
CAB2
UPT2
CAB3
UPT3
CAB5
UPT5
CAB6
UPT6
e
f
g
h
D
E
b)
RGI
RGR
c)
Z
d)
LEGENDA
RG = OFF
RG = ON

FIG. 22

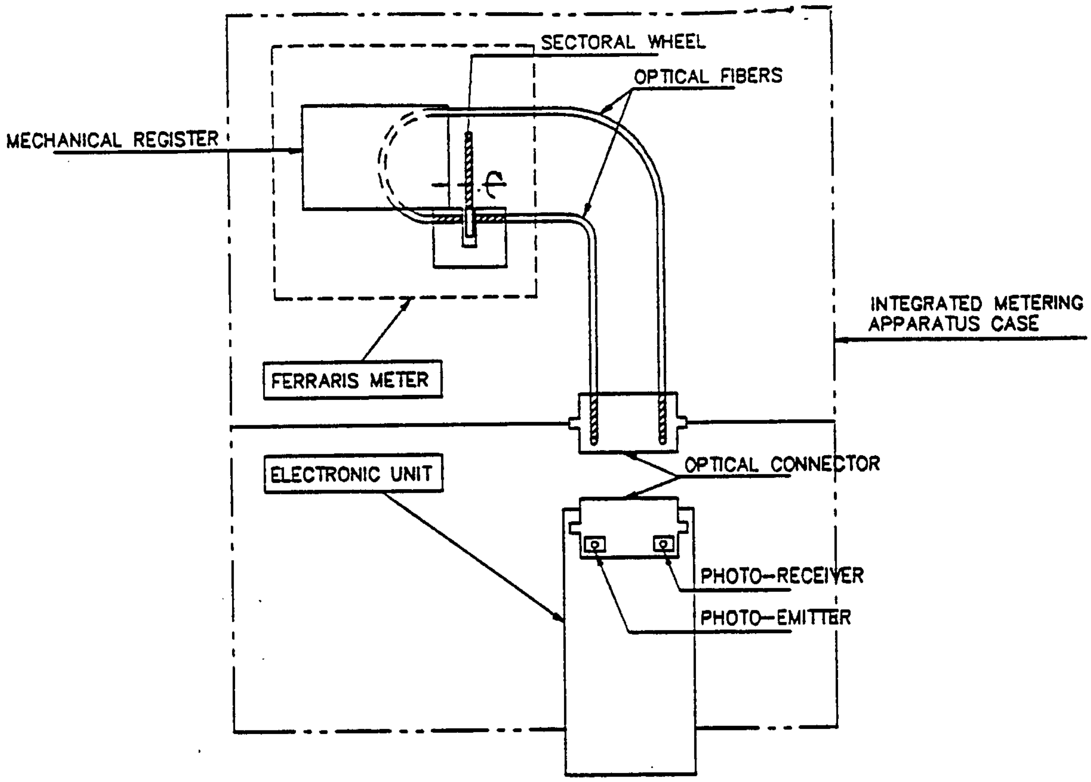

SECTORAL WHEEL
OPTICAL FIBERS
MECHANICAL REGISTER
INTEGRATED METERING APPARATUS CASE
FERRARIS METER
ELECTRONIC UNIT
OPTICAL CONNECTOR
PHOTO-RECEIVER
PHOTO-EMITTER

FIG. 23

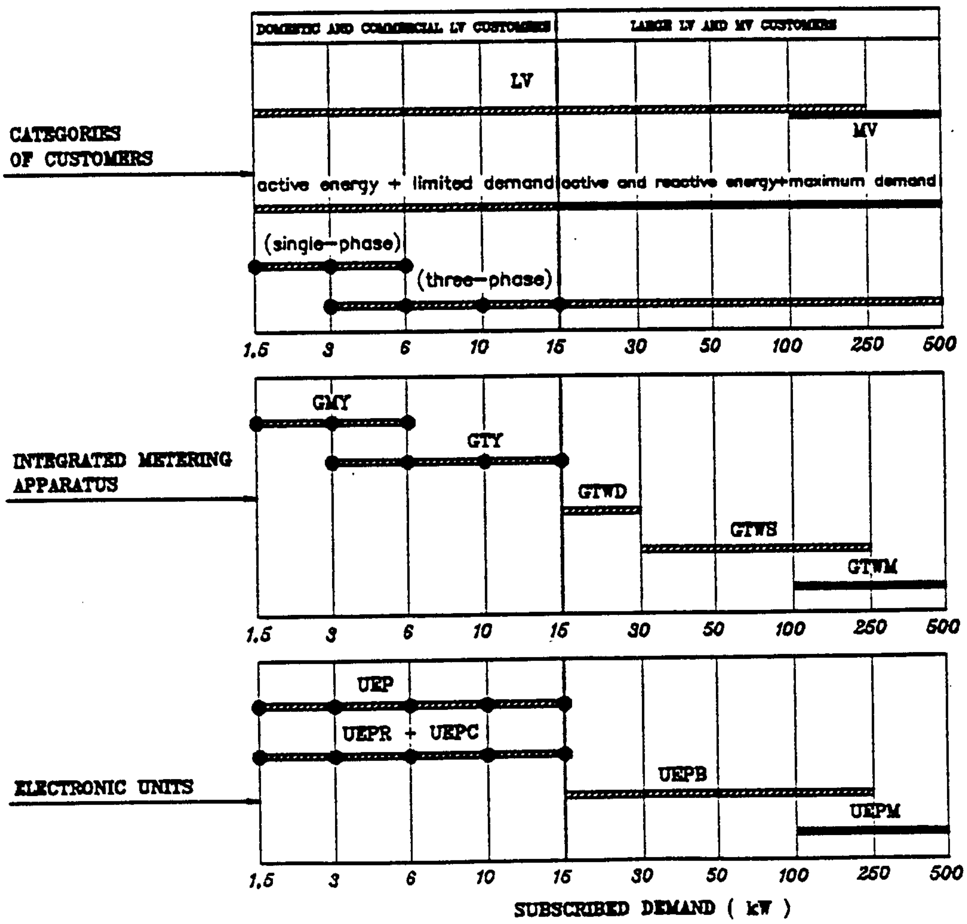

CATEGORIES OF CUSTOMERS
LV
MV
active energy + limited demand
active and reactive energy+maximum demand
(single-phase)
(three-phase)
1.5 3 6 10 15 30 50 100 250 500
INTEGRATED METERING APPARATUS
GMY
GTY
GTWD
GTWS
GTWM
1.5 3 6 10 15 30 50 100 250 500
ELECTRONIC UNITS
UEP
UEPR + UEPC
UEPB
UEPM
1.5 3 6 10 15 30 50 100 250 500
SUBSCRIBED DEMAND (kW)

FIG. 24

GMY

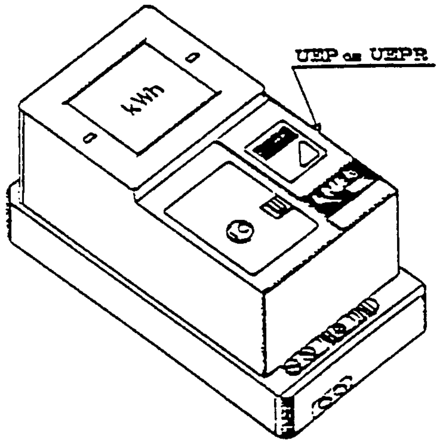


FIG. 25

GTY

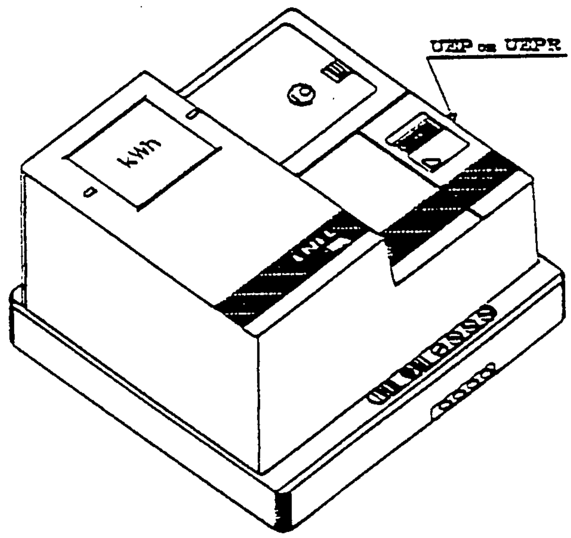


FIG. 26

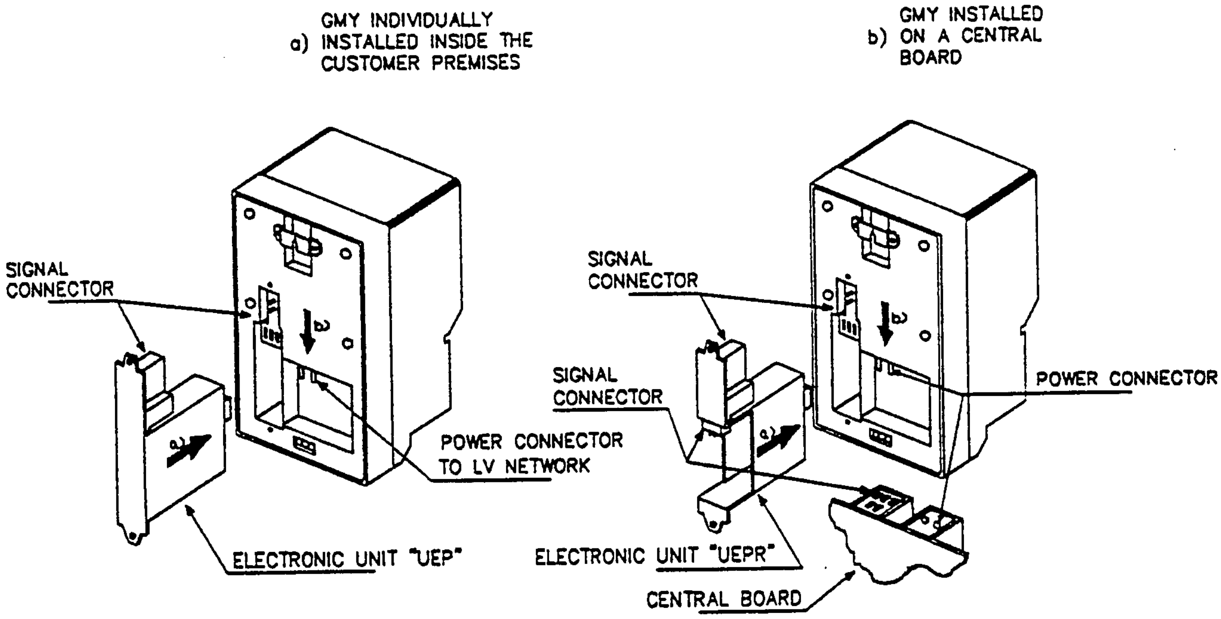

GMY INDIVIDUALLY
a) INSTALLED INSIDE THE
CUSTOMER PREMISES
GMY INSTALLED
b) ON A CENTRAL
BOARD
SIGNAL
CONNECTOR
SIGNAL
CONNECTOR
SIGNAL
CONNECTOR
POWER CONNECTOR
POWER CONNECTOR
TO LV NETWORK
ELECTRONIC UNIT "UEP"
ELECTRONIC UNIT "UEPR"
CENTRAL BOARD

FIG. 27

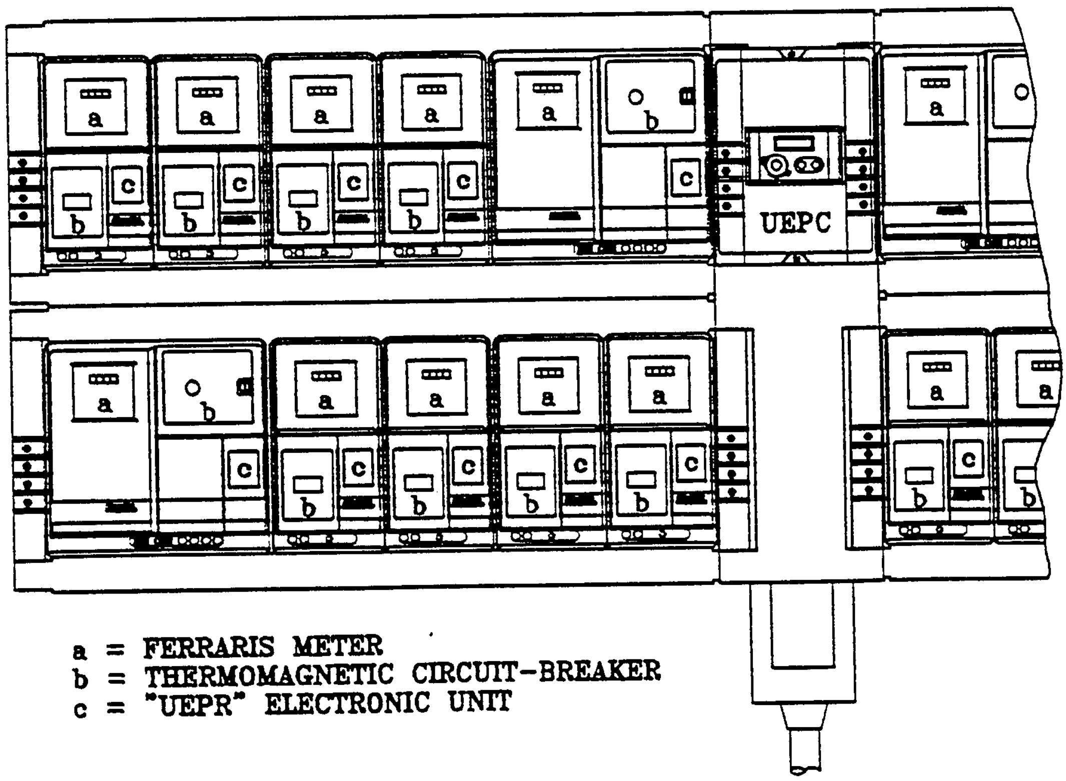

UEPC
a = FERRARIS METER
b = THERMOMAGNETIC CIRCUIT-BREAKER
c = "UEPR" ELECTRONIC UNIT

FIG. 28

GTWD

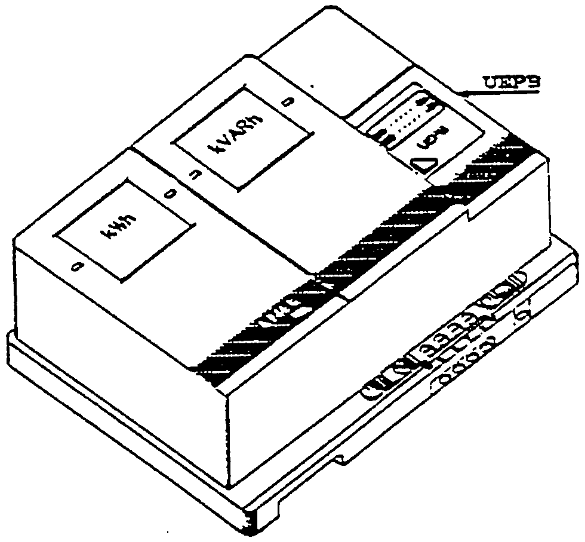


FIG. 29

GTWS

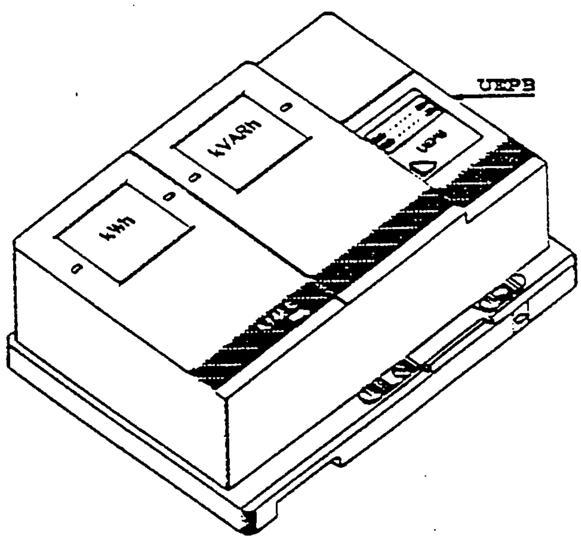


FIG. 30

GTWM

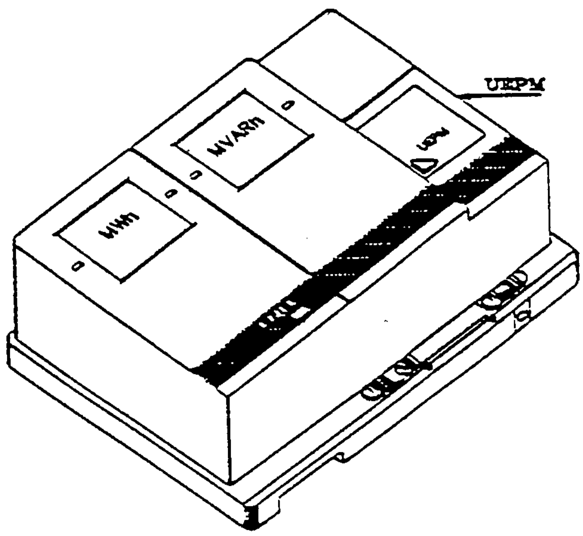


FIG. 31

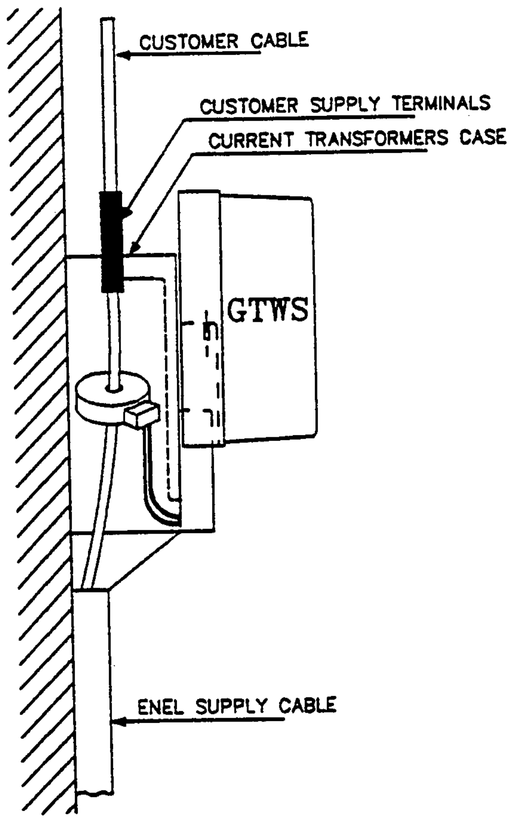

CUSTOMER CABLE
CUSTOMER SUPPLY TERMINALS
CURRENT TRANSFORMERS CASE
GTWS
ENEL SUPPLY CABLE

FIG. 32

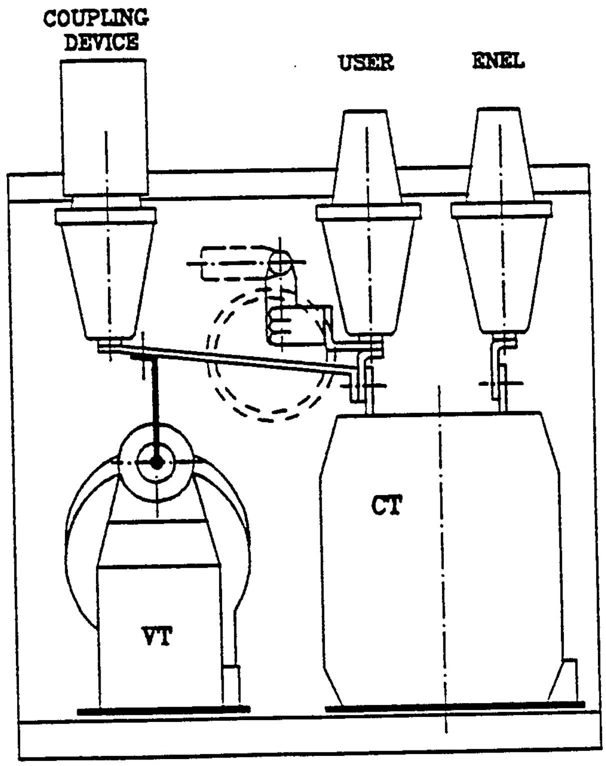

COUPLING DEVICE
USER
ENEL
CT
VT

FIG. 33