MV NETWORKS PLANNING TOOLS INTEGRATED WITHIN THE GEOGRAPHIC INFORMATION SYSTEM

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INTRODUCTION

In ENEL the planning of MV distribution networks can basically be subdivided into the following two activities:
- strategic planning which aims at determining the general network options
- operational planning which defines the location of the HV/MV substations and the optimum configuration of the MV networks.
The paper particularly deals with this second activity in describing the computer planning tools used in ENEL for managing the MV distribution networks information, monitoring the current electrotechnical status of the systems and simulating load growth and network developments.
Moreover the paper stresses the importance of the integration of such computer tools within a Geographic Information System (GIS) in order to simplify their interactive use.

GENERAL CONSIDERATIONS

ENEL has produced a Technical Guide [1] describing general concepts and planning criteria for medium voltage distribution networks. In order to employ such criteria, the Operative Teams require a knowledge of the network and load over a long-term period (up to 20 years for strategic planning and 5 - 10 years for operational planning).
Strategic planning studies consist in defining the general network options (such as the voltage level, the rating of standardized network elements, the network structure, the reliability levels, and so on) constituting the guidelines for expansion of the MV distribution system over the long term. These options, related to large areas of the territory, must take into account the whole variability range of those parameters which define the different local situations: therefore, the above mentioned studies require certain calculations which would prove extremely difficult if suitable models were not used [2].
Once the guidelines have been determined, operational planning aims at locating the HV/MV substations and defining the optimum configuration of the MV networks by analysing numerous network alternatives, obviously taking into account the characteristics and geographical distribution of loads and their evolution versus time. Such calculations would be practically impossible without a supporting database. ENEL has developed the MEPR (Network Module of the ENEL Distribution information system) Data Base for operation and short-medium term planning of the MV networks; such a Data Base is made widely available through ENEL's Territorial Distribution Units.
Moreover it is important to define the network reinforcements alternatives and priorities for the particular networks in order to determine the financial requirements and sharing budget resources. This means scheduling the work programme.
In the following paragraphs only the operational planning methodology is considered as the strategic planning has

been already described in other papers presented at previous CIRED Conferences [2], [3] and [4]. Here it will only be recalled that strategic planning activity focuses on large areas and uses analytical models in order to simulate the operating conditions of adequately stylized networks. DIRED computer program [2] is the main software tool supporting this planning activity. It can be used to study both rural areas with a predominantly overhead network and urban areas with underground cable network. The study model, whilst being oriented more specifically towards MV networks, takes into account also the interaction with upstream HV networks and downstream LV networks, so allowing an optimization of the whole distribution system.

OPERATIONAL PLANNING METODOLOGY

General guidelines

The aim of operational planning, as already mentioned, is to optimize the siting of the new HV/MV substations and the requirements and priorities of new MV installations as well as the renewal of existing plants to meet the increase of load while guaranteeing adequate and pre-established service quality levels, at the lowest possible cost.
Fig. 1 illustrates in schematic form the general organization for operational planning of the MV networks envisaged by ENEL. The main activities are the following:

- load forecast over the territory
- MV network expansion and allocation of the HV/MV substations
- MV network reinforcements alternatives and priorities.

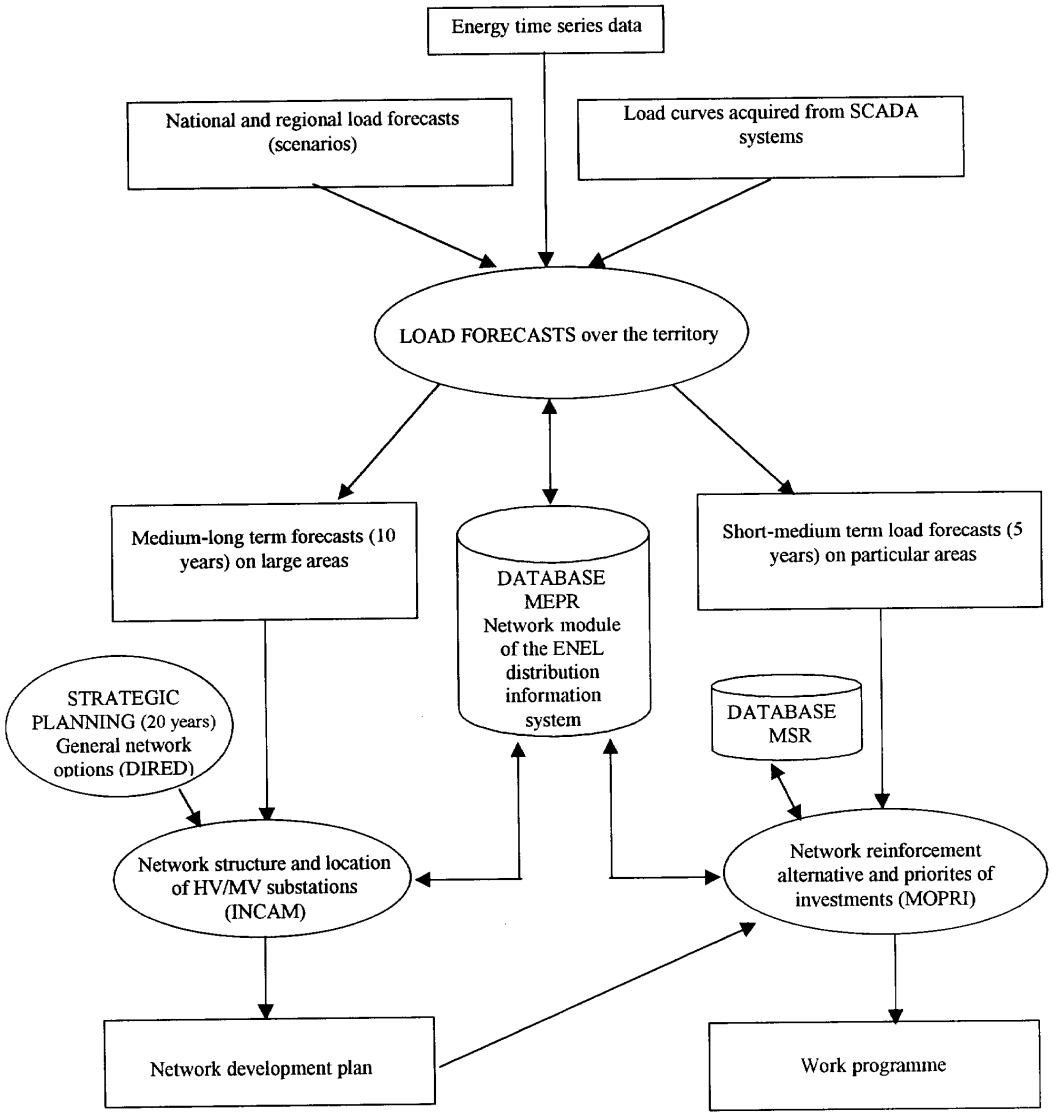

Fig. 1 Organization of operational planning envisaged by ENEL

Load forecast

A fundamental assumption for the planning activity is the knowledge of the future load in the study area.
The methodology applied by ENEL [4] consists in the analysis and extrapolation of invoiced energy time series relating to ENEL's geographical organization according to their historical trend and in compliance with the constraints of the national and regional load forecasts performed by the Central Planning Department. Such constraints (scenarios) obviously take into account the partial liberalisation of the electric market (in Italy the electric market is now being gradually opened for large customers, whilst persist monopolistic conditions for small consumers).
The above mentioned energy time series are disaggregated by subdividing the users in different classes for each voltage supply level (LV, MV and HV). Moreover, in order to transform energy forecasts into future power demand, a statistical load model is then used: this model, acquiring load curves from SCADA systems, enables the load diagram to be obtained for each typical day of the year.
The load forecasts obtained as automatic constrained extrapolation of energy time series are surely much more precise the closer the time frame to which they refer and the greater the area grouping level. This is why, among other things, that the strategic planning must aim at large portions of the territory and in any case with time frames of no greater than 20 years. It is only at the operational planning level with time frames limited to 5-10 years that it becomes significant to analyse small territory areas and the real particular networks.
In any case the load forecasts automatically obtained may be integrated and corrected on the basis of specific factors (socio-economic and urbanistic data) locally available.

MV network expansion

As above mentioned, this activity aims at defining the location of the new HV/MV substations and the optimum configuration and expansion of the MV networks compatible with the general guidelines specified by the strategic planning.
Accomplishing this activity involves the study of numerous network alternatives, obviously taking into account the characteristics and geographical distribution of loads as well as their forecasted increasing. Therefore ENEL has developed the network expansion model ESPRED, which has been already described in another paper, presented at previous CIRED Conference[5] and will only shortly recalled here. ESPRED, using an algorithm based on the "link/exchange" method for analysing the various network development alternatives, determines the best one which, whilst respecting the pre-established quality of supply standard levels, minimizes the target function "total present worth cost" including investments, losses, maintenance and risk (non delivered energy cost).
The use of this computer program involves the knowledge of the electrical and topological characteristics, the costs of the network components (HV/MV substations, MV lines, automatic sectionalizing devices and so on) as well as the unit cost of losses and non-delivered energy. All these data are automatically available from the relational DataBase MEPR that comprises all the information related to territory, network and loads [6].
Taking into account the calculation complexity and the very high number of network alternative, the maximum network extension that can be studied with ESPRED program, whilst keeping the computation time within reasonable bounds, is some 500 nodes. The necessity to analyse more complex networks taking into account the interactions between the whole system, particularly when the problem to optimize the best allocation of new HV/MV substations arises, has resolved to increase the computation capacity of the above mentioned software tool. The new INCAM computer program, allowing a substantial increasing of the dimension of the network that can be jointly studied (up to some 2000 MV nodes corresponding to the network feeding a big town) is now being carried out. It uses clustering techniques in order to reduce the number of nodes by which to represent the loads (MV/LV substations and MV customers) over the territory. Moreover the whole system analysed is subdivided into smaller subsystems and their interactions are taken into account by introducing suitable “network equivalents”.
At the moment only a prototype of INCAM procedure has been developed. This will be provided to ENEL’s Territorial Distribution Units in the near future in order to support the definition of MV network development plans. So as to make its use easier and faster, as indicated in the following paragraph, it will be integrated within the Geographic Information System (GIS).

MV network reinforcements alternatives and priorities

Once the MV network development plan as well as the allocation of new HV/MV substations have been defined, it is necessary to programme and coordinate the interventions on the particular networks, taking into account the local situations [7].
ENEL has applied the software tool MOPRI (MOnitoring and PRogramming network Interventions) for managing the network information, monitoring the current electrotechnical status of the supply system and programming the interventions and their priorities to meet the load growth, to improve the supply quality and the network performance and to solve critical situations due to plants obsolescence or to environmental problems.
The procedure MOPRI makes use of a suitable set of indices, provided by the MEPR database, describing the MV distribution network state. These indices concern quality of supply, network performance, plants obsolescence and environmental problems. Moreover the MSR data base containing all information specifically

obtained by network monitoring (inspections, complaints by customers and so on) is now being carried out.
It must be stressed that the Planning Operator in any case, on the basis of the knowledge of the territory and the peculiarities of network has the discretion in choosing the more convenient network intervention, also taking into consideration the opportunity to ensure high quality service to particularly sensitive consumers (hospitals, industries etc.).
MOPRI procedure, interfaced with the geographic Information System (GIS), carry out the main following calculations:

- load flow computations (by using a statistical approach to consider the load variability as indicated in [8], whether in normal or emergency conditions and assuming both the existing and forecasted future network configurations;
- economic rentability analysis of the different possible network interventions considered;
- valuation of the main indices concerning quality of service before and after the network interventions.

The use of MOPRI is very easy and fast as the operator can simulate directly, through graphic interfaces, the network interventions (new line, new substation, etc.) as well as the appearing of new customers or increasing their power demand. Moreover the procedure makes it possible to investigate the electrotechnical status of the systems in the presence of dispersed generation in order to quantify the possibilities and limits of its interconnection in the public energy supply network.
Fig. 2 shows an example of raster image used by the program. Other information relevant to the electric network (topology, loads, electric characteristic of network components, etc.) are stored in MEPR and must be retrieved from the Host and transferred into the local situation.

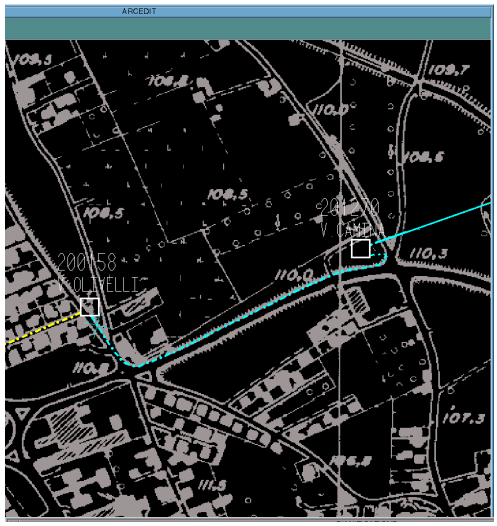

Fig. 2: Example of raster image

At the moment the prototype of MOPRI procedure is being used only in a few ENEL's Territorial Units. On the basis of such experience, the definitive version of the procedure will be soon developed and released to all the Operative Teams.
Fig. 3 shows an example of the application, for a simple network, of MOPRI computer program with the main results obtained. The figure shows the most convenient network configuration meeting the load growth and complying with the required quality of the service standard.

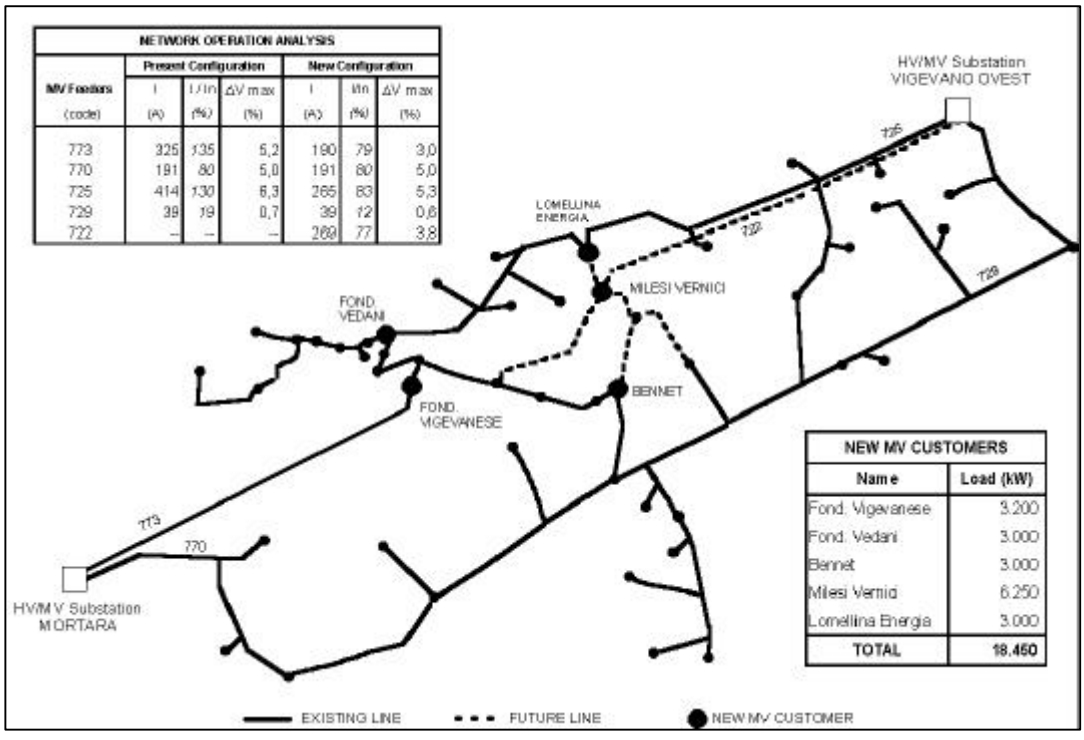

Fig 3: Example of application of MOPRI computer program.

PLANNING TOOLS GIS INTEGRATION

Generalities

The GIS interfaces make the interaction with database easier and faster as they allow the access to the database by means of graphical selection of the network elements.
Beyond the usual operation of data upgrading they allow the concise graphical representation of complex information [9,10].

Present system

To manage the MV network data the Medium Scale (MS) GIS is used (scales 1:5000-1:25000). As concerns the background layer for network geographic description, taking into account the different types (scale, accuracy and information content) of basic maps produced by different authorities, it was decided to give priority to regional maps (scales 1:5000 - 1:10000) and to employ IGMI (national geographic military institute) maps (scales 1:25000) should the regional maps not be available.
Loading background maps is normally performed by numeric conversion of vector files available from the responsible authorities (if no vector files are available digitizing or optical scanning paper sheets are preferred). At the moment, such loading is in progress, and will soon completed for the entire national territory.
The MS-GIS application was developed in the nineties so as to add graphical functions for the managing of the data stored in the above mentioned DataBase MEPR.
At present the main characteristics of hardware and software platforms are the following:

- hardware: IBM RISC/6000 workstation, plotter A0+
- software: AIX operative system, GIS ARC/INFO, RDBMS INFORMIX.

A “client/server” architecture has been developed to implement communication, by means of TCP-IP protocol, between MS-GIS (ARC/INFO environment) with database MEPR (INFORMIX environment). The network entities in the two environments are in bijective mapping.
The integration between graphic and alphanumeric data enables the operator to update and retrieve information via graphic facilities.

New architecture

At present ENEL is renewing its informative system to integrate all the subsystems relevant to the organisation processes, reconsidering methodologies, tools and software architecture.
On the other hand a wide use of graphical and GIS interface is required; thus the GIS data must be available to other subsystems both in a local and in a remote way.
In this frame ENEL is developing the SIGRAF system that is the new Graphical Information System of the ENEL Distribution. All the applications of the ENEL Distribution are made available in a single system that operates by means of the GIS interface thus uniforming the operation and simplifying the management, the maintenance and the support that require the knowledge of only one hardware/software architecture.
At present the first release of SIGRAF has just been completed and comprises the functions for the representation, on a large scale, of the territory and the MV e LV network.
The main characteristics of hardware and software platforms are the following:

- hardware: Intel processor
- software: WINDOWS NT operative system, ORDBMS ORACLE and ENEL program based on ILOG Views for the graphical visualisation.

CONCLUSIONS

The approach adopted by ENEL for the planning of the medium-voltage distribution networks envisages a strategic planning activity model-based for determining the general network options and more specific studies (operational planning) on the particular networks in order to identify the most suitable actions and upgrading measures for the short and medium term period. This last activity involves the knowledge of the network characteristics, as well as many calculations to analyse numerous network development alternatives. Therefore ENEL has developed appropriate software tools and data base containing all information required.
In order to simplify and speed up the use of computer programs for the operational planning and in the frame of the renewing of its informative system, ENEL is reconsidering methodologies, tools and software architecture towards a wide use of graphical and GIS interfaces.

REFERENCES

[1] ENEL - Divisione Distribuzione, "GUIDA TECNICA DELLA DISTRIBUZIONE. Criteri e Metodi di Pianificazione" - Roma, Marzo 92.

[2] F. Di Salvatore, G.L. Fracassi, A. Invernizzi, L. Malafarina, M. Mazzoni, "Planning of medium voltage distribution networks by dynamic models", CIRED, Birmingham 1993.

[3] R. Cicoria, G. Malacrida, M. Mazzoni, W. Palenzona, A. Proietti, "Integrated software tools for MV distribution networks planning", CIRED, Buenos Aires, 1996.

[4] R. Cicoria, G.L. Fracassi, M. Mazzoni, "Methodologies for load forecasting and planning on MV distribution networks", CIRED, Amman 1996.

[5] C. Muscas, W. Palenzona, F. Pilo, "Expansion of

large MV networks: a methodology for the research of optimal network configurations" CIRED, Buenos Aires 1996.

[6] E. Colucci, L. Dalle Rive, M. Mele, M. Silvestri, "ENEL information system for the distribution technical function", UNIPEDE, Lisbon, October 1989.

[7] M. Silvestri, L. Tarchioni, "The new procedure to support investment plans in ENEL distribution networks", CIRED, Birmingham 1997.

[8] E. Comellini, G.L. Fracassi, U. Magagnoli, M. Silvestri, " ENEL information system for the distribution technical function", UNIPEDE, Lisbon, October 1989.

[9] P.G. Pacquola, S. Nevaloro, E. Ricci, M. Silvestri "The AM/FM-GIS System for ENEL distribution grid" CIRED, Brussels 1995.

[10] P. Laterza, R. Bianchi, F. Miticocchio "L'informatizzazione del territorio per le attività inerenti le reti elettriche" AICA, Gallipoli (LE) 1993.