Special Report – Technical Theme 5

SYSTEM DEVELOPMENT

Chairman: A Invernizzi, Italy
Rapporteur: A Ardito, Italy

INTRODUCTION

Technical Theme 5 "System Development" deals with efficiency and cost reduction, increasing of distribution capacity, new automation functions to improve network operation. All these aspects are aimed to the renovation of distribution systems related mainly to the liberalization of the electric market.
The relation between market liberalization and quality of supply is still an open question and the experience of countries that are experiencing the opening of the market is extremely interesting.
The changed scenario requires the development of new system planning and design methodologies and related SW tools to deal with demand forecast, losses calculation, reliability analysis, optimum network expansion and higher exploitation of plants and components.
This Session consists of two sub-sessions:

- **5A,** on p*lanning issues*, dealt with mainly by papers from 1 to 17.
- **5B,** on *planning methodologies and IT tools*, dealt with mainly by papers from 18 to 34.

The round table on *market liberalization and quality of supply* is also relevant to session 5 and it is dealt with by papers from 35 to 38.

PLANNING ISSUES

Distribution planning is still of great concern, due to the need of cost reduction; this holds both in countries where liberalization is already established or it is going on and in those where the development of the electric system is still vertically integrated and centrally planned by government institutions.
Cost reduction, that is related to efficiency, is faced in all its aspects, i.e. investment costs for new networks or for revamping/restructuring of the existing ones, operation & maintenance costs and costs of losses.
In order to save investment costs, distribution companies tend to a higher degree of exploitation of network components. This approach requires careful technical analyses in order not to worsen the quality of supply and the losses. On the contrary, distribution companies declare to be engaged in a strong effort to improve quality of supply and not to increase the losses. Higher degrees of exploitation of network components and consequent postponements of investments imply a reduction in operation margins; thus an accurate estimation of the associated risks of inadequate quality of supply is necessary.
Some distributors, mainly the ones who are facing the liberalization of the market, declare that network restructuring and adoption of new network schemes together with advanced automation and protection systems allow cost reduction and improvement of supply quality.

Question A1
How can distribution companies pursue the reduction of costs by higher exploitation of network components and in the same time pursue the reduction of losses and improve service reliability and quality of supply?
What is the experience of distributors to face up to this challenge and what are the results of this process?

In some countries, electrical losses have to be reduced not only in order to reduce costs but to meet the requirements of law and regulation, too. The tariff system itself can be conceived to stimulate reduction of losses.

Question A2
What are laws and rules that compel or stimulate reduction of losses, in different countries?
At what extent do such rules, imposed by governments or regulators, force to reduce losses, besides the mere increase of profit due to the reduction of cost of losses, but balanced by a consequent increase of investment costs?

In the present scenario dominated by competition, asset management is aimed to reach the maximum profit. Saving of investment costs and their postponements imply an accurate forecast of load evolution in the future in order to be able to meet the demand from customers, mainly in countries where a significant grow of electric demand is expected. This problem can be dealt with by a risk analysis approach too, that should imply more sophisticated methodologies and more intense evaluation efforts than before liberalization, when investments were decided on the basis of a very long pay-back period and the electricity

supply was considered a mere social service dominated by political considerations.

Question A3
What are the managing approaches and methodologies currently used by distributors to take decisions on their investments?
What are the results of application experiences?

Dispersed generation may have significant effects on the evolution and the operation of distribution networks. One of this aspects is the reduction of losses, due to the proximity of the generation to the load. The reduction of losses will surely affect the transmission system, since the power to be transmitted over long distances from large power station located far from load centres would be lower, and an estimation of this decrease is rather simple. On the other hand, the impact of dispersed generation on the losses of the distribution system where it is connected could be rather more difficult to be adequately evaluated in the planning stage, mainly when power transfer reversal is accepted, allowing exchange of power among feeders connected on the same bus, in the hypothesis of keeping distribution networks radial.

Question A4
Is the effect of the dispersed generation taken into account in distribution system planning as far as the reduction of losses is concerned?

Distribution service tariffs are typically stated by governments or regulatory authorities in order to ensure the coverage of full justified costs and a suitable rate of return of invested capital, and to give incentives to lower distribution costs and to higher overall efficiency. Tariffs can be stated starting from the costs incurred in the past or on the basis of planned costs. Consumers load profiles that describe the patterns of electricity use by consumers, are also needed for tariff system development. Such profiles, that are influenced by demand side management and tariff system, can be adequately drawn through relatively short-term load research projects, involving selected consumers.

Question A5
In what way, in different countries, are tariffs conceived in order to stimulate higher distribution efficiency, investments in network renewal and technological innovation?

Operators of the electric market and users claim for technological innovation in order to reduce costs and to improve the quality of supply.
Technological innovation can affect both power equipment and automation & protection systems.
Manufacturers are offering new kinds of power equipment for distribution networks, such as fast acting circuit-breakers, fault current limiters and even flexible dc link, together with power electronic devices for power quality enhancement ("*custom power*"). However, up to now such devices have been typically considered in order to solve specific problems, but not affecting distribution system planning.
On the other side, very innovative systems are offered for distribution automation and protection, including advanced metering systems. In general distributors have to provide regulators not only with data and measurements of energy transferred on their network, but also with data relevant to the continuity of supply and to the quality of voltage and power.
These automation and metering systems allow even to offer additional services to the users connected to the distribution network.
Even the quality itself of supply can be customised depending on the requests and needs of customers, when rules acknowledge different quality degrees.

Question A6
At what extent is new technically advanced power equipment taken into account in distribution planning and how can they affect this process?
More specifically, in what way can new automation systems affect distribution planning by allowing higher exploitation of power components currently in operation, thus delaying investments for new power equipment?

Rural electrification is a big challenge, mainly for developing countries, where, in many cases, is considered a social priority. Investment costs for rural electrification are often prohibitive, mainly when, in a liberalized context or not, costs have to be totally or even only partially covered by tariffs. In order to save costs, rural distribution planning has to take into account innovative solutions based on local generation, often by using renewable resources. Quality of supply is often a secondary issue, even if its target level has to be stated anyway.

Question A7
At what extent are innovative low-cost solutions taken into account in rural distribution planning?
What are the results of application experiences?
What are the target levels of quality of supply?
What is the expected, or experienced, reliability-continuity of supply for isolated small distribution systems with local generation only?

PLANNING METHODOLOGIES AND IT TOOLS

A big effort is currently being made in order to develop and make available effective and efficient methodologies and IT tools for distribution planning purposes; distributors have to

decide investments in a short time and the cost analysis has to be more accurate than before. Moreover methodologies are requested to tackle uncertainties in the scenario of demand evolution, since network manager will no longer necessarily have access to all the invoicing and commercial data that enables a confident forecast of demand. In an open market, commercial data are reserved, at a large extent, and thus not directly available to the distributor unless as regards his own direct customers.
To identify groups of customers, the statistical modelling is proposed and applied, but it implies the use of a large quantity of data.
A time-dependent load model is proposed together with the analysis of operational network conditions in order to better evaluate existing distribution capacities and network expansion. This model is based on an input data set integrated into a management tool, but customer's data could be only partially available.
On the other hand, a probabilistic load-flow has to be adopted in order to make a profitable use of a statistical description of loads.
Errors in the load forecast, indeed, lead either to have higher investment costs than needed or, on the contrary, to be unable to meet the stated power supply quality. In both cases the error will reflect directly on the economic margin of the distributor, without the possibility to compensate, as it was usual in the old scenario of vertically integrated monopolistic public companies.
Load forecasting is an issue of distribution operation, too, where a methodology based on Artificial Neural Networks is proposed to cover two time frames, namely one or more 15-minutes intervals and 24 hours.

Question B1
What are the used or proposed methodologies for the load forecasting starting from data set now available to distributors?
In what way do used or proposed methodologies tackle uncertainties in distribution network expansion planning?

Few methodological contributions concerning the dispersed generation in distribution planning have been presented, and generally, up to now, dispersed generation is considered as an aspect of rural electrification, when resorting to renewable resources can easily save investment costs in the grid.
On the contrary, many experts expect a significant penetration of dispersed generation even in high load density areas.
A very simplified methodological approach dealing with dispersed generation in distribution planning consists of modelling it as a "negative load", thus simply reducing the actual load to be fed by the distribution network downstream from the transmission network with its main generation.
This simplified approach is valid when the power produced by dispersed generation is low compared with the load demand, namely in low load condition, but more sophisticated methodological approaches are needed to face the problem of high dispersed generation power capability.

MV distribution networks are radially operated even if they are often built as meshed. No contribution takes here into account the possibility to have meshed operation of the MV distribution network when an high power capacity of dispersed generation is connected. Meshed operation of the distribution network should imply a revolution in its design and management, with substantial changes in its automation and protection system, besides changes of power equipment. However, meshed operated networks, as used in transmission systems, could assure an higher quality of service as it should be required when a lot of dispersed generation be connected to the distribution system.

Question B2
What are the proposed methodologies to take into account dispersed generation in distribution planning, when its overall power capability is large compared to local demand, namely in low load condition?
Is it available any distribution planning/design methodology dealing with meshed operating MV distribution network when an high installed capacity of dispersed generation is connected?
What are the problems, if any, that suggest to avoid any meshed operating configuration for distribution systems?

Rural network distribution planning is a critical issue from a methodological point of view, since technical constraints often result more critical than in case of high load density areas, thus implying a more constrained problem to be solved. Moreover, as far as costs are concerned, the sensitivity of the solution versus the value of the controlled variables is often very high, thus sub-optimal solutions can result economically far from the optimal one.
Many approaches have been proposed in literature to solve the problem; some of them are based on traditional algorithms such as quadratic programming, branch-and-bound, branch-exchange, but all supported by heuristics in order to override what traditional algorithms are not apt to solve by themselves. Other approaches are based on non-traditional algorithms, such as neural networks, expert systems, genetic algorithms.
Genetic based optimization is reported to be very accurate but with slow convergence; thus its application to the planning activity is plain, while it requires network partitioning methods for the application to the operation stage.

Question B3
What is the merit of different methodologies and algorithms for rural distribution planning?

Are the same methodologies and algorithms effective and efficient for planning of both rural and high density load areas, or different approaches have to be adopted?
Are non-traditional algorithms more effective and efficient than the traditional ones even supported by heuristics?

Evaluation of losses is traditionally one of the main issues in distribution network planning, as it regards not only the investment costs for network expansion, but the optimal radial operating configuration of a meshed network, fulfilling the set of technical constraints. A compromise has typically to be reached between losses minimization and reliability, continuity and quality of supply. This applies mainly to high density load area, but to rural distribution too.
In the operation planning stage, the networks, in order to be operated with minimal energy losses, should preferably be equipped with remote control switches to enable a rapid change of the radial network configuration.

Question B4
In a radial operating configuration of a meshed distribution network, what are the methodologies proposed in order to find the best compromise between minimum losses and maximum reliability and continuity of supply?

As regards the computation of technical losses, a methodology is proposed consisting in the subdivision of the distribution system into eight different segments, covering all system equipment in a great detail up to losses in the LV energy meters. However, some parameters, such as mainly load curves associated to each kind of customers, seem to be quite difficult to be estimated with adequate precision to justify a very detailed computation method for evaluation of losses.
Another simplified method is proposed to evaluate technical losses in the overall distribution network, up to LV; it starts from the incoming energy through the boundary of distribution company and the outgoing energy sold to its own customers plus the energy transmitted for other agents of the market. However the accuracy in the estimation of non-technical losses seems to be a weakness of this methodology.

Question B5
A very detailed and precise methodology for the evaluation of losses is proposed in distribution operation: at what extent is it really justifiable and profitable taking into account the uncertainties on input data, mainly as far as load curves of customers and non-technical losses are concerned?

The Geographical Information System (GIS) has become the information core of today's distribution company and its role is growing. Engineering operation and planning departments rely on data emanating from the GIS; their main issue is to get valid and sufficiently detailed models for power distribution system simulation and analysis.
From the IT point of view, the main problem lies in the link between GIS and power system analysis.
Different approaches have been adopted: the oldest one consists of extracting data from the GIS, creating a separate data-base, adding and manipulating data and then using a classic stand-alone power engineering SW in order to carry out all necessary analyses. An innovative solution is based on a simulation engine embedded and fully integrated inside the GIS: this approach has many advantages in the representation and maintenance of data, but has some drawbacks, among which a lack of flexibility in the power system analysis and an unavoidable big effort necessary to develop entirely new SW for power system simulation, embedded inside the GIS thus wasting the existing stand-alone SW.
Other intermediate solutions are proposed in order to reach a compromise between either approaches above reported.

Question B6
What are the problems in the link between GIS and power engineering SW?
What is the best solution in order to achieve flexibility in engineering analysis, full data alignment, easy maintenance of data base, ease of use?