EDP'S DECISION SUPPORT APPROACH TO PLANNING LV SMART DISTRIBUTION NETWORKS WITH DER

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ABSTRACT

This paper addresses the problem of large scale low voltage distribution network planning. The focus is on the interaction between probabilistic approach and the recently available metering hourly profile data, and how such interaction enables a better planning. This is especially important to be able to plan for large-scale integration of distributed energy resources in LV networks. EDP has been involved in the development of a comprehensive methodology that integrates the available advanced metering infrastructure, intensive computing resources and algorithms together with an efficient display of results.

INTRODUCTION

Traditionally, low voltage (LV) network analysis has mostly been made in the context of investment planning. The analysis consists of studying a feeder at a time, using estimated peak values for loads and empirically defined simultaneity factors. Load information comes from the number of clients, their requested capacity and some empirical rules. As one moves upstream, from the loads to the transformer station, at every load junction a predefined simultaneity factor applies (Note that nodal Kirchhoff's law for power applies only if powers are multiplied by the corresponding simultaneity factors). That empiric approach has been an effective, computationally simple approach that served our industry well. It is an approach adequate for a simple computer program, an equivalent to today's spreadsheets. As the perception that the LV planning problem grew to be an economically important problem and that the LV networks need to be analysed together and more often, so did grow the demand for a more adequate technical solution. Clearly new loads and load growth can be accommodated in many possible ways and not simply by providing for a new feeder or extending an existing feeder. Neighboring feeders, from the same transformer station or from a neighboring transformer station can be considered at the same time, as one problem, thus enlarging the decision space of the problem, allowing for a more integrated, better solution. This naturally comes with an increased effort to deal with the increased computational complexity.

Other important technical issues should also be addressed: (1) to use load diagrams instead of single peak values; (2) to substitute the traditional simultaneity factors by a scientific approach based on probability distributions; (3) to consistently set the network configuration for maximum efficiency and the protections for maximum system security and safety. These issues are addressed and dealt with in this paper.

Perhaps an even more relevant issue, also addressed in this paper, is due to the leading role of LV distribution networks as a receiver of distributed energy resources (DER). This role comes together with an emergent availability of massive telemetered data and more demanding performance requirements for efficiency, safety and security. This is an entirely new challenge for the LV network management, as the LV network cannot satisfactorily be analysed little by little. Hundreds of feeders need to be thoroughly analysed, for efficiency, security and safety, as the power pattern changes, as the system gets reconfigured and/or as new investments enter into service.

This ability to perform a thorough analysis of large scale LV networks is becoming a requirement not only for investment studies, but also for operations planning, maintenance and day-to-day management. This paper shows how with Advanced Metering Infrastructures (AMI) and today's planning technologies one can satisfy such a requirement.

PROBABILISTIC VS CHRONOLOGICAL

LV networks are at the final level with respect to proximity with clients. Clients' loads, including residential loads, are of an intermittent, non-continuous discrete nature. The LV network has to supply the loads as they happen. Due to this proximity effect and the nature of the loads, the utilization factor of the LV network could be very low, particularly at the lower level of the LV network where the number of clients is smaller. There are large discrepancies between the peak condition and the off peak – a ratio many times larger than that of a medium voltage or high voltage network.
The traditional way for the planning engineer to handle such problem of supplying the LV loads in good technical conditions and within a reasonable investment effort has consisted of making use of simultaneity tables. Those

tables establish the discount that should be given to loads as one moves along the radial network, from the loads to the source point, i.e. to the secondary of a power transformer. That way Kirchhoff's Current Law (KCL) is not observed in the strict sense, as for each node a looked up simultaneity factor applies.

Another way to approach the problem is to assume that at any given time (say hour) at any given point of network the load is a random variable. This way, KCL must now be observed strict sense for the corresponding random currents. There is no need for simultaneity factors, as all network laws are naturally observed. The power flow is now a probabilistic power flow and the corresponding results are probabilistic branch currents and probabilistic node voltages. For planning purposes, the probabilistic approach is more appropriate as it allows for results to me met at specified levels, e.g., a 95% confidence level of meeting peak load requirements. An appropriate, full-fledged LV probabilistic power flow program has been developed over the years with EDP [1-2].

Nowadays, in addition to the probabilistic characterization of the loads, there is a growing need to an appropriate probabilistic characterization of the renewable, distributed generation connected to the LV network. This characterization of DERs and the corresponding integration as one probabilistic network power flow problem has also been successfully developed.

EDP – Distribuição is developing a major smartgrid project, InovGrid, under which installed advanced meters with advanced communication technologies in all the LV costumers on a municipality (Évora). The ensuing availability of frequent measurements, including hourly load values for each day, has created many new opportunities. One opportunity is to run synchronous data as they come from the measurements and thus, by synchronous power flow analysis, gathering all network information along time (say hourly). Another opportunity is to improve the load's and DER's probabilistic characterization. These opportunities have been seized and are now current activities. The present paper shows some results in this regard.

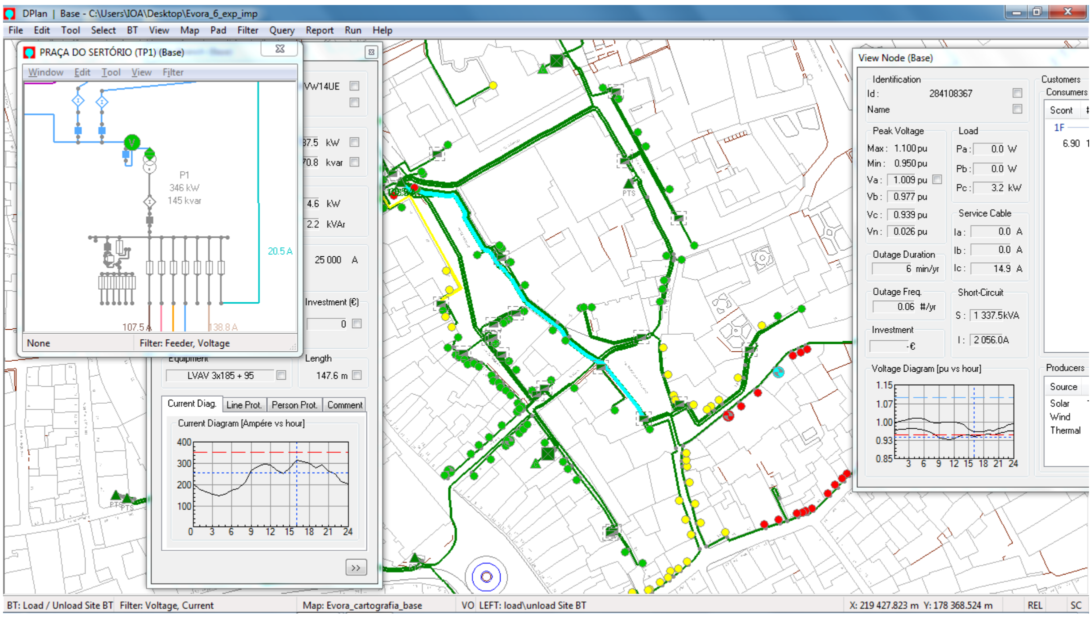

Fig. 1. Illustration of probabilistic analysis results for part of the InovCity network of Évora

OVERALL PLANNING METHODOLOGY

Fig. 2 illustrates the overall methodology. The basis for all planning data comes from a large integrated information system, SIT. SIT contains all technical data, including all network details and customers' info. Such data enables a probabilistic analysis and assessment of the network performance. A computer analysis allows for the identification of the network weaker points and prompts the planning engineer to introduce a set of possible remedies, which may include new investments or new configuration possibilities. The network will then be optimized according to EDP's planning criteria [3]. A subset of the possibilities introduced will be selected by optimization, usually a very small subset. The network can be further tested for a long series of chronological data. The planning process may involve several iterations along those stages so as to compare the proposed optimal solutions.

Fig. 3 shows side by side two views of the same node of a network. The views correspond to a chronological simulation (on the left hand side) and to a probabilistic simulation (on the right hand side). The node corresponds to a small consumer and also a small DER (solar PV, right hand side of Fig. 4). In addition to other standard data, including the highest and lowest voltage for each phase, (a, b, and c) the views show 24 hour daily diagrams for the node voltages. Note that the LV network at a high level of load proximity is very unbalanced.

Also notice that there are two curves (a band): one corresponding to higher values and the other to lower values. The higher values correspond to the highest of the three phase voltage values at each hour. Conversely, the lower values correspond to the lowest of the three phase voltage values at each hour.

Of course the diagrams of the two pictures shown do not coincide. The chronological works like a particular sample of the probabilistic. This particular sample clearly does not reflect the lower possible values for that node voltage.

Fig. 4 illustrates side by side the currents behavior of a particular branch. The issues are similar to those of Fig. 3. The currents shown correspond to the highest values and are phase dependent. The values corresponding to the probabilistic analysis are considerably higher than the chronological values. Indeed the probabilistic curve corresponds to a 95% confidence, a tail value in the currents' probabilistic distributions. The particular sample shown corresponds to a more central value, as expected.

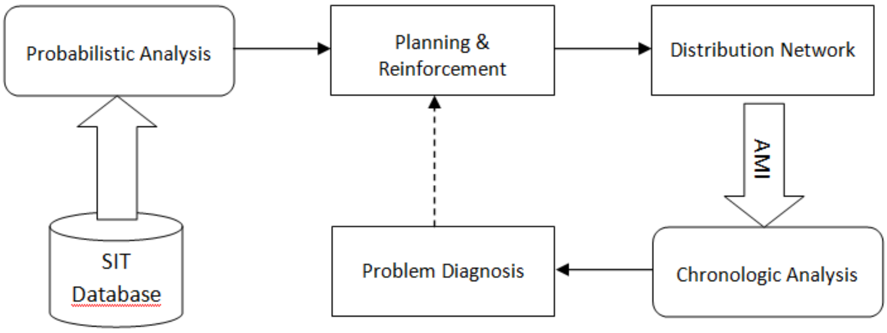

Fig. 2. Illustration of the overall planning methodology.

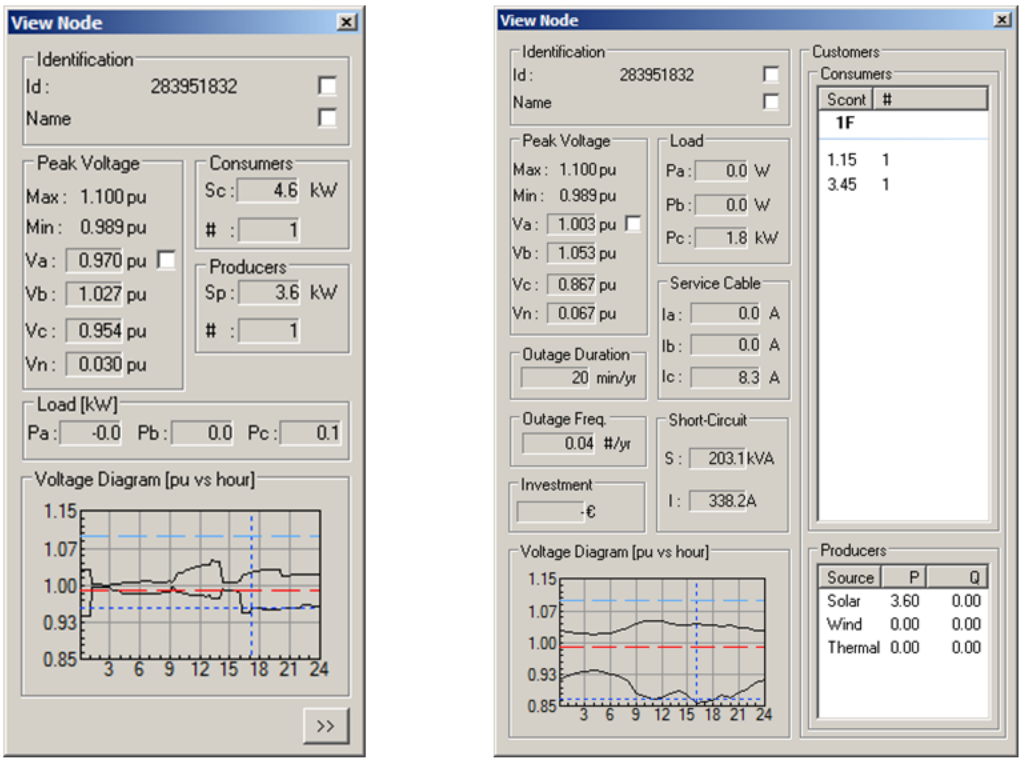

Fig. 3 Node analysis results corresponding to a chronological simulation (on the left hand side) and to a probabilistic simulation (on the right hand side)

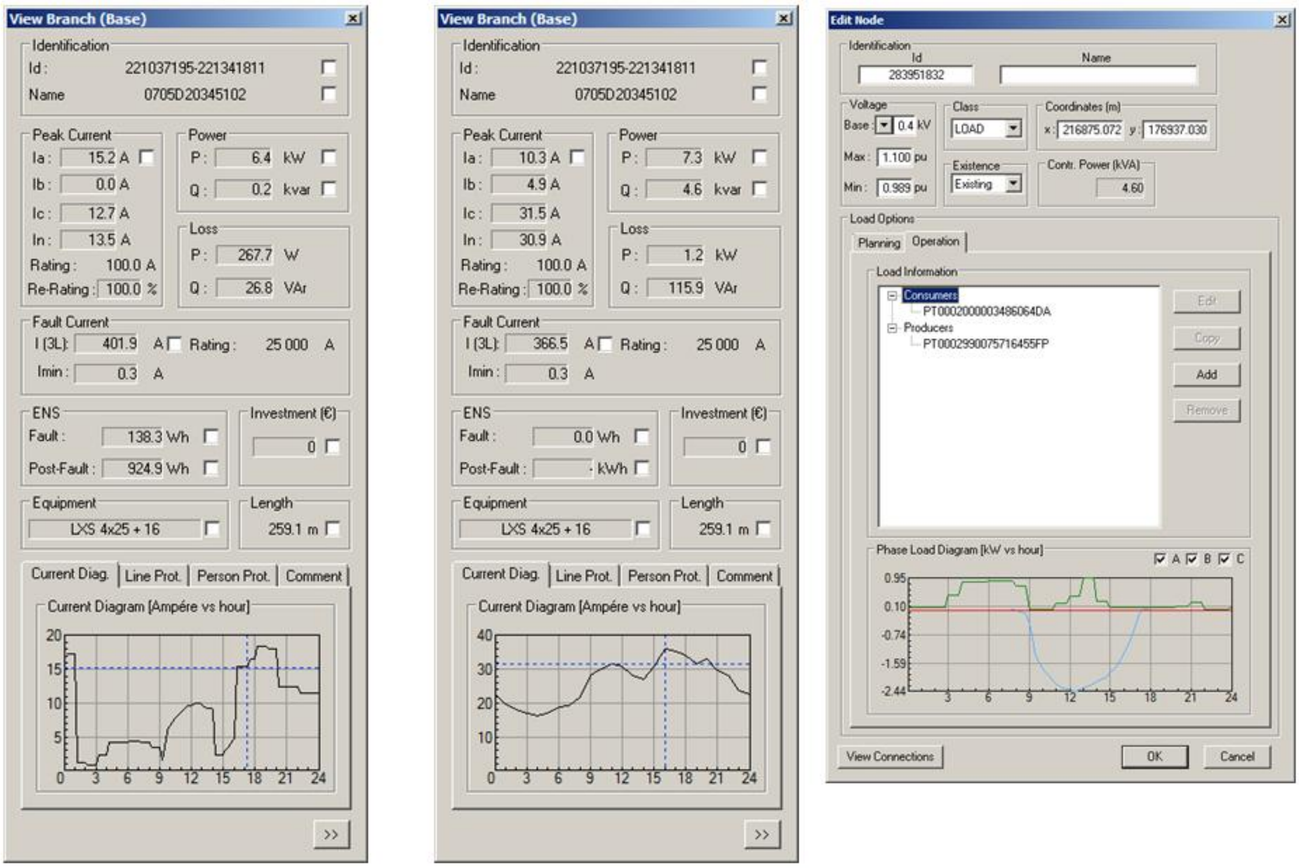

Fig. 4 Branch analysis results corresponding to a chronological simulation (on the left hand side) and to a probabilistic simulation (on the right had side). Load input information for a neighbor connection point with PV single-phase resource and single-phase load.

CONCLUSION

LV networks are playing an increasingly important role in utilities business environment. Network planning is becoming more and more demanding as consumers claim for increasing quality of service and DER integration. That new role of LV networks planning requires from the utility a frequent, thorough assessment for safety, security and efficiency of LV networks.

In this paper, we have presented EDP's advances in assessment technologies to support planning. Such assessment technologies consist of advanced probabilistic models, fast chronological simulation supported in AMI information, and a framework to integrate both within current planning systems.

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