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Evolution of Distribution Grid Planning Rules Considering the New Smart Grids Paradigms

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Abstract

The planning of distribution networks consists in choosing the necessary investments to satisfy the electricity supply respecting the technical, economic, environmental and social constraints. Until now those choices corresponded to the former networks: big and centralized energy plants feeding in a unidirectional way conventional and passive loads. With the development of renewable energies, information and communication technologies, storage technologies and electric vehicles, the major technical choices for distribution grids can be questioned since new solutions appear to ensure the good operation of the network. Thus rules for planning have to be adapted to those new paradigms in order to answer the new challenges while taking into account this new operation modes.

Keywords: Smart Grids ; Distribution Networks ; Planning ; Architectures ; Distributed Generation ; Optimization ; Monte Carlo

1. Optimization of traditional planning

The choice of the architecture – i.e. choosing the way to build lines between the loads (MV loads and MV/LV substations) and the sources (HV/MV substations) – is one of the main steps of the planning. The studied networks are French and take place in urban area, so the reference architecture is the secured feeder architecture because of its extensive use and its simplicity. Each line goes from a source, then feeds several loads and finally ends in the same or another source. This structure guarantees a good quality of supply thanks to the possibility of switching the sources when a fault occurs, by changing the location of the normally opened switch along the line.

1.1. Objective functions and settings

Algorithms to optimally build the architecture of distribution grids have been developed. The main objective for those algorithms is to reduce the total length of conductors in the network because it strongly influences the investments costs – conductors and trenches – and the costs of technical losses and energy not supplied. In order to well evaluate the real length of conductors, streets were taken into account. Location of loads and topology of the streets allow the creation of a graph and the use of methods from the Graph Theory. Thereby optimal paths between the different loads are evaluated and the right orders to connect loads with lines are given by solving the Travelling Salesman Problem.

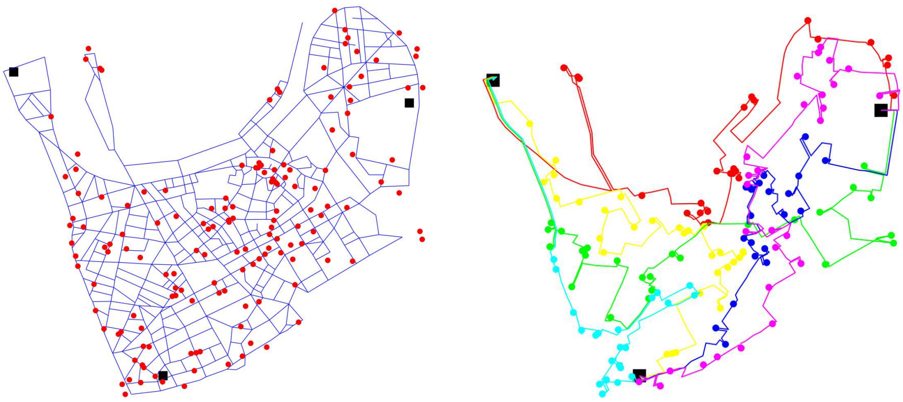

Fig. 1. (a) Map of streets and MV/LV substations; (b) Secured feeder architecture

1.2. Algorithms used for architecture building

The partitioning problem – i.e. the allocation of each load between the different lines – is solved with meat-heuristic methods. The example of the French city Grenoble is used and the results are compared to its real distribution network. The simulated annealing algorithm is chosen because it offers the best results with easy parameters setting, a low variance of results and a low computation time. The gain of length is almost seven kilometers, which represents 17,5 % gain. The weak point of the tested heuristic methods is that the optimality of results is not guaranteed. That is why other methods from the combinatory optimization are currently studied.

Table 1. Comparison between the Grenoble Network and the results of different optimization algorithm.

	Total length of conductors	Cost of cables and trenches	Cost of technical losses over 30 years	Cost of switches and energy not supplied over 30 years	Total cost
Grenoble Network	38,70 km	4 461 k€	134 k€	194 k€	4 789 k€
Ant Colony Algorithm	37,38 km	4 325 k€	146 k€	205 k€	4 676 k€
Genetic Algorithm	35,92 km	4 156 k€	137 k€	194 k€	4 487 k€
Taboo Search	32,84 km	3 795 k€	147 k€	176 k€	4 118 k€
Simulated Annealing	31,90 km	3 696 k€	132 k€	168 k€	3 996 k€

2. New paradigms of Smart Grids

Automatic tools have been developed in order to help the distribution system operator obtain architectures with minimized costs of investment and operation while respecting the constraints of the traditional planning. The second objective is to propose new type of architectures and rules for planning that will increase the insertion rate of distributed generators (DG) and none-conventional loads in the distribution networks.

The first step to build new architecture more robust to a massive insertion of DGs is to use analyzing tools that can evaluate the insertion capacity of a distribution network. Stochastic tools were already developed[1]. They are based on Monte Carlo method. Each experience of Monte Carle consists on a randomly generated case of insertion of DGs. The number, the location and the power of the generators and randomly chosen. The only parameter is the insertion rate of DGs in the network, which is:

$$\tau = P_{GED} / P_{Network}.100 \text{ (in \%)} \tag{1}$$

Where P_{GED} is the maximal total power of the DGs and $P_{Network}$ the maximal total consumption of the network. For example, an insertion rate equal to 50 % means that half of the consumed power in the network is produced by the DGs. For each insertion rate, the probability that the network operates correctly is evaluated and corresponds to:

$$P(\tau) = N_{success} / N_{test}.100 \text{ (in \%)} \tag{2}$$

Where N_{test} is the number of experiences of Monte Carlo and $N_{success}$ is the number of cases for which technical constraints – i.e. voltage and current limitations – are respected. In the following figures we can identify the lines of the networks – for an insertion rate τ equal to 100% – that are more or less sensible to a massive insertion of DGs:

The next step is to locate the risk areas and proceed to reinforcement, creation of new dedicated lines, rebuilding the architecture or anticipate the future operation plan in those areas.

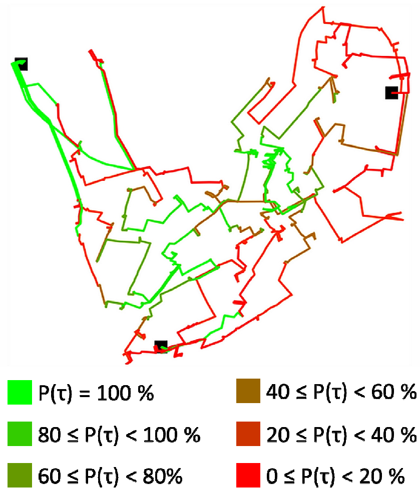

Fig. 2. Probability of good operation for each line of a network for an insertion rate equal to 100%.

References

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3. Acknowledgement

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