Sustainable Energy, Grids and Networks 1 (2015) 20–27

Contents lists available at ScienceDirect

Sustainable Energy, Grids and Networks

journal homepage: www.elsevier.com/locate/segan

Meshed distribution network vs reinforcement to increase the distributed generation connection[☆]

M.-C. Alvarez-Herault [a,c,*], N. N'Doye [c], C. Gandioli [c], N. Hadjsaid [a,c], P. Tixador [b,c]

[a] The Grenoble Electrical Engineering Laboratory (G2Elab), Saint Martin d'Hères, France

[b] CNRS, CRETA and Grenoble-InP, Saint Martin d'Hères, France

[c] Univ. Grenoble Alpes, G2Elab, F-38000 Grenoble, France

ARTICLE INFO

Article history:
Received 12 September 2014
Accepted 24 November 2014
Available online 3 December 2014

Keywords:
Power system planning
Stochastic optimization
Monte Carlo
Distributed power generation
Power distribution

ABSTRACT

The expected increase of distributed generation connected to the distribution network will bring many technical constraints. Meshing the network can be a cost effective solution but requires changing the protection scheme that does not suit to a meshed operation. The normally open switches of the network could be replaced by "quick deloopers" based on a fault current limiter device. This system would enable to mesh the network in normal condition and to bring it radial in case of fault so that the standard protection scheme could locate and isolate it. If loops are well selected, the more the network is meshed, the higher the amount of connectable distributed generation without violating technical constraints will be. This paper investigates on the best location to loop the network considering a given target of distributed generation penetration. Several algorithms are proposed to get closer to the optimal solution and tested on a real French network.

1. Introduction

DISTRIBUTED generations (DGs) are small power units that are connected to the distribution network due to their range of power ($<$12 MW in France and 10 MW in USA [1,2]). In the planning hypotheses to develop the distribution network, DGs that used to be marginal are not considered. In other words, the lines sizing, the protection scheme and the network topology are chosen considering only unidirectional power flows (from the HV/MV substations to the consumers). The economic rule to choose lines and cables follows the actualization of power losses costs during their life duration (about 30 years). This rule leads to choose an oversized cable or line to face the expected increase of the load in the following years. While DGs remain marginal, if some technical constraints appear (such as overvoltages or overcurrents), the reinforcement of the network is the current solution. Nevertheless, it is definitely not a cost-effective long term solution if the DGs penetration increases. New solutions have to be found so that the distribution network could accept a higher level of DGs. Operational solutions based on information and communication technologies are currently explored. For example, the management of active and reactive power in the network [3–8] and the association of storage devices with renewable energy [9–12] are explored. Structural solutions also must be thought. Indeed, optimizing the operation of a network whose topology is not adapted to the new paradigms is under-optimal. The optimization of the power flow distribution has an impact on the current flow and voltage drops. Consequently, it will increase the penetration of distributed generation. Rebuilding the entire distribution network with new topologies and operation modes is extremely expensive and not possible in a short term horizon. Then the question is how to increase the penetration of DGs with minor changes in the topology of the network?

The distribution network topology all around the world is mainly operated in a radial way, with only one path to supply consumers (MV/LV substations) from the HV/MV substations. The distribution network is actually a meshed graph but the presence of normally open switches (NOS) ensures its radial operation as depicted in Fig. 1.

In urban areas, due to the high load density, all the MV/LV substations are directly connected to main feeders. In rural areas, it is not economically possible to have the same structure and

☆ This work was supported in part by the European Union Seventh Framework Programme (FP7/2007–2013) under Grant 241285 in the ECCOFLOW project.

* Corresponding author at: The Grenoble Electrical Engineering Laboratory (G2Elab), Saint Martin d'Hères, France.

E-mail addresses: Marie-Cecile.Alvarez@g2elab.grenoble-inp.fr (M.-C. Alvarez-Herault), Nouredine.Hadjsaid@g2elab.grenoble-inp.fr (N. Hadjsaid), Pascal.Tixasor@g2elab.grenoble-inp.fr (P. Tixador).

http://dx.doi.org/10.1016/j.segan.2014.11.001
2352-4677/

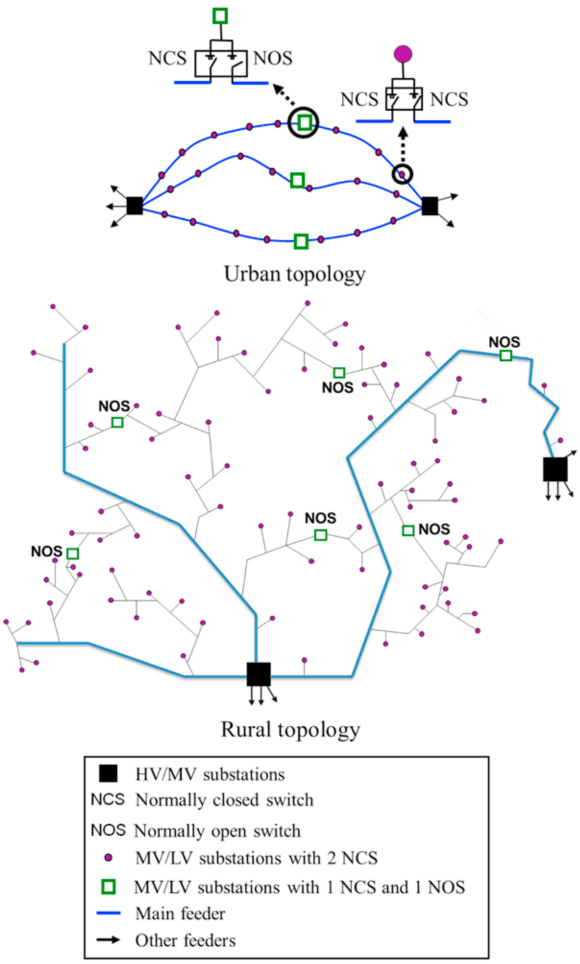

Fig. 1. Classical distribution architectures.

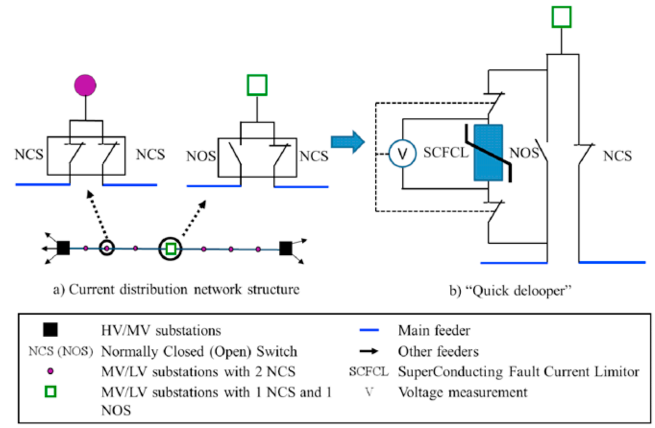

Fig. 2. "Quick delooper" principle.

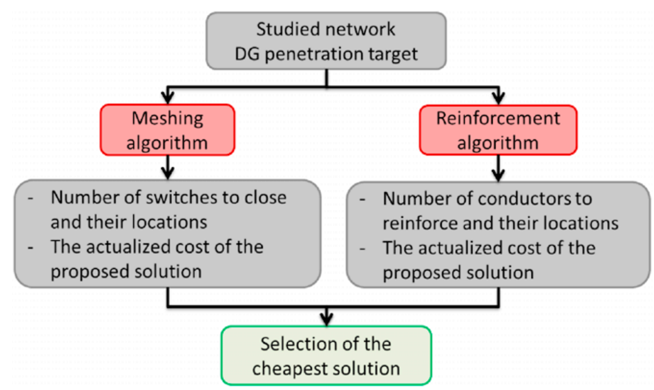

Fig. 3. Proposed planning algorithm.

an arborescent structure is more adapted. The common point between urban and rural architectures is the presence of normally open switches which enable to reconfigure the network in case of faults to reenergize as many consumers as possible. These switches can introduce flexibility by making the topology of distribution network evolve. For example, Ref. [13] changes their location to optimize power losses and [14] to minimize the Non-Delivered Power. In [15], reliability and cost operation are added in a multi-objective function and the presence of DGs in the network is also studied. Then, if these normally open switches are closed, the network can be operated as meshed. Ref. [14] shows that meshing the network has many advantages such as minimizing power losses and increasing DGs penetration by better balancing power flows. This solution is not considered nowadays by Distribution Network Operators (DNOs) because in case of faults, short-circuit currents may increase due to the decrease of the fault impedance. Moreover, the existing protection scheme in the distribution network would not be able to locate and isolate the fault. Consequently, meshing the network would lead to change or adapt the protection scheme which would be complicated and expensive.

This paper proposes a new mixed operation of the distribution network. In normal condition, the distribution network is in a meshed way and brought radial in fault condition thanks to a "quick delooper" based on a SuperConducting Fault Current Limiter (SCFCL) proposed in [16]. Fig. 2 shows its structure. It will be located in parallel to the existing normally open switches that could be used for maintenance. This device is made of an SCFCL with two normally closed switches and has a voltage measurement feature. In normal condition, the SCFCL has a null resistance thanks to the superconductor technology so the network is meshed and the measured voltage is zero. If a fault occurs in the network, the resistance of the SCFCL will rapidly increase and the voltage will also increase. If the voltage becomes higher than a critical value, an order of opening is sent to the two normally closed switches: the loop will be opened. The "quick delooper" can act in 100 ms (fault detection by the SCFCL, opening of the normally closed switches). Then it is faster than the classical protections of the distribution network. Consequently, the network will be brought radial by the "quick delooper" before that the classical protection scheme acts. [16] validates the sizing and the adjustment of the "quick delooper" on a real French network and with different kind of faults.

In this paper, the planning algorithm of Fig. 3 is proposed. Considering a desired DG insertion target, the meshing solution is compared to the reinforcement solution in terms of global cost. In Section 2, the indicators used in the planning algorithm are defined. Then in Section 3, the meshing algorithm and the reinforcement algorithm are described. For the meshing algorithm, several methods will be presented to identify the optimal number of switches to close and their location considering a DG insertion target. Then in Section 4, both algorithms are validated on a simple test network and on a real French network. For both networks, an economic comparison will justify the interest of meshing the network compared to the classical reinforcement.

2. Indicators

In the planning algorithm, two kinds of indicators are required: an economic indicator and a DG penetration indicator.