Optimal Distribution Feeders Configuration for Active Power Losses Minimization by Genetic Algorithms

Gian Luca Storti, Francesca Possemato, Maurizio Paschero, Antonello Rizzi, Fabio Massimo Frattale Mascioli
University of Rome "La Sapienza", Information Engineering, Electronics and Telecommunications Department
Polo per la Mobilità Sostenibile (POMOS) Laboratories
Email: gianluca.storti@uniroma1.it

***Abstract*—In this paper we face the problem of the joint optimization of both topology and network parameters in order to minimize the total active power losses in a real Smart Grid. It is considered a portion of the Italian electric distribution network managed by the *ACEA Distribuzione S.p.A.* located in Rome which presents back-flows of active power for 20% of the annual operative time. It includes about 1200 user loads, 70 km of MV lines, 6 feeders, a thyristor voltage regulator (TVR) and 6 distributed energy sources (5 generator sets and 1 photovoltaic plant). Network topology can be changed by 106 breakers. The grid has been accurately modelled and simulated in the phasor domain by Matlab/Simulink, relying on the SimPowerSystems ToolBox, following a Multi-Level Hierarchical and Modular approach. Network optimization is faced by defining and solving a suited multi-objective optimization problem, considering suited constraints on nominal operative ranges on voltages and currents, as well as on generator's capability functions, in order to take into account safety and quality of service issues. To this aim it is adopted a genetic algorithm, defining a suited fitness function. Tests have been performed by feeding the simulation environment with real data concerning dissipated and generated active and reactive power values. First results are very interesting, showing that relying on evolutionary computation it is possible to yield a satisfactory power factor correction, confirming that the proposed optimization technique can be adopted as the core of a hierarchical Smart Grid control system.**

I. Introduction

The wide diffusion of Distributed Generation (DG) represents a possible development of modern electrical distribution systems that can evolve towards Smart Grids (SG). An SG can be defined as an electrical network able to perform an intelligent integration of all the users connected to it (*i.e.* producers and consumers), with the purpose of distributing the electrical power in a safe, efficient and sustainable fashion. In short, it can be stated that a SG is a new generation electrical network where smartness, dynamicity, safety and reliability are achieved through the use of Information Communication Technologies (ICT) [1], [2]. Recently electrical distribution networks have grown quickly without a global planning finalized to the optimization of energy transportation. Moreover the backbones of the existing infrastructures have been built when DG was not considered at all. As a consequence, electric power is distributed to the final user through an unidirectional transportation infrastructure. This configuration implies a considerable transportation power consumption due to the long distance between producers and consumers. The main problems concerning actual networks are listed below:

- Losses due to long distance between producers and users
- Not optimal management of energetic flows
- Inefficient use of DG related to renewable energy generators
- Lag in the reaction time in case of blackout
- Incomplete and inaccurate knowledge on the instantaneous status of the infrastructure

In order to overcome these drawbacks, a large number of sensors must be installed on the network to obtain a complete information on the instantaneous status of the infrastructure. This information can be used as the input of an optimization control algorithm capable to determine in real time the best network configuration in order to satisfy the instantaneous power request and to drive suitable actuators in order to optimize a given objective function. DGs can impact the bus voltage, line power flow, short-circuit current and power network reliability, so that it is very important in SG design and realization to be able to control DGs [3],[4]. Another important degree of freedom is offered by the opportunity to perform the distribution feeders reconfiguration (DFR). This operation consists in opening and closing a certain number of breakers altering the topological structure of the network, ensuring that no loop are formed and the totality of the loads are supplied. The main advantage of DFR is that a different topology may result in reduced active power loss, increased security for the system and enhanced power quality. Conversely, the main drawback of DFR is that it results in a complex nonlinear combinatorial problem since the status of the switches is non-differentiable. In general, considering a SG as a complex, dynamic, nonlinear and stochastic system, computational intelligence (CI) can provide support for designing safer and more efficient control systems, in line with emerging technologies. From the point of view of the CI, the SG managing and control is a highly complex problem given the non-linearity and the dynamic of the system, as well as the heterogeneity of the elements that compose it (generators, transformers, transmission lines, time-variant loads, telecommunications system, market regulations). Concerning DFR, in recent years many researchers have proposed

978-1-4799-0348-1/13/$31.00 ©2013 IEEE

interesting solutions. Probably the first contribution in this direction can be found in [5], where a branch and bound type optimization technique is used in order to find the minimal loss operating configuration for the distribution system at a specific load condition. The system is modelled my means of a tree structure. After this work a few different techniques have been proposed by many researchers. Most of them make use of heuristic methods for DFR [6], [7]. Among the variety of techniques offered by CI the use of Genetic Algorithms (GA) seems to be a promising technique for DFR problems. In [8] the refined genetic algorithm (GA) has been proposed in order to reduce losses. In [9] is presented a method based on GA to determine the network configuration. The proposed method takes into consideration both the normal condition and faults into account. In order to ensure that the distribution system structure will not form closed loops, the chromosomes are encoded using the Prufer number. In [10] a method based on a fuzzy mutated genetic algorithm is proposed to perform the optimal reconfiguration of radial distribution systems. The presented approach overcomes the combinatorial nature of the reconfiguration problem allowing to deal with non-continuous multi-objective optimization. Beside DFR problems GA have been also successfully used to manage different issues related to SGs. In [11] an adaptive GA is used to establish the best distributed generation siting and sizing on a distribution network, showing that the optimal siting and sizing of DG units can effectively reduce the network loss and improve the system voltage level. In [12] it is shown that GAs can deal well with the stochastic nature of the distribution grid and can be successfully used as an optimization method for solving the control problems. Beside theoretical studies it is important to have the opportunity to validate the designed optimization strategy on real data. Moving in this direction, a cooperation with *ACEA Distribuzione S.p.A.* [13] has been engaged with the aim to design a control strategy for the SG under development in the west area of Rome. First results of this joint project have been discussed in [14], while in this paper the topology optimization problem is faced. The paper is organized in sections. A brief description of the real network taken into consideration is given in Sec. II. The implemented network simulator is described in Sec. III. In Sec. IV the multi-objectives optimization problem is formulated and the use of a GA is proposed in order to solve it. In Sec. V it is shown how the proposed control strategy can be successfully used to optimize network topology, modulating at the same time the power fed into the network by DGs in order to reduce active power losses, taking into account suited constraints on voltages and currents levels, as well as the available working points of DGs. Finally, conclusions and works in progress are discussed in Sec. VI.

II. Network Specifications

The portion of the network under consideration is located in the west area of Rome. The entire SG is made up of:

- N.5 feeders at 20 kV
- N.1 feeder at 8.4 kV
- N.2 substations (High Voltage/Middle Voltage, HV/MV)
- N.76 substations (Medium Voltage/Low Voltage, MV/LV)
- N.5 generator sets
- N.1 photovoltaic generator
- N.1 thyristor voltage regulator (TVR)
- N.106 three-phase breakers
- 70 km of cables
- 1200 user loads

In each HV/MV substation there is a transformer with 150 kV at the primary winding and 20 kV at the secondary winding. The cables, the photovoltaic plant, the MV/LV substations and the TVR are located in the MV network, whereas the user loads and the 5 generators set are located in the LV network.

The TVR is a series voltage compensation device. It performs a bi-directional voltage regulation that maintains the system voltage within specified ranges. It is used essentially to compensate the voltage variation in very long feeders. In fact, in order to maintain the feeder's voltage in the admissible range in every condition, the TVR has been placed in the middle of the 8.4 kV feeder, which is the longest one. The bi-directional relation between the input and the output voltage is defined as follows:

$$V_{out} = V_{in} + N_{tap}\Delta V \quad N_{tap} \in \{0, \pm1, \pm2, \pm3\} \qquad (1)$$

where the values of V_{in} and V_{out} are expressed in kV and the ΔV is 0.1 kV. The voltage rated value of V_{in} is 8.4 kV.

Each HV/MV and MV/LV substation is equipped with 2 breakers (switches) placed at the beginning and at input and output bus bars, respectively. By changing the state of these switches it is possible to modify the topology of the network. Among all the possible configurations, the admissible ones are only a proper subset. A configuration is admissible if it respects all the rules listed below:

- each MV/LV substation must be fed by only one HV/MV substation
- each MV/LV substation must not be fed by DG only (is not allowed the "island mode")

III. Network Simulation

The simulator that reproduces the SG described in the previous section has been implemented, using the MatLab/Simulink SimPowerSystems ToolBox following a Multi-Level Hierarchical and Modular approach. The Multi-Level Hierarchical design improves, through the definition of suitable I/O interfaces, the readability of the whole simulation model. The Modular approach allows to change, in a simple way, all the parameters of each component models. The SG simulation model is made up of 2 macro blocks called *Network Inputs* and *Electrical Network*, respectively. The *Network Inputs* block contains all the inputs of the simulation, *i.e.* the user loads and DGs power profiles. More precisely for the user loads it is given the active and the reactive hourly power profile whereas, for the DGs, the active and the reactive power are specified through the following equations:

$$P = kP_r \qquad Q = P\tan\phi \qquad (2)$$

where P_r, k and ϕ represent the rated power, the gain and the phase, respectively.

The *Electrical Network* block contains all the models of the physical components *i.e.* cables, transformers etc. The network voltages and the currents, corresponding to a given imputed power profiles, represent the output of the simulation.

Inside the *Electrical Network* block there are the MV and the LV networks and a block labelled *State Breakers*. The HV/MV and MV/LV transformers are modelled using a built-in block called *Three-Phase Transformer Inductance Matrix Type (Two Windings)*. The cables are modelled by using the built-in block based on lumped parameters (Π model). The power driven loads and generators are modelled using the same custom block. This block is essentially a voltage controlled current source, with $I = [(2P)/V]^*$ where the value of P is read from the corresponding data file and the voltage V is measured at the three phase-port of the block modelling the load (* represents the conjugate operator). The TVR has been modelled using a built-in block named *Multi-Windings Transformer*.

Inside the *State Breakers* block there are several flags that identify the state of the breakers. In order to respect the topological rules mentioned above, and considering that 2 switches in series are logically equivalent to a single one, only a subset of all physical breakers are taken into consideration. This subset is composed by 20 virtual breakers, represented in the simulator by a binary string of 20 bits. The graph associated with the SG, where the 20 lines with a virtual breaker are highlighted in red, is shown in Figure 1.

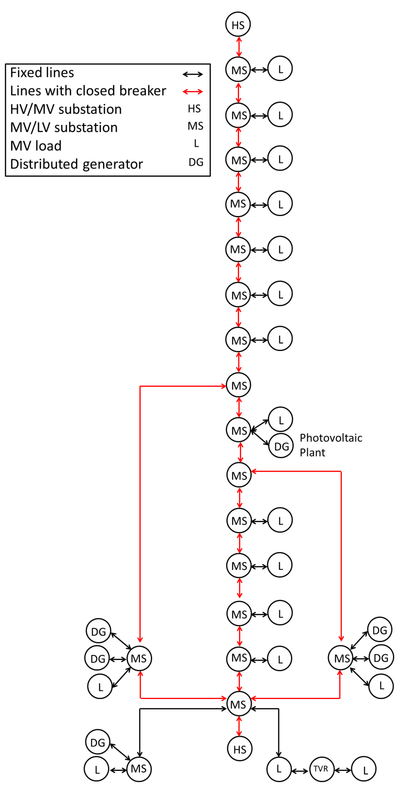


Figure 1: The simplified graph network representation for the SG.

The SimPowerSystem of MatLab/Simulink allows to use, for three phase network simulation, three solution methods: Continuous, Discrete and Phasor. Since the simulation sampling time is equal to 1 hour, it is possible to consider exhausted any transient response. For this reason the electrical network analysis has been carried out by using Phasor method.

IV. Optimization Procedure

In this section it is described how the considered active power losses optimization problem can be formulated in terms of a multi-objective optimization problem and solved by adopting a suitable evolutionary computation approach. The faced problem consists in finding the optimal network parameters and topological configuration that minimize the value of the total active power losses in the network, considering the constraints imposed on voltages and currents due to safety or quality of service issues.

Consider, an admissible set E and a suitable cost function $J : E \rightarrow \mathbb{R}$ that associates a real number to each element in E. Formally, the problem consists in minimizing the function J in E. Without loss of generality it has been considered possible to measure the voltages and the currents at all locations in the network in order to compute the cost function. It is not possible to control the active power of photovoltaic generator. However, it is possible to indirectly control the reactive power of the remaining 5 generator sets through the phase parameter ϕ as expressed in (2). Moreover it is possible to chose the N_{tap} value (see Eq.(1)) of the TVR and the topological configuration of the network. In particular, the parameters that have to be optimized are the phases of the five electric generators $\phi_1, \phi_2, \phi_3, \phi_4, \phi_5$, the tap N_{tap} of the TVR and each of the bits $b_1, ..., b_{20}$ associated one to one with the state of the 20 virtual breakers that control the topology of the network. According with the rules listed at the end of Section II, the number of admissible configurations obtained considering the 20 virtual breakers is 58, much less than 2^{20}. Once all these configurations have been identified by visual inspection on a simplified graph representation, each one can be identified by an integer number $N_{conf} \in [1, 58]$. The bits string associated with each one of these 58 configuration is obtained by means of a suitable mapping procedure. Although neither the N_{tap} value and the configuration number N_{conf} are real number (being the first one a discrete ordinal variable and the latter a discrete nominal one), in order to simplify the optimization procedure, they will be both mapped into suitable ranges of real numbers. More precisely, N_{tap} and N_{conf} will be considered as real variables uniformly distributed in the range $[-3.49, 3.49]$ and $[0.50, 58.49]$, respectively. These real variables will be then mapped back into integer numbers through a rounding procedure. For example each value of $N_{tap} \in [-3.49, -2.50]$ will be mapped in -3. Each phase parameter will span in a given range specified by the capability functions of the corresponding generator set. Summarizing, the candidate solution vector $\mathbf{k} = \{\phi_1, \phi_2, \phi_3, \phi_4, \phi_5, N_{tap}, N_{conf}\}$ will span in the set defined below:

$$A = \{ \mathbf{k} \subset \mathbb{R}^7 : -0.2 \leq \phi_1, \phi_2 \leq 0.45 \quad (3)$$
$$-0.2 \leq \phi_3 \leq 0.55$$
$$0.0 \leq \phi_4 \leq 0.64$$
$$-0.32 \leq \phi_5 \leq 0.45$$
$$-3.49 \leq N_{tap} \leq 3.49$$
$$0.50 \leq N_{conf} \leq 58.49 \}$$

In order to be valid a solution must satisfy the constraints on voltages and currents defined below:

$$B = \left\{ \mathbf{k} \subset \mathbb{R}^7 : 0.9V_{nom_j} \leq V_j(\mathbf{k}) \leq 1.1V_{nom_j}, j = 1,..,N \right\} \quad (4a)$$

$$C = \left\{ \mathbf{k} \subset \mathbb{R}^7 : |I_j(\mathbf{k})| \leq I_{max_j}, j = 1,..,R \right\} \quad (4b)$$

in which N and R represents the total number of nodes and branches of the network, respectively, whereas V_{nom_j} and I_{max_j} are the nominal value of the voltage of the j-th node and the maximum current allowed in the j-th wire, respectively.

The definitions given above allow to define the admissible set E as follows:

$$E = A \cap B \cap C \quad (5)$$

The cost function J has been defined as follows:

$$J(\mathbf{k}) = \frac{P_{loss}(\mathbf{k})}{P_{gen}(\mathbf{k})} = \frac{P_{gen}(\mathbf{k}) - P_{load}}{P_{gen}(\mathbf{k})} \quad (6)$$

where $P_{gen}(\mathbf{k})$ is the total power generated by all sources, P_{load} is the total power absorbed by the loads, and their difference $P_{loss}(\mathbf{k})$ represents the total losses in the network.

Given a particular determination $\overline{\mathbf{k}}$ of the vector $\mathbf{k}$, the value returned by (6) is equal to the normalized total active power losses in the network, and can be considered as a measure of how well $\overline{\mathbf{k}}$ solves the optimization problem. Since it is not practically possible do derive expression (6) in closed form as a function of $\mathbf{k}$, in this paper a GA (derivative free approach) has been employed. The constrained optimization problem can be faced by defining a multi-objective optimization, by relying on the following fitness function:

$$F(\mathbf{k}) = \alpha J(\mathbf{k}) + (1 - \alpha)\Gamma(\mathbf{k}) \quad (7)$$

where α is a coefficient between 0 and 1 used to adjust the relative weight of the power losses term $J(\mathbf{k})$ over the constraints term $\Gamma(\mathbf{k})$. The function $\Gamma(\mathbf{k})$ is defined as follows:

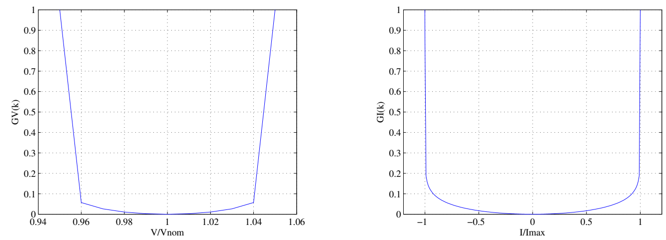
$$\Gamma(\mathbf{k}) = (1 - \beta)\Gamma_I(\mathbf{k}) + \beta\Gamma_V(\mathbf{k}) \quad (8)$$

in which β is a real number between 0 and 1 used to adjusts the relative weight of the violation of current constraints with respect to the term related to voltages violation. The function $\Gamma_V(\mathbf{k})$ and $\Gamma_I(\mathbf{k})$ are defined below:

$$\Gamma_V(\mathbf{k}) = \max_{i=0..N} \{G_V(V_i(\mathbf{k})/V_{nom_i})\} \quad (9a)$$

$$\Gamma_I(\mathbf{k}) = \max_{i=0..R} \{G_I(I_i(\mathbf{k})/I_{max_i})\} \quad (9b)$$

where V_{nom_i} is the nominal value of tensions and I_{max_i} the maximum value of the currents on the i-th node and in the i-th line, respectively. The penalty functions G_V and G_I are shown in Figure 2 part (a) and (b), respectively. The problem solved in this paper consists in minimizing the function $F(\mathbf{k})$ in the admissible domain A.

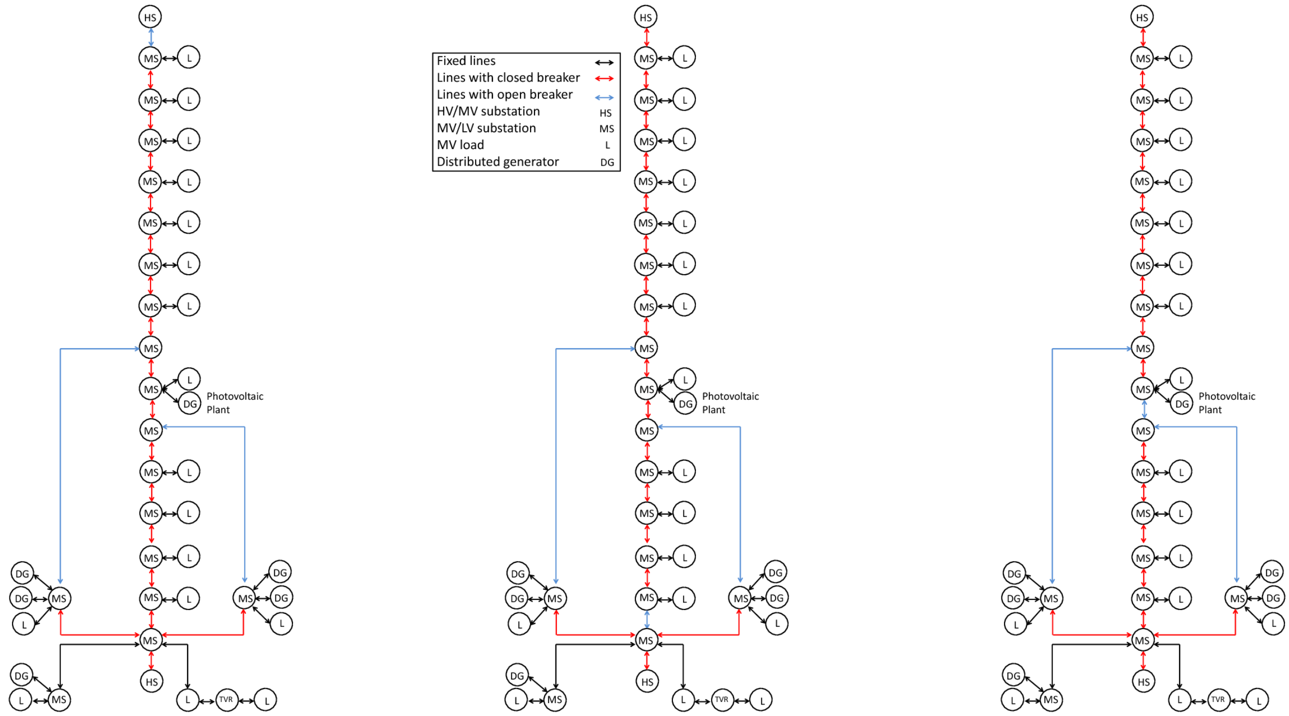


(a) (b)

Figure 2: Penality functions: (a) $G_V(\mathbf{k})$, (b) $G_I(\mathbf{k})$.

V. Tests and results

Considering the active power loss optimization problem introduced in the previous section, in order to test the effectiveness of the proposed optimization procedure several runs of the GA has been performed. In these runs the GA has tried about the 80% of the 58 admissible configurations. Thus is reasonable to assume that the set of all the evaluated topologies contain the best one. Analysing the obtained results it is possible to make a few considerations on the actions of the entire control system and the behaviour, generation by generation, of the GA. The first generation of each run of the GA has been set choosing randomly point in the domain A defined in (3). This initialization does not guarantee the satisfaction of the constraints defined in (4). This choice has been made in order to verify if the optimization algorithm is able to bring back the network in a configuration satisfying all the constraints, possibly minimizing the total active power losses. The SG has been simulated and validated for a single sample of time (one hour). More precisely, in order to stress the network, the chosen sample is the 1.00PM one when the photovoltaic plant generates the maximum power. All the simulations have been realized using the Matlab Global Optimization Toolbox together with the developed Simulink network simulator. Without loss of generality, voltages and currents have been measured in some critical nodes and branches chosen on the basis of the network topology. For each run, the number of generations has been set equal to 50, the number of individuals for each generation has been set equal to 10, α coefficient has been set equal to 0.9 and β coefficient has been set equal to 0.2. Due to the discontinuities in the fitness function caused by N_{conf} parameter, the GA is in charge to solve a difficult optimization problem. Anyway it is reasonable to assume that the topology associated with the individuals belonging to the latest generation will be more performing than the remaining ones. For this reason, among the different topologies associated with the individuals of the last generation, the 2 best ones in term of active power loss,



(a) (b) (c)

Figure 3: Network graph representations: (a) over-voltage configuration, (b) first best configuration, (c) second best configuration.

have been taken into consideration. The graphs that represent the network topology for the over-voltage configuration and the 2 best configurations are shown in Figure 3 part (a) (b) and (c), respectively. In order to compare the optimization procedure performance with or without topology optimization, an additional run of GA has been done, with a fixed over-voltage topology. The values of the fitness function, after the optimization procedure, for the topologies associated with the graphs shown in Figure 3 parts (a), (b), and (c) are 0.0462, 0.0097 and 0.0096, respectively.

The percentages of the power distribution in the loads, DGs, network and at the balance nodes are shown in Table I parts (A), (B), (C) and (D), for the not optimized over-voltage topology, the optimized over-voltage topology, the first best and the second best solutions, respectively. The balance nodes are the 2 HV network nodes at 150 kV that provide the energy balance of the active and the reactive power in the SG.

Comparing Table I part (A), (B), (C), and (D) it is possible to figure out the distribution of absorbed active power (AAP), generated active power (GAP), inductive reactive power (IRP) and capacitive reactive power (CRP) among the loads, the DGs, the balance nodes and the network for the 4 cases taken into consideration. Some relevant comments can be made about the absorbed and generated reactive power in the various conditions. In the uncontrolled over-voltage configuration the IRP associated with the Loads and the Balance Nodes is 58.33% and 41.67%, respectively whereas the CRP associated with DGs and the network is 92.10% and 7.99%, respectively. Instead, in the optimized over-voltage configuration, the IRP

Table I: Percentage of power distribution among Loads, DGs, Network and Balance Nodes: (A) not optimized over-voltage configuration, (b) optimized over-voltage configuration, (c) first best solution, (D) second best solution.

	Loads[%]	DGs[%]	Balance Nodes[%]	Network[%]
AAP	75.61	0.00	21.01	3.38
GAP	0.00	100.00	0.00	0.00
IRP	58.33	0.00	41.67	0.00
CRP	0.00	92.10	0.00	7.99

(A)

	Loads[%]	DGs[%]	Balance Nodes[%]	Network[%]
AAP	75.61	0.00	21.99	2.40
GAP	0.00	100.00	0.00	0.00
IRP	77.04	22.96	0.00	0.00
CRP	0.00	74.90	14.00	11.10

(B)

	Loads[%]	DGs[%]	Balance Nodes[%]	Network[%]
AAP	64.20	0.00	34.80	1.00
GAP	0.00	85.01	14.99	0.00
IRP	100.00	0.00	0.00	0.00
CRP	0.00	48.30	43.70	8.00

(C)

	Loads[%]	DGs[%]	Balance Nodes[%]	Network[%]
AAP	64.80	0.00	34.20	1.00
GAP	0.00	86.06	13.94	0.00
IRP	100.00	0.00	0.00	0.00
CRP	0.00	27.90	69.10	3.00

(D)

associated with the Loads and DGs is 77.04% and 22.96%, respectively; the CRP associated with the DGs, the Balance Nodes and the Network is 74.90%, 14% and 11.10%, respectively. Therefore the optimization procedure reduces the total amount of reactive power from 12.44 MVar in the not optimized configuration to 9.28 MVar in the optimized configuration performing a power factor correction (PFC). In the first best topology the IRP associated with the Loads is 100% and the CRP associated with the DGs, the Balance Nodes and the Network is 48.30%, 43.70% and 8.00%, respectively. Also in the second best topology the IRP associated with the Loads is 100% and the CRP associated with the DGs, the Balance Nodes and the Network is 27.90%, 69.10% and 3.00%, respectively. In both cases the GA still performs a PFC, reducing the total amount of reactive power flowing in the network to the minimum possible value, *i.e.* the value required by the Loads (7.14 MVar). More precisely, the fixed amount of IRP associated with the loads is compensated by the CRP associated with the DGs, the Balance Nodes and the Network. A very important aspect concerns the presence of black-flow of active and reactive power. The aim of the optimization procedure is to cancel this return of power. The GA, acting on the ϕ of the DGs, is able to cancel black-flows of the reactive power, but it is not able to cancel black-flows of the active power being not allowed to act on the generetor sets gain k_i. Finally, the total (absorbed or generated) active power in Table I parts (A) and (B) is 19.52 MW, in part (C) is 22.98 MW and in part (D) is 22.61 MW. The total (inductive or capacitive) reactive power in Table I part (A) is 12.44 MVar, in part (B) is 9.28 MW and in part (C) and (D) is 7.14 MW. In each run, after 20 generations the trend of the fitness function becomes almost stable. With respect to the uncontrolled over-voltage configuration, in the optimized over-voltage configuration the total power loss decreases by approximately 30 % (from 0.7 MW to 0.5 MW). Instead, with respect to the uncontrolled over-voltage configuration, in both the first and the second best topologies the decrease of power loss is 80% (from 0.7 MW to 0.13 MW). All the network configurations shown in Figure 3 part (a), (b) and (c) are compliant with all constraints on voltage and current mentioned in (4).

VI. Conclusions

In this paper it has been proposed a control system able to reduce power losses in the *ACEA Distribuzione S.p.A.* Smart Grid in the west area of Rome. The network has been accurately modelled and simulated relying on the MatLab/Simulink SimPowerSystems ToolBox, which allows to rapidly and easily build models to simulate power systems. A GA is in charge of modulating the DGs active and reactive powers, fixing the TVR working point and determining the best network topology by changing breakers state, while considering suitable constraints on voltages and currents imposed by safety and quality of service issues. Moreover the constraints imposed by safe operational limits established by the Capability Curve of generator sets have been considered. The optimization problem has been faced as a multi-objective one, since power losses minimization and constraints satisfaction are conflicting objectives. Although the introduction of state breakers in the objective function domain (topology optimization) defines a challenging optimization problem due to high discontinuities in the fitness function, first results are very encouraging. Future works will concern on automatic and distributed algorithms to determine the set of admissible network topologies and on considering a representation for breakers state based on network state transition diagrams, in order to redefine more suitable mutation and crossover operators.

Acknowledgments

The authors wish to thank Acea Distribuzione S.p.A for providing loads and energy consumption profiles and for their useful support during the SG simulator design and test phases. Special thanks to Ing. Stefano Liotta, Chief Network Operation Division, and to Ing. Silvio Alessandroni, Chief Electric Power Distribution Remote Control Division.

References

[1] L. Dahu, “Electric power communication system of the future smart grid,” *Telecommunication for Electric Power System*, vol. 32, no. 222, Apr. 2011.
[2] S. Qiang, “The communication system of smart grid,” *Equipment Manufacturing Technology*, no. 3, 2011.
[3] L. Caihao and D. Xianzhong, “Distribution generation and its impaction on power system,” *Automation of Electric Power System*, vol. 6, pp. 53–56, 2001.
[4] C. Jinlan and L. Tianqi, “Distributed generation and its grid interconnection issue,” *Modern Electric Power*, vol. 3, no. 24, pp. 53–57, 2007.
[5] A. Merlin and H. Back, “Search for a minimal loss operating spanning tree configuration in an urban power distribution system,” in *Proceedings of 5th Power System Computation Conference Cambridge U.K.*, 1975, p. 118.
[6] S. Civanlar, J. Grainger, H. Yin, and S. Lee, “Distribution feeder reconfiguration for loss reduction,” *IEEE Transactions on Power Delivery*, vol. 3, no. 3, pp. 1217–1223, 1988.
[7] T. McDermott, I. Drezga, and R. Broadwater, “A heuristic nonlinear constructive method for distribution system reconfiguration,” *IEEE Transactions on Power Systems*, vol. 14, no. 2, pp. 478–483, 1999.
[8] J. Zhu, “Optimal reconfiguration of electrical distribution network using the refined genetic algorithm,” *Electric Power Systems Research*, vol. 62, pp. 37 – 42, 2002.
[9] Y. Hong and S. Hu, “Determination of network configuration considering multi-objective in distribution systems using genetic algorithm,” *IEEE Transactions on Power Systems*, vol. 20, no. 2, pp. 1062–1069, 2005.
[10] K. Prasad and R. Ranjan, “Optimal reconfiguration of radial distribution system using a fuzzy mutated genetic algorithm,” *IEEE Transactions on Power Delivery*, vol. 20, no. 2, pp. 1211–1213, 2005.
[11] X. Lili, Q. Xiaoyan, W. Xiwen, and L. Xingyuan, “Research of distribution generation planning in smart grid construction,” in *Power and Energy Engineering Conference (APPEEC), Asia Pacific*, 2010.
[12] P. C. Ramaswamy and G. Deconinck, “Relevance of voltage control, grid reconfiguration and adaptive protection in smart grids and genetic algorithm as an optimization tool in achieving their control objectives,” in *International Conference on Networking, Sensing and Control*, Delft, the Netherlands, 11-13 April 2011.
[13] [Online]. Available: www.aceaspa.it/section.aspx/en/history?lang=en
[14] G. Storti, F. Possemato, M. Paschero, S. Alessandroni, A. Rizzi, and F. F. Mascioli, “Active power losses constrained optimization in smart grids by gentic algorithms,” *Prooceeding of 22nd Italian Workshop on Neural Networks (WIRN 2012)*, 2012.