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Radial Distribution Network Expansion Planning by using Genetic Algorithms

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ABSTRACT

Distribution network expansion planning denotes where, when and how many new lines should be installed at distribution system in order to cope with load growing. In distribution systems, the load is usually increased and an expansion planning is required to satisfy the demand in the future. In this paper, distribution network expansion planning is presented to deal with load evolution. The expansion problem is mathematically formulated as a constrained optimization programming and solved by using genetic algorithms. A radial distribution network is considered as test system. The simulation results demonstrate the validity of the proposed method.

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INTRODUCTION

The optimal expansion of distribution network to meet the growing electrical demand without compromising the reliability is a complicate and nonlinear multi-objective optimization planning. The problem often aims at minimizing cost subject to technical and economical constraints. The objective function mainly comprises investment, operation, and reliability costs. Distribution network expansion planning has been widely investigated (Carvalho *et al.*, 2000; Asakura *et al.*, 2003; Cossi and Mantovani, 2009; Martin and Borges, 2011; Wang *et al.*, 2011; Cossi *et al.*, 2012; Millar *et al.*, 2012; El-Zonkoly, 2013; Khodaei and Shahidehpour, 2013; Samper and Vargas, 2013a; Samper and Vargas, 2013b). Paper (Ravadanagh and Roshanagh, 2014) implements new developed imperialist competitive algorithm for the optimal expansion planning of distribution network. The topology of medium voltage distribution network is designed by optimal sizing, sitting, and timing of medium voltage network components. A multistage expansion planning is proposed to consider dynamic behavior of the system parameters asset management and geographical constraints. In order to reach the global solution an efficient coding is developed for ICA parameters. The Greedy algorithm is used to solve the minimum spanning tree problem to construct a radial configuration of the mesh network. A sensitivity analysis is used to show the robustness of the results with respect to ICA parameters variation. Paper (Borges and Martins, 2012) addresses a methodology for active distribution networks dynamic expansion planning based on Genetic Algorithms, where Distributed Generation integration is considered together with conventional alternatives for expansion, such as, rewiring, network reconfiguration, installation of new protection devices, etc. All aspects related to the expansion planning problem, such as multiple objective analysis, reliability constraints, modeling under uncertainties of demand and power supplied by Distributed Generation units and multistage planning, which are usually dealt with separately, are considered in an integrated model. Uncertainties are represented through the use of multiple scenario analysis. An algorithm based on the pseudo-dynamic programming theory incorporates multiple stages. Popović *et al.*, (2014) provides a hybrid simulated annealing (SA) and mixed integer linear programming (MILP) approach for static expansion planning of radial distribution networks with distributed generators (DGs). The expansion planning problem is first modeled as MILP optimization problem with the goal of minimizing the investment cost, cost of losses, cost of customer interruptions due to failures at the branches and at DGs and the cost of lost DG production due to failures at branches. In order to reduce the complexity of planning problems the decomposition of the original problem is proposed into a number of sequences of sub-problems (local networks) that are solved using the MILP model. The decomposition and solution process is iteratively guided and controlled by the proposed SA algorithm that employs the proper intensification and diversification mechanism to obtain the minimum total cost solution. Aghaei *et al.*, (2013) presents a multiobjective optimization algorithm for the MDEP (Multi-Stage Distribution

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Expansion Planning) in the presence of DGs using nonlinear formulations. The objective functions of the MDEP consist of minimization of costs, END (Energy-Not-Distributed), active power losses and voltage stability index based on SCC (Short Circuit Capacity). A MPSO (modified Particle Swarm Optimization) algorithm is developed and used for this multiobjective MDEP optimization. In the proposed MPSO algorithm, a new mutation method is implemented to improve the global searching ability and restrain the premature convergence to local minima. In paper (Sedghi), HV/MV substations, main and reserve MV feeders, dispatch able DG sources and storage units are considered as possible solutions for multistage distribution expansion planning. A three-load level is used for variable load and some strategies are proposed for DG and storage units operation. A modified PSO algorithm is applied to solve the complex optimization problem. Numerical results of the case studies show the ability of the modification. Moreover, the proposed strategies improve the distribution network from both economical and reliability points of view compared with the other methods.

In this paper, distribution network expansion planning is addressed. The problem is presented as a constrained optimization programming and solved by using genetic algorithms. A 30-bus test system is considered as illustrative test case. Simulation results demonstrate the ability of the proposed method at minimizing cost subject to technical constraints such as voltage profile and line flow limitations.

Mathematical Modeling:

From view of mathematical modeling, distribution expansion planning is a constrained optimization problem and can be formulized as below:

$$\text{Min} \left[\sum_{t=1}^T XL_t \times IC_t \right] \quad (1)$$

Subject to

$$S_{ij} \leq S_{ij}^{\max} \quad (2)$$

$$S_{ji} \leq S_{ji}^{\max} \quad (3)$$

$$V^{\min} \leq V \leq V^{\max} \quad (4)$$

$$\Sigma P_i - \Sigma P_o = 0 \quad (5)$$

$$\Sigma Q_i - \Sigma Q_o = 0 \quad (6)$$

In the presented problem, objective function (1) indicates the investment cost of new lines in network, where, vector XL_t shows the new lines at stage t and vector IC_t represents the investment cost of new lines at stage t . This objective function should be minimized during planning. Constraints (2) and (3) show the maximum allowable apparent power of lines, and the apparent power from both terminals of each line should be less than the proposed maximum value; where, S_{ij} shows the apparent power from bus i to bus j . Constraint (4) represents the voltage limitation at all buses of the network. Constraints (5) and (6) show the equilibrium of active and reactive powers at all nodes, where P_i and P_o show the active input and output powers respectively, Q_i , and Q_o show the reactive input and output powers respectively.

Genetic Algorithm:

Genetic algorithm (GA) is a search heuristic that mimics the process of natural selection. This heuristic is routinely used to generate useful solutions to optimization and search problems. Genetic algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover. Genetic algorithms find application in bioinformatics, phylogenetics, computational science, engineering, economics, chemistry, manufacturing, mathematics, physics, pharmacometrics and other fields (Haupt and Haupt, 2014).

In a genetic algorithm, a population of candidate solutions (called individuals, creatures, or phenotypes) to an optimization problem is evolved toward better solutions. Each candidate solution has a set of properties (its chromosomes or genotype) which can be mutated and altered; traditionally, solutions are represented in binary as strings of 0s and 1s, but other encodings are also possible. The evolution usually starts from a population of randomly generated individuals, and is an iterative process, with the population in each iteration called a generation. In each generation, the fitness of every individual in the population is evaluated; the fitness is usually the value of the objective function in the optimization problem being solved. The more fit individuals

are stochastically selected from the current population, and each individual's genome is modified (recombined and possibly randomly mutated) to form a new generation. The new generation of candidate solutions is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population. A typical genetic algorithm requires (Haupt and Haupt, 2014):

- A genetic representation of the solution domain
- A fitness function to evaluate the solution domain

A standard representation of each candidate solution is as an array of bits. Arrays of other types and structures can be used in essentially the same way. The main property that makes these genetic representations convenient is that their parts are easily aligned due to their fixed size, which facilitates simple crossover operations. Variable length representations may also be used, but crossover implementation is more complex in this case. Tree-like representations are explored in genetic programming and graph-form representations are explored in evolutionary programming; a mix of both linear chromosomes and trees is explored in gene expression programming.

Initialization:

Initially many individual solutions are (usually) randomly generated to form an initial population. The population size depends on the nature of the problem, but typically contains several hundreds or thousands of possible solutions. Traditionally, the population is generated randomly, allowing the entire range of possible solutions (the search space). Occasionally, the solutions may be "seeded" in areas where optimal solutions are likely to be found.

Selection:

During each successive generation, a proportion of the existing population is selected to breed a new generation. Individual solutions are selected through a fitness-based process, where fitter solutions (as measured by a fitness function) are typically more likely to be selected. Certain selection methods rate the fitness of each solution and preferentially select the best solutions. Other methods rate only a random sample of the population, as the former process may be very time-consuming. The fitness function is defined over the genetic representation and measures the quality of the represented solution. The fitness function is always problem dependent. For instance, in the knapsack problem one wants to maximize the total value of objects that can be put in a knapsack of some fixed capacity. A representation of a solution might be an array of bits, where each bit represents a different object, and the value of the bit (0 or 1) represents whether or not the object is in the knapsack. Not every such representation is valid, as the size of objects may exceed the capacity of the knapsack. The fitness of the solution is the sum of values of all objects in the knapsack if the representation is valid, or 0 otherwise.

Crossover and Mutation:

The next step is to generate a second generation population of solutions from those selected through genetic operators: crossover (also called recombination), and/or mutation. For each new solution to be produced, a pair of "parent" solutions is selected for breeding from the pool selected previously. By producing a "child" solution using the above methods of crossover and mutation, a new solution is created which typically shares many of the characteristics of its "parents". New parents are selected for each new child, and the process continues until a new population of solutions of appropriate size is generated. Although reproduction methods that are based on the use of two parents are more "biology inspired", some research (Cossi and Mantovani, 2009; Millar *et al.*, 2012) suggests that more than two "parents" generate higher quality chromosomes. These processes ultimately result in the next generation population of chromosomes that is different from the initial generation. Generally the average fitness will have increased by this procedure for the population, since only the best organisms from the first generation are selected for breeding, along with a small proportion of less fit solutions. These less fit solutions ensure genetic diversity within the genetic pool of the parents and therefore ensure the genetic diversity of the subsequent generation of children.

Termination:

This generational process is repeated until a termination condition has been reached. Common terminating conditions are: A solution is found that satisfies minimum criteria; Fixed number of generations reached; Allocated budget (computation time/money) reached; The highest ranking solution's fitness is reaching or has reached a plateau such that successive iterations no longer produce better results; Manual inspection.

Test System:

An 11 kV distribution system with 30 buses is considered as case study. The system has a main feeder and three laterals. Single line diagram of the system is depicted in Figure 1. The data for the system are listed in

Table 1 and other data can be found in (Eminoglu and Hocaoglu, 2005). Initial voltage magnitude at all buses is considered to be the same as the source bus. The power flow results of the initial system is depicted in figure 2 and it is seen that voltage constraints in some buses are violated and expansion is necessary. The horizon planning for expansion is 5 years and load is annually 5% increased. A static expansion planning is assumed and all lines are installed at first year. The voltages limitations are 0.95 and 1.05 per unit.

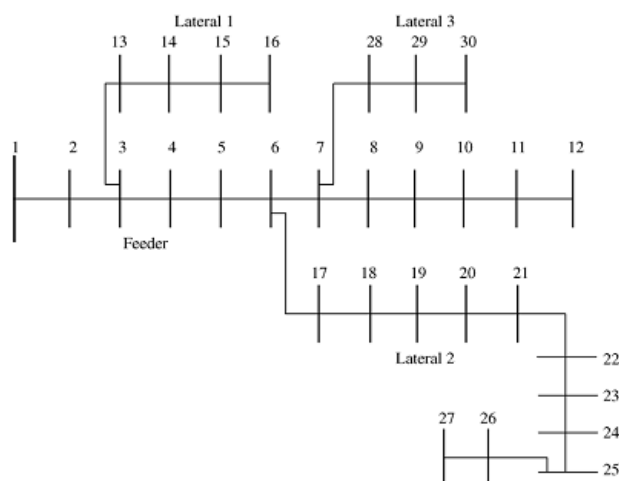


Fig. 1: 30 bus radial distribution system.

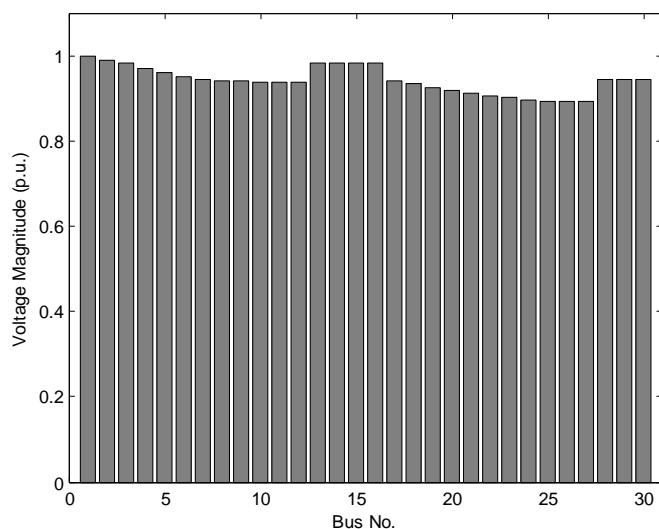


Fig. 2: Voltage magnitude profile.

Table 1: The network data.

Feeder section	Load		R+jX(pu)
	P(pu)	Q(pu)	
1-2	0.0042	0.0026	0.0967+0.0397i
2-3	0	0	0.0886+0.0364i
3-4	0.0042	0.0026	0.1359+0.0377i
4-5	0.0042	0.0026	0.1236+0.0343i
5-6	0	0	0.1236+0.0343i
6-7	0	0	0.2598+0.0446i
7-8	0.0042	0.0026	0.1732+0.0298i
8-9	0.0042	0.0026	0.2598+0.0446i
9-10	0.0041	0.0025	0.1732+0.0298i
10-11	0.0042	0.0026	0.1083+0.0186i
11-12	0.0025	0.0015	0.0886+0.0149i
3-13	0.0011	0.0007	0.1299+0.0223i
13-14	0.0011	0.0007	0.1732+0.0298i
14-15	0.0011	0.0007	0.0886+0.0149i
15-16	0.0002	0.0001	0.0433+0.0074i
6-17	0.0044	0.0027	0.1483+0.0412i
17-18	0.0044	0.0027	0.1359+0.0377i
18-19	0.0044	0.0027	0.1718+0.0391i
19-20	0.0044	0.0027	0.1562+0.0355i

20-21	0.0044	0.0027	0.1562+0.0355i
21-22	0.0044	0.0027	0.2165+0.0372i
22-23	0.0044	0.0027	0.2165+0.0372i
23-24	0.0044	0.0027	0.2598+0.0446i
24-25	0.0044	0.0027	0.1732+0.0298i
25-26	0.0044	0.0027	0.1083+0.0186i
26-27	0.0026	0.0016	0.0886+0.0149i
7-28	0.0017	0.0011	0.1299+0.0223i
28-29	0.0017	0.0011	0.1299+0.0223i
29-30	0.0017	0.0011	0.1299+0.0223i

Simulation Results:

The proposed method for expansion is performed based on the given test system and results are listed in Table 2. It is seen that in order to satisfy the voltage constraints, the new lines are installed at end of feeders. The voltage profile after expansion has been shown in Figure 3 and it is seen that the voltage profile has been appropriately enhanced. The results show that constraints have been successfully satisfied and also the planning cost has been minimized.

Table 2: the expansion planning results.

From bus	To bus	Number of lines
12	23	2
26	27	2
27	28	2

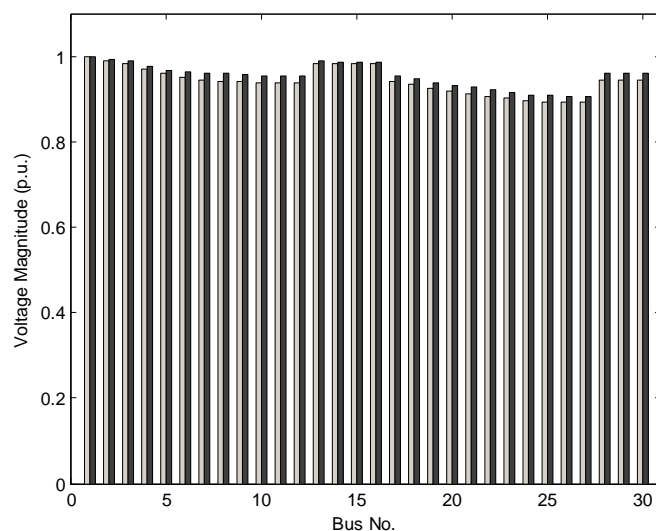


Fig. 3: voltage magnitude profile after expansion in comparison with before expansion.

Conclusion:

Distribution expansion planning based on a radial network was addressed in this paper. The problem was presented as a constrained optimization programming and solved by using genetic algorithms optimization technique. The proposed planning was tested at a 30 bus test system and simulation results showed the ability of the method. The proposed method successfully minimized cost subject to technical constraints such as voltage profile, line flow limitations and power flow equations.

REFERENCES

- Aghaei, J., K.M. Muttaqi, A. Azizivahed and M. Gitizadeh, 2013. "Distribution expansion planning considering reliability and security of energy using modified PSO (Particle Swarm Optimization) algorithm," *Energy*, 65: 398-411.
- Asakura, T., T. Genji, T. Yura, N. Hayashi and Y. Fukuyama, 2003. "Long-term distribution network expansion planning by network reconfiguration and generation of construction plans," *IEEE Transactions on Power Systems*, 18: 1196-1204.
- Carvalho, P.M.S., L.A.F. Ferreira, F.G. Lobo and L.M.F. Barruncho, 2000. "Distribution network expansion planning under uncertainty: a hedging algorithm in an evolutionary approach," *IEEE Transactions on Power Delivery*, 15: 412-416.
- Cossi, A.M. and J.R.S. Mantovani, 2009. "Integrated planning of electric power distribution networks," *IEEE Latin America Transactions*, 7: 203-210.

Cossi, A.M., L.G.W. da Silva, La, R.A.R. zaro and J.R.S. Mantovani, 2012. "Primary power distribution systems planning taking into account reliability, operation and expansion costs," *IET Generation, Transmission & Distribution*, 6: 274-284.

El-Zonkoly, A.M., 2013. "Multistage expansion planning for distribution networks including unit commitment," *IET Generation, Transmission & Distribution*, 7: 766-778.

Eminoglu, U. and M.H. Hocaoglu, 2005. "A new power flow method for radial distribution systems including voltage dependent load models," *Electric Power Systems Research*, 76: 106-114.

Haupt, R.L. and S.E. Haupt, 2004. *Practical genetic algorithms*, John Wiley & Sons.

Khodaei, A. and M. Shahidehpour, 2013. "Microgrid-Based Co-Optimization of Generation and Transmission Planning in Power Systems," *IEEE Transactions on Power Systems*, 28: 1582-1590.

Martins, V.F. and C.L.T. Borges, 2011. "Active Distribution Network Integrated Planning Incorporating Distributed Generation and Load Response Uncertainties," *IEEE Transactions on Power Systems*, 26: 2164-2172.

Millar, R.J., S. Kazemi, M. Lehtonen and E. Saarijarvi, 2012. "Impact of MV Connected Microgrids on MV Distribution Planning," *IEEE Transactions on Smart Grid*, 3: 2100-2108.

Popović, Ž.N., V.D. Kerleta and D.S. Popović, 2014. "Hybrid simulated annealing and mixed integer linear programming algorithm for optimal planning of radial distribution networks with distributed generation," *Electric Power Systems Research*, 108: 211-222.

Ravadanegh, S.N. and R.G. Roshanagh, 2014. "On optimal multistage electric power distribution networks expansion planning," *International Journal of Electrical Power & Energy Systems*, 54: 487-497.

Samper, M.E. and A. Vargas, 2013. "Investment Decisions in Distribution Networks Under Uncertainty With Distributed Generation"; Part I: Model Formulation," *IEEE Transactions on Power Systems*, 28: 2331-2340.

Samper, M.E. and A. Vargas, 2013. "Investment Decisions in Distribution Networks Under Uncertainty With Distributed Generation"; Part II: Implementation and Results," *IEEE Transactions on Power Systems*, 28: 2341-2351.

Sedghi, M., M. Aliakbar-Golkar and M.R. Haghifam, 2013. "Distribution network expansion considering distributed generation and storage units using modified PSO algorithm," *International Journal of Electrical Power & Energy Systems*, 52: 221-230.

Wang, D.T.C., L.F. Ochoa and G.P. Harrison, 2011. "Modified GA and Data Envelopment Analysis for Multistage Distribution Network Expansion Planning Under Uncertainty," *IEEE Transactions on Power Systems*, 26: 897-904.