Published by IASE

Annals of Electrical and Electronic Engineering

Journal homepage: www.aeeej.org

Power network reconfiguring using binary genetic algorithm technique

M. Krasniqi *, Q. Bytyçi, S. Thaçi

Department of Computer Science, Faculty of Technical Sciences, University of Vlorë, Vlorë, Albania

ARTICLE INFO

Article history:
Received 15 March 2019
Received in revised form
12 July 2019
Accepted 13 July 2019

Keywords:
Genetic Algorithm
Crossover
Mutation
Convergence
Security

ABSTRACT

Electrical power network reconfiguration is an effective approach for enhancing power quality. The configuration of the electrical power network is a nonlinear and complicated optimization problem. With increasing the demand for electrical energy, many problems have emerged in electrical power network. The most important of these problems is a high level of power loss in transmission lines. In this paper, a smart technique based on a genetic algorithm is suggested to reduce the power loss in transmission lines. The proposed method uses a genetic algorithm to reconfigure the power network. This optimization problem has many constraints and limits that be satisfied during the optimization procedure. Also with finding the optimal configuration of the power network, the security of the network will be enhanced and the voltage profile will be improved significantly. The proposed method is tested on the standard IEEE 19- bus system. The simulation results demonstrate the powerfulness of the proposed method.

1. Introduction

The issue of electrical power network reconfiguration is a nonlinear and complicated mathematical problem. This problem has many limits and constraints that must be considered during the solution method. The best reconfiguration of system has many advantages such as power loss reduction, improvement of voltage profile and enhancement of power system security. Also the findings of optimal system configuration reduce the system price significantly. In the reconfiguration of power system, the feeder topology arrangement, the status of breakers (open or close) and switches status are modified. In majority of published papers the reduction of active power loss is considered as main target. But in these reported methods, the security of system is neglected and in some area the power is cancelled for final customer. The most important subject of power network companies is the power quality. Therefore the security of system during the system reconfiguration is vital subject (Chen et al., 2015; Zhang et al., 2015).

In previous works related to power network reconfiguration, the main target was power loss reduction and the problem was considered as multi objective issue. In modern electrical power networks there are many devices and sections such as generators, transformers, breakers, transmission lines, compensators, FACTS devices and many other devices. For this purpose the power network reconfiguration is high order mathematical problem and it is very nonlinear and complicated. For finding good solution for this nonlinear and complicated problem, one powerful solution method is needed. In some cases authors and researchers used heuristic techniques for reconfiguration of network (Baran and Wu, 1989; Guimaraes et al., 2010; Mendoza et al., 2006). The first heuristic method for solve the reconfiguration introduced in Baran and Wu (1989). The proposed method in Baran and Wu (1989) started with meshed topology of power network. This algorithm and similar algorithms were not adequate solution for large power networks. These algorithms were adequate only for small and medium electrical power networks.

In next year's with developing the computer programming and algorithms, many new techniques proposed by researchers. The nature based optimization algorithms were efficient and effective in many fields. These algorithms inspired from the flock of animals in searching the food resource in nature. These algorithms have good ability in solving of nonlinear and complicated optimization problems. For this purpose application of this nature based optimization algorithm has been proposed by researchers in electrical power network reconfiguration (Ozturk et al., 2015).

With development in computer capability in computing and solving nonlinear problem, the solution of this problem is come easier. In last decades the nature based optimization algorithms are emerged such as genetic algorithm (GA), particle swarm optimization (PSO) algorithm, bee's algorithm (BA), imperialist competitive algorithm (ICA) and cuckoo optimization algorithm (COA) (Liu et al., 2015). One of the most efficient and powerful of these algorithms is genetic algorithm. This optimization algorithm has many applications in many areas of industrials and sciences (Herath et al., 2015). In this paper an intelligent technique is proposed for reactive power variable setting. In each optimization algorithm to features are essential: exploration and extraction. The exploration feature is the capability of finding the global solution's vicinity. The extraction feature is capability of optimization algorithm to find the global solution from this vicinity. The genetic algorithm has good exploration and extraction capability. Therefore in this study exploration and extraction is selected as optimization algorithm.

In this paper a smart system based on genetic algorithm (GA) is proposed for electrical power network reconfiguration. The genetic algorithm is an optimization system that models the human genetic process in the real world. This algorithm similar to other swarm intelligence optimization don't need to gradient

* *Corresponding Author.*
Email Address: *mirlind.krasniqi@gmx.com (M. Krasniqi)*
https://doi.org/10.21833/AEEE.2019.08.003

based information. For this feature of nature based optimization algorithms, these algorithms are capable to solve nonlinear and complicated optimization and mathematical problems. More details about the GA are presented in next sections. Also more details the regarding the power network and reconfiguration concept can be found in Souza et al. (2015).

2. Genetic algorithm

In soft computing science, genetic algorithm is an optimization algorithm that models the process of natural selection in animals and human. The genetic algorithm is used for many optimization problems that are very complicated and nonlinear. Also genetic algorithm can be used for discrete optimization problem. The genetic algorithm is one of the evolutionary algorithms (EA) that generate random solutions to optimization problems that this procedure is based on natural events in human or animal's life. The genetic algorithm has several main operators: elitism, crossover, mutation and roulette wheel. The flowchart of genetic algorithm is depicted in Fig. 1.

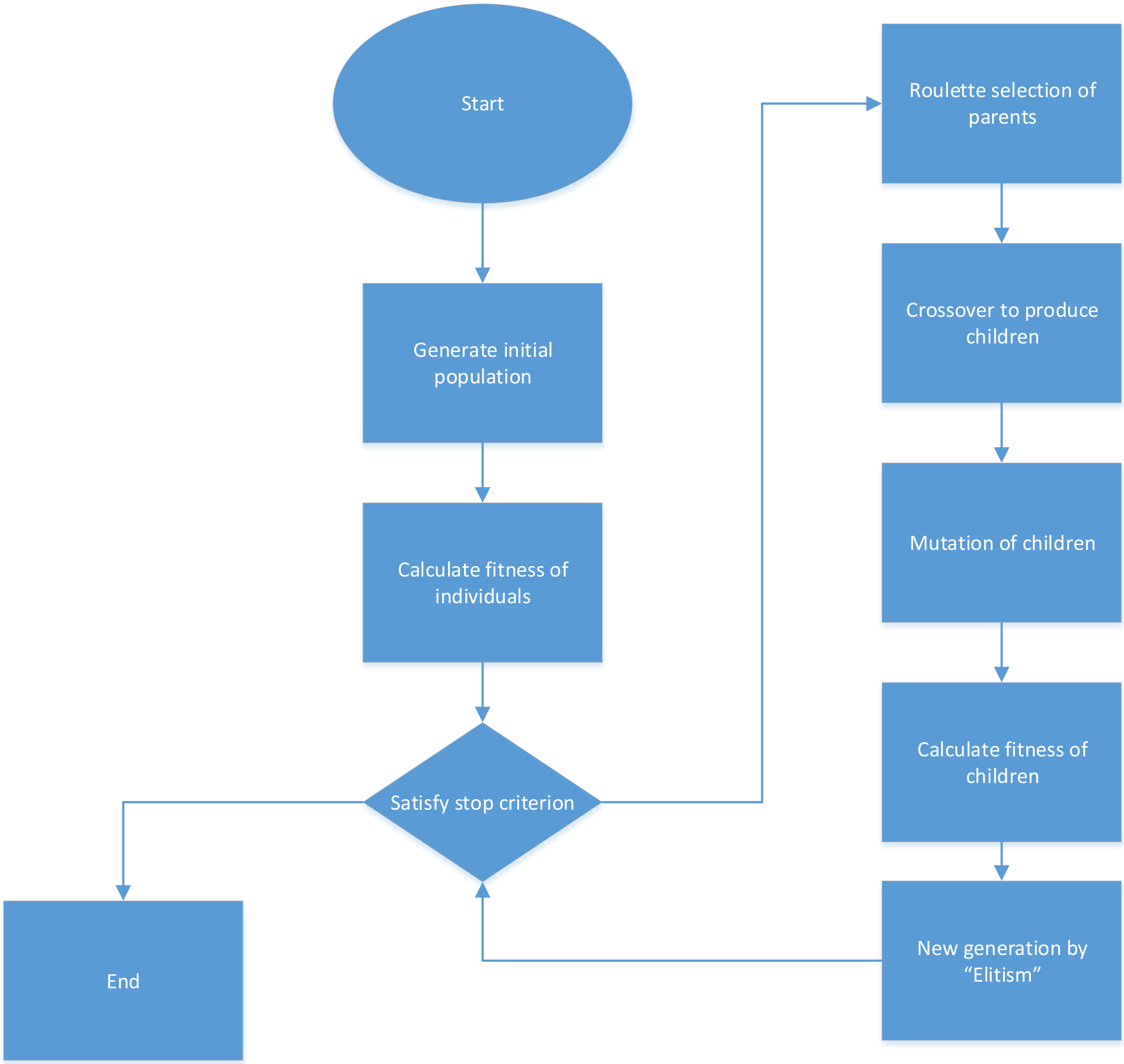

Fig. 1. GA flowchart.

In the genetic algorithm like other nature based optimization algorithms, initial random population is generated. The each candidate in initial random population is called chromosome. These chromosomes are like particle in particle swarm optimization algorithm, bee in bee's algorithm or countries in imperialist competitive algorithm. The chromosomes must be generated in predetermined search space. The low boundary and maximum boundary of each problem is unique. The optimization process starts with initial random population, and in each iteration or generation, the fitness function is calculated. Based on the evaluated fitness function for each chromosome, the elitism and crossover is performed. The chromosomes with high level of fitness are randomly chosen from the existing population, and each chromosome is modified by crossover operator. The new generated population is used in following iteration. The same procedure is performed iteratively. In any iteration the stopping criteria must be checked. If the stopping criteria are satisfied, the algorithm will stop the searching procedure. Fig. 2 shows the crossover operation. Also Fig. 3 shows the mutation operation. Fig. 4 shows the pseudo code of GA.

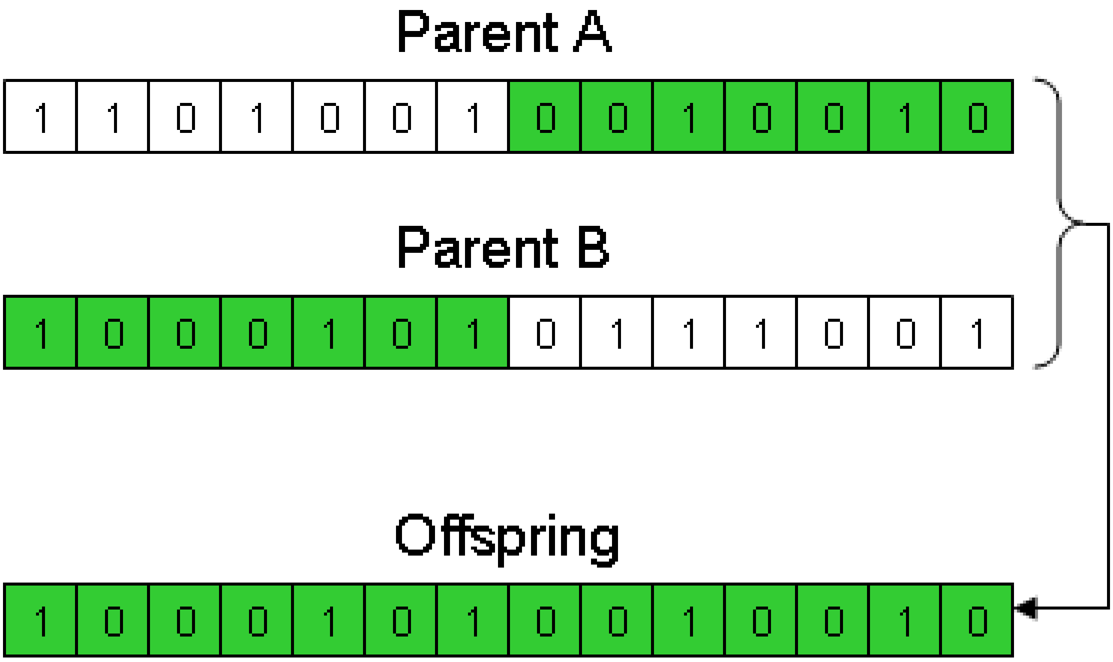

Fig. 2. Crossover operation.

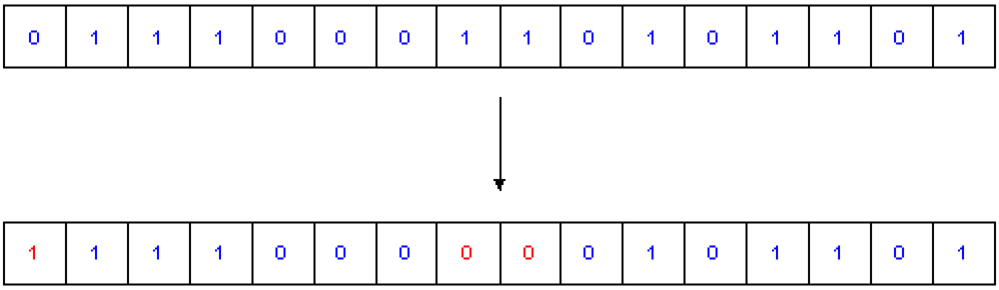

Fig. 3. Mutation operation.

```
0. GENERATE POPULATION P[0]
1. DO{
      1.1 EVALUATE FITNESS OF INDIVIDUALS IN P[k]
      1.2 DO{
             SELECTION (ROULETTE WHEEL)
             APPLY GENETIC OPERATORS:
                   PMX CROSSOVER (PROBABILITY pc)
                   MUTATION (PROBABILITY pm)
          }
          WHILE NEW GENERATION NOT COMPLETED
      1.3 EXECUTE CREATE-ELITE
      }
      WHILE {TERMINATION CRITERIA = NO}
2. PRINT BEST ASSIGNMENT SOLUTION ui

FUNCTION CREATE-ELITE:
{
      SELECTION OF BEST INDIVIDUALS
      MUTATION (PROBABILITY pm)
      ELITE = MUTATED ELITE + NOT-MUTATED ELITE
      INSERT ELITE INTO POPULATION:
           P[k+1]=INSERT(ELITE,P[k])
}
```

Fig. 4. The pseudo code of GA algorithm.

3. Proposed method and simulation results

In this section the proposed method and obtained computer simulation results is presented. All the computer simulations are performed in MATLAB software. In the proposed an intelligent technique is introduced based on GA to enhance the power network by reconfiguration of its topology. The state of sectionalizing and tie switches (open/close) are the vital parameters in optimization procedure. The optimization algorithm must determine the state of these devices. In this respect every chromosome is composed of zero and one arrays. The number of each chromosome arrays is equal to the number of sectionalizing and tie switches in the power system. The important issue in this technique is the check of limits and constraints. In each proposed random chromosome, the radial configuration of system must be satisfied.

The proposed method is tested on real IEEE standard 19-bus system. This system has 25 independent transmission branches, 18 sectionalizing switches device and 4 tie switches sections. In the original power system and without reconfiguration in its topology, the real power loss is about 159.3 KW. For reducing the amount of real power loss, GA is applied to reconfigure the power network topology. In the genetic algorithm the control parameters have very vital role in its speed and convergence. For this purpose we must select these parameters by accuracy. In GA the number of chromosome (n) is indicates the number of all the particles that spread in search space in first step. If the value of n will be high, then the simulation time will be high. Also if the value of n is low, then the probability the convergence of optimization algorithm will be low. Thus we will select the n by accuracy. Table 1 shows the GA parameters.

Table 1
GA parameters.

Parameter	Value
Number of chromosome	30
Crossover rate	0.75
Mutation rate	0.25
Number of iterations	100

Table 2 shows the obtained results from proposed method. The obtained results show that the reconfiguration of network reduces the power loss significantly. The power loss after optimization is 126.2 KW. Also the minimum and maximum voltage of two networks is calculated through the simulations. The listed results in Table 2 show that the proposed method improves voltage profile significantly. Also in Table 3, the voltage of all terminals are listed.

Table 2
Obtained results from proposed method.

Method	Power loss (KW)	V_{min}	V_{max}
Original system	159.3	0.91 P.U	1.1 P.U
GA	126.2	**0.989P.U**	**1.009 P.U**

Table 3
The voltage before and after optimization.

Row	Voltage of original system		Voltage of nodes after optimization	
1	V_{n1}	0.921	V_{n1}	0.996
2	V_{n2}	0.913	V_{n2}	1.003
3	V_{n3}	0.916	V_{n3}	0.989
4	V_{n4}	0.911	V_{n4}	0.995
5	V_{n5}	0.910	V_{n5}	0.991
6	V_{n6}	0.911	V_{n6}	0.994
7	V_{n7}	0.921	V_{n7}	1.005
8	V_{n8}	0.912	V_{n8}	1.002
9	V_{n9}	0.942	V_{n9}	0.996
10	V_{n10}	0.926	V_{n10}	0.993
11	V_{n11}	0.939	V_{n11}	1.009
12	V_{n12}	0.913	V_{n12}	1.008
13	V_{n13}	0.925	V_{n13}	0.998
14	V_{n14}	0.911	V_{n14}	0.993
15	V_{n15}	0.927	V_{n15}	0.997
16	V_{n16}	0.905	V_{n16}	0.993
17	V_{n17}	0.909	V_{n17}	1.001
18	V_{n18}	0.903	V_{n18}	1.002
19	V_{n19}	0.918	V_{n19}	1.009

In Fig. 5, the bus voltages before and after optimization is plotted. It can be seen that the genetic algorithm can improve the voltage profile significantly.

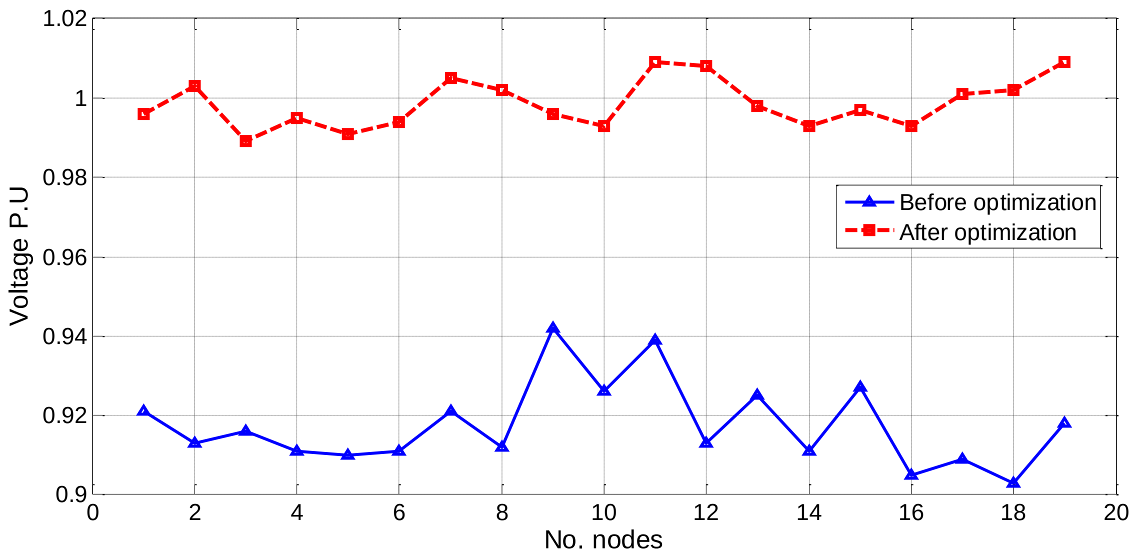

Fig. 5. Bus voltages before and after optimization.

4. Conclusion

In this paper an intelligent technique based on nature based optimization algorithms for power network reconfiguration is proposed. The power network reconfiguration can reduce the real power loss and enhance the voltage profile. Also power network reconfiguration improves the system security. For this purpose GA is chosen as optimization algorithm. In each optimization algorithm, two main criteria are important: The finding of global solution vicinity or exploration and the main global solution finding exactly or extraction. The simulation results show that the GA has good convergence speed and accuracy. The obtained results show that the power network reconfiguration using GA has good effects on power loss and voltage profile.

References

Baran ME and Wu FF (1989). Network reconfiguration in distribution systems for loss reduction and load balancing. IEEE Transactions on Power delivery, 4(2): 1401-1407.
https://doi.org/10.1109/61.25627

Chen Y, Mahalec V, Chen Y, Liu X, He R, and Sun K (2015). Reconfiguration of satellite orbit for cooperative observation using variable-size multi-objective differential evolution. European Journal of Operational Research, 242(1): 10-20.
https://doi.org/10.1016/j.ejor.2014.09.025

Guimaraes MAN, Castro CA, and Romero R (2010). Distribution systems operation optimisation through reconfiguration and capacitor allocation by a dedicated genetic algorithm. IET generation, transmission & distribution, 4(11): 1213-1222.
https://doi.org/10.1049/iet-gtd.2010.0020

Herath, M. T., Natarajan, S., Prusty, B. G., & John, N. S. (2015). Isogeometric analysis and genetic algorithm for shape-adaptive composite marine propellers. Computer Methods in Applied Mechanics and Engineering, 284, 835-860.
https://doi.org/10.1016/j.cma.2014.10.028

Liu Y, Niu B, and Luo Y (2015). Hybrid learning particle swarm optimizer with genetic disturbance. Neurocomputing, 151: 1237-1247.
https://doi.org/10.1016/j.neucom.2014.03.081

Mendoza J, López R, Morales D, López E, Dessante P, and Moraga R (2006). Minimal loss reconfiguration using genetic algorithms with restricted population and addressed operators: real application. IEEE Transactions on Power Systems, 21(2): 948-954.
https://doi.org/10.1109/TPWRS.2006.873124

Ozturk C, Hancer E, and Karaboga D (2015). Dynamic clustering with improved binary artificial bee colony algorithm. Applied Soft Computing, 28: 69-80.
https://doi.org/10.1016/j.asoc.2014.11.040

Souza, S. S., Romero, R., & Franco, J. F. (2015). Artificial immune networks Copt-aiNet and Opt-aiNet applied to the reconfiguration problem of radial electrical distribution systems. Electric Power Systems Research, 119, 304-312.
https://doi.org/10.1016/j.epsr.2014.10.012

Zhang C, Sun L, Wen F, Lin Z, Ledwich G, and Xue Y (2015). An interpretative structural modeling based network reconfiguration strategy for power systems. International Journal of Electrical Power & Energy Systems, 65: 83-93.
https://doi.org/10.1016/j.ijepes.2014.09.030