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Distribution network reconfiguration using improved colonial competition optimization algorithm

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Abstract:- The implementation of a distribution network is generally aimed at increasing system efficiency, increasing the level of optimal operation, increasing the stability of the power grid, reducing blackouts, and increasing reliability. By providing general definitions of networks and the principles of optimal operation and reliability indicators and loss reduction in power systems, the general principles of network control and optimal operation are presented and finally, practical ideas for the optimal operation of power networks with The approach of increasing system reliability and maximum productivity of distributed production resources is presented. In the presence of a distribution network and by using appropriate control algorithms, it is possible to optimize the power network in different working conditions; After the occurrence of a disturbance in the network, the power system is exposed to instability. The network can restore the stability of the system by communicating critical conditions to the subscribers as well as rearranging the network structure and shut down the least number of subscribers. Implementation of a distribution network in general with the aim of increasing system efficiency, increasing the level of optimal exploitation, increasing the stability of the power grid, reducing outages and increasing reliability.

Keywords*: reconfiguration-distribution network-colonial competition optimization algorithm.*

1. Introduction

In general, the implementation of a distribution network aims to increase system efficiency, increase the level of optimal exploitation, increase the stability of the power network, reduce outages, and increase reliability. Due to the uncertainty of system loads in different feeders that vary from time to time, the implementation and control of distribution systems is more complicated, especially in areas where load density is high [1-2]. Power losses in the distributed network For a fixed network configuration for all cases in order to meet the required level of load demand, DG units in a distribution network to improve the voltage characteristics, reliable and uninterrupted power supply and also to achieve economic benefits such as minimizing power losses. , energy efficiency and load regulation have been integrated [3].

2. Objectives

Today, network reconfiguration and DG placement in distribution networks are investigated independently. Although, in this method, network reconfiguration suggestions and DG installation are used simultaneously to improve the loss minimization and voltage characteristics. The problem of network reconfiguration in a distribution system is to find the best radial network configuration that provides the minimum power loss while satisfying operational constraints, such as feeder current capacity and distribution system radial structure and voltage range. The limitations are [4-5]. The power loss of communication buses of a linear section between K and K+1 after network reconfiguration can be optimally calculated in a combined manner. In this research, the colonial competition optimization algorithm will be used. The objective function of the problem will be calculated to maximize the power loss reduction in the distribution system. This solution will be simulated to solve the network reconfiguration problem of distribution system with distributed generation. The algorithm will be tested on 33 and 96 Shin systems, the goals of this research are stated below:

Reducing power loss in the network by reconfiguring the distribution network based on the proposed process

Improving network reliability using the proposed approach for network reconfiguration Improving voltage by reconfiguring the distribution network using the proposed approach

The most important innovation in this research is the definition of a new combined objective function using voltage improvement and loss reduction functions in the field of reconfiguration of the distribution network based on the improved algorithm of colonial competition, which in the next part of both the power function and voltage improvement and determining these parameters using the algorithm Colonial rivalry explained.

The organization of this research is in such a way that at first the topics are related to the generalities of the research, in which the statement of the problem and the objectives of the research will be raised. The second part is related to the basics and background of the research, in which the exact basics of the research will be presented and explained. In the third part, the proposed research method is presented in detail, and in the fourth part, the simulation results and research results are stated, and finally, in the fifth part, the conclusion and future works are stated.

3. Research background

The implementation of a distribution network is generally aimed at increasing system efficiency, increasing the level of optimal operation, increasing the stability of the power grid, reducing blackouts, and increasing reliability. By providing general definitions of networks and the principles of optimal operation and reliability indicators and loss reduction in power systems, the general principles of network control and optimal operation are presented and finally, practical ideas for the optimal operation of power networks with The approach of increasing system reliability and maximum productivity of distributed production resources is presented. In the presence of a distribution network and by using appropriate control algorithms, it is possible to optimize the power network in different working conditions; After the occurrence of a disturbance in the network, the power system is exposed to instability. The network can restore the stability of the system by communicating the critical conditions to the subscribers and also by rearranging the network structure and cause blackouts to the least number of subscribers. The implementation of a distribution network is generally aimed at increasing system efficiency, increasing the level of optimal exploitation, increasing the stability of the power grid, reducing outages, and increasing reliability[6].

Interruptions usually occur in distribution networks (DS). Although these interruptions have not affected the reliability of distribution systems, in the not too distant future, the reduction of supply quality will have a negative effect on this issue. However, it is important to consider possible measures that can help improve network reliability. Reconfiguration (DSR) of distribution systems can be defined as a method of changing the network topology using branch switches, which is an existing strategy for each topology, taking into account all constraints such as network radiality as well as current and voltage constraints. It is operational. Distribution networks are usually constructed as mesh systems but operate using open normal points in a radial configuration. This is primarily to reduce the number of network components at risk per individual feeder in the event of a network fault. Due to the uncertainty of system loads in different feeders that vary from time to time, the implementation and control of distribution systems is more complicated, especially in areas where load density is high. Power losses in the distributed network For a fixed network configuration for all cases in order to meet the required level of load demand, DG units in the distribution network to improve the voltage characteristics, reliable and uninterrupted power supply and also to achieve economic benefits such as minimizing power losses. , energy efficiency and load regulation are integrated. Today, network reconfiguration and DG placement in distribution networks are investigated independently. Although, in this method, the suggestions of grid reconfiguration and DG installation are used simultaneously to improve the loss minimization and voltage characteristics[7].

Because network reconfiguration is a complex combinatorial inseparable constrained optimization problem, many algorithms have been proposed in the past. At first, Beck and Merlin proposed the network reconfiguration problem and used a branch and continuous optimization technique. The drawback of this technique is that it is very time-consuming because there are n2 possible configurations, which are n line segments equipped with switches. Based on Back and Merlin method, an innovative algorithm was proposed by Hong and Shirmohamadi.

The disadvantage of this algorithm is to consider the switch at the same time reconfiguring the transmitter. Civanlar proposed an innovative algorithm that provided a simple formula to determine the change in power dissipation due to a branch exchange. The drawback of this method is that only one pair of switching operations is considered at a time, and the network configuration depends on the state of the primary switch. Das presented an algorithm based on heuristic rules and a fuzzy multi-professional method to optimize the network configuration. The lack of advantage in this method for choosing to produce membership for the purposes has not been determined. Nara presented a solution using a Genetic Algorithm (GA) to find the loss minimization configuration in the distribution system. Zhu proposed a corrective genetic algorithm (RGA) to reduce losses in distribution system. In RGA, the usual crossover and transformation schemes are modified with a competitive mechanism. Rao proposed the Harmony Search Algorithm (HSA) to solve the network reconfiguration problem for simultaneous optimal switch integrations in the network to minimize real power losses in the distribution network[8-9-10].

The reorganization of electricity markets in many countries of the world has created new perspectives for the distributed production of electrical energy using renewable energy sources with low capacity. Usually, the capacities of KW5 to MW10 DG units are installed to provide electric power closer to the end user, because choosing the best locations and sizes of DG units is also a complex optimization problem, and many methods have been proposed in this field in recent years. Rosehart and Nowicki presented a Lagrange-based method to determine optimal locations for placing DOs in distribution systems, taking into account economic and stability constraints. Celli presented a multi-objective algorithm using GA to measure D6 in a distribution system. Wong and Nehrir proposed an analytical method to determine the optimal location to place a D6 in the distribution system to minimize power loss. Agalgaonkar discussed the level of penetration and placement of DGs under the SMD framework[11].

Usually, in different researches, reconfiguration is done as an optimization problem with the aim of saving energy consumption, voltage deviation or load imbalance or maximizing reliability. Reconfiguration is a hybrid nonlinear optimization problem, which can often be solved using heuristic algorithms, some of these optimization algorithms are the branch exchange method, the genetic algorithm (GA); Particle optimization (PSO); Ant colony search algorithm; cuckoo search; optimization of weeds; And the optimization is based on teaching-learning. Although heuristic optimization algorithms do not guarantee an optimal solution, they identify better quality solutions.

In different researches in the field of reconfiguration, the goal is to reduce losses and improve load balance through new configuration. This requires searching for a number of radial grid settings. Che et al. conducted a research on the impact of distribution network reconfiguration for power quality (such as voltage harmonic distortion and unbalance), along with losses, with distributed generation (DG) and reactive power sources. In a research in this field, a parallel genetic algorithm based on adaptive fuzzy logic has been used to solve the optimization problem.

In another research, weed optimization method has been used for the number of switching operations and load balance index, which uses a round-trip load flow for power flow calculations. Among evolutionary algorithms, the advantage of optimization methods in cuckoo search research and optimization based on training and learning is that they do not have many control parameters[12].

Reconfiguring the distribution network involves searching for a number of network settings. The size of the problem search space is related to the number of components. The state vector in network reconfiguration represents the distribution of a particular network topology. The length of the state vector is equal to the number of branches involved in the network reset.

In these researches, it is tried to simultaneously minimize the losses and reduce the maximum voltage deviation of the node of each loop. In this case, the length of the state vector is defined by the number of loops. These two options have been compared in the research and it has been shown that the second alternative option is a better method in terms of optimization time and the number of target performance evaluations.

From the perspective of reliability, Brown et al. used DSR in a study to improve the reliability of DS. In this research, reliability models are used to evaluate load points (LP) and the DSR problem is implemented considering energy loss and reliability in a multipurpose framework. Patrakis et al. also presented a multi-objective optimization method considering energy consumption cost and three system reliability indices.

In Sarantakos et al.'s paper, condition-based failure rates are used to determine network reliability compared to the standard approach using average failure rates. Networks with several evaluation parameters are considered and their reliability is configured according to the component-to-whole conditions, which can lead to different reliability indices. The proposed objective function of this research is a general performance, which considers reliability and power dissipation in terms of cost. Reliability is considered through ECOST, which is calculated not only for interruptions resulting from the primary DS (network between distribution and distribution transformers (TX)) but also for outages caused by a component.

The method used in this paper considers loads as fixed. In particular, average load values are considered for reliability assessment and peak values - together with the load loss factor - for loss costs. System reliability and loss cost are calculated for an annual period, but this does not preclude the use of the proposed method for discrete time periods. For example, in case of planned maintenance of the transformer or if new condition data is available to the DSO, the methodology presented in this paper can be implemented in order to find the optimal network configuration for this data.

4. Methods

In the proposed idea, a new method for reconfiguring and installing distribution units simultaneously in the distribution system is proposed. Different loss reduction methods (grid reconfiguration only, DG installation only, DG installation after reconfiguration) will also be simulated to determine the properties of the proposed method. A meta-heuristic effective colonial competition algorithm is used in the optimization process of grid reconfiguration and DG installation The proposed method and other methods are tested on 33-bus and 96-bus systems in three different load levels, i.e. light, nominal and heavy. Using the proposed method, reconfiguring and installing DG simultaneously reduces power loss and improves the voltage profile in Comparison with other methods will be more effective. In this research, in the proposed objective function, the effect of the number of DG installation locations and its effect on reducing power loss at different load levels is considered. Power loss in the linear part of connecting K and K+1 buses with Using equation 1, we get:

$$P_{Loss}(k,k+1) = R_k . \frac{(P_K^2 + Q_K^2)}{|V_k|} \tag{1}$$

The total power loss of the transmitter, the P loss may then be determined by the sum of the losses of all the linear sections of the transmitter, which is presented as equation 2:

$$P_{T,Loss} = \sum_{K=1}^{n} p_{loss}(k,k+1) \tag{2}$$

Network reconfiguration is the process of changing the topological structure of the feeders by changing the open and closed states and connecting the switches. In general, the networks are reconfigured to reduce the real power loss and suppress the overload in the network. However, due to the dynamic nature of the loads, the total load of the system is greater than its production capacity, which causes load shedding on the feeders. Power losses even with the presence of DG in an optional location in the network are presented as 3:

$$P_{DG,Loss} = \frac{R_k}{v_2^k}(p_k^2 + q_k^2) + \frac{R_k}{v_2^k}\left(p_g^2 + q_g^2 - 2p_k p_g - 2Q_k Q_g\right)\left(\frac{G}{L}\right) \tag{3}$$

In this research, using the process of multi-objective functions, using the proposed algorithm, we will try to improve the voltage and power at the same time. The steps of the proposed procedure are specified below: choose some random points on the function and form initial empires. Move the colonies to the imperialist country (matching policy). If there are colonies in an empire that cost less than the imperialist, swap the colony and the imperialist. Calculate the total cost of an empire (with Consider the cost of the imperialist and their colonies. Choose a colony from the weakest empire and give it to the empire most likely to take it. Remove the weak empires.

If there is only one empire left, stop, otherwise go to 2. Like other evolutionary algorithms, this algorithm also has a number of random initial populations, each of which is called a "country"; Starts. Some of the best elements of the population (equivalent to elites in the genetic algorithm) are selected as imperialists. The rest of the population is also considered as a colony. The colonizers, depending on their power, these colonies with a specific process that follows; They pull towards themselves. The total power of any empire depends on both its constituent parts, the imperialist country (as the central core) and its colonies. Mathematically, this dependence is modeled by defining imperial power as the sum of the power of the imperialist country, plus a percentage of the average power of its colonies. With the formation of early empires, the imperial competition between them begins. Any empire that cannot succeed in the colonial competition and increase its power (or at least prevent its influence from decreasing), will be removed from the colonial competition scene. Therefore, the survival of an empire will depend on its ability to absorb the colonies of rival empires and bring them under control. As a result, in the course of imperialist competition, the power of bigger empires will be gradually increased and weaker empires will be eliminated. In order to increase their power, the empires will have to develop their colonies as well. Over time, the colonies will become closer to the empires in terms of power and we will see a kind of convergence. The final limit of the colonial competition is when we have a single empire in the world, with pensions that are very close in terms of position to the imperialist kingdom itself. In optimization, the goal is to find an optimal solution according to the variables of the problem. We create an array of problem variables to be optimized. In the genetic algorithm, this array is called chromosome 1. Here we call it a country N. In an N-dimensional var 1 optimization problem, a country is an array of var. This array is defined as follows.

$$country = [p_1, p_2, p_3, \ldots, p_{N_{var}}] \quad (4)$$

The values of variables in a country are displayed as decimal numbers.

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5. Results

In order to demonstrate the effect of the proposed method (reconfiguring the network and installing DG units simultaneously) using the proposed method, it has used two test systems including 33 and 96 buses. In the network simulation, as in the basic article, 5 scenarios are considered to analyze the characteristics of the selected method.

1- Scenario 1

The system is without reconfiguration and distributed generator (base case)

2- Scenario 2

Same as scenario 1 except that the system is reconfigured by existing partitions and tie switches.

3- Scenario 3

Same as scenario 1 except that DG units are installed on candidate busbars in the system.

4- Scenario 4

DG units are installed after network reconfiguration.

5- Scenario 5

System with feeder reconfiguration and DG allocation simultaneously, all scenarios were programmed in MATLAB.

4-1- The results of the process

This test system is based on the basic paper of a 33-bus distribution system with 5 tie switches and 32 segment switches. In the network, segmentation switches (normally closed) were numbered from 1 to 32 and tie switches (normally open) were numbered from 33 to 37. The load and grid line data are taken from the basic paper and the total real reactive power loads on the system are 2311 KVAR and 3715 kw.

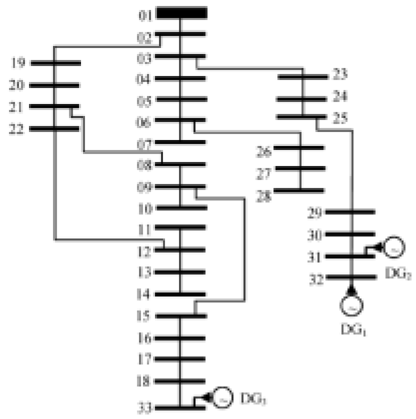
Using sensitivity analysis, the sensitivity factors for installing DG units in candidate bus locations for scenarios 3, 4 and 5 have been calculated. After calculating the sensitivity factors of all tires, they were stored and ranked. Table 1 shows the results of the process:

Table 1-Results of the 33-bass system

Min vol	Loss reduction	Power loss	Swiches opend	Scenario
0.98	28.4	33.98	33,34,35,36	Scenario1
0.97	29.5	32.18	33,34,35,36	Scenario2

0.98	28.6	32.68	33,34,35,36	Scenario3
0.96	29.1	31.95	33,34,35,36	Scenario4
0.938	28.5	33.98	33,34,35,36	Scenario5

Only the above three locations were selected to install DG units in the system. The range of DG unit sizes selected for installation at candidate bus locations is from 0 to 2 MW. Candidate locations for scenarios 3, 4, and 5 are presented in Table 1-4. To evaluate the performance, the network was simulated at 3 load levels. 1.5 (light), 1.1 (nominal) and 1.9 (heavy) and the simulation results are presented in Table 1. From Table 1, it can be seen that in the light load, the power loss in the form of KW in the system is reduced by 5 And 4, 3, 2 scenarios of use with 71/17, 54/23, 23/26, 17/33, which is 19/47. The percentage of loss reduction for scenarios 2 to 5 is 51/26, 51/3, respectively. , 46.61 and 92.22 percent. Similarly, the loss reduction percentage for scenarios 2 to 5 under nominal and heavy load conditions for 23.99 and 17.54, 93.54, 19.33 and nominal load for 69/93, 17/52, 29/52, and 11/31 is a heavy order. This shows that for all three load levels, the power loss reduction using scenario 5 has the highest value, which shows the superior feature of the proposed method over other methods.



Optimum network structure after DG configuration and installation simultaneously Although as the load increases from light to heavy level, the improvement in loss reduction is almost the same in the scenarios. According to Table 1-4, it can be seen that the improvement in reducing power and voltage losses for scenario 5 is higher compared to scenario 4. This shows that the installation of DG after reconfiguration (scenario 4) does not have favorable results in maximizing the reduction of power loss and does not improve the voltage. Percentage improvement in minimum system voltage for scenario 2 to 5 at light, nominal and heavy load according to is 11/37, 9/91, 6/92, 4/11, 5/17, 3/97, 5/91, 2/23, 3/33, 2/21, 2/52, 1/29 in order We find that the improvement in minimum system voltage for scenario 5 has the highest value. In addition, it can be seen that the decrease in minimum voltage with increasing load from light to peak is minimal in case of scenario 5. The voltage profile curves are shown in Figure 7a to 7c. The shapes of the voltage profiles in all three load levels for the 5 scenarios are almost the same except for the minimum change in the voltage value. To study the effect of the number of DG installation locations on the power losses for the 5 scenario, DGs are installed in the optimal candidate bus locations in the working stages and the results It is shown in Table 2-4. By sensitivity analysis, the candidate bus locations considered for DG installation are 32, 31, 33 and 31. According to Table 2-4 in light load, it can be seen that the percentage of power loss reduction has improved because the number of DG installation locations has increased from one to four, but the improvement rate is decreasing. Similar results may be obtained from Table 2-4 with respect to other load levels. It is believed that the load loss is reduced when four DGs are installed. The effect of adding a fourth DG on the power loss is marginal. So, three DG installations provide near-optimal power dissipation with a near-optimal size compared to other installations.

Table 2-The effect of the number of DG installations

	DG Number	1	2	3	4
light	size	0.43	0.91	0.87	0.97
	Power loss	23	17	16	18
	Loss reduction	52	60	62	61
Nominal	size	0.43	0.91	0.87	0.97
	Power loss	23	17	16	18
	Loss reduction	52	60	62	61
hheavy	size	0.43	0.91	0.87	0.97
	Power loss	23	17	16	18
	Loss reduction	52	60	62	61

Table 3-Comparison of the simulation results of the 33 Shin system

	DG Number	1	2	3	4
light	size	0.43	0.91	0.87	0.97
	Power loss	23	17	16	18
	Loss reduction	52	60	62	61
Nominal	size	0.43	0.91	0.87	0.97
	Power loss	23	17	16	18
	Loss reduction	52	60	62	61
hheavy	size	0.43	0.91	0.87	0.97
	Power loss	23	17	16	18
	Loss reduction	52	60	62	61

To compare the performance of the proposed method, all scenarios are simulated with GA and RGA (only at nominal load) and the results are presented in Table 3. This is a large-scale distribution system of 96 busses with 91 partitions and 5 tie switches. The configuration, tie fault data, Load is dashed. The total system loads for the base configuration are 3112/16 kw and 2964/19 KVAR. The partition switches are named from 1 to 91 and the tie switches from 96 to 73. Algorithm parameters used to simulate this test system It is similar to the case of test system 1. Like test system 1, this test system was also simulated for 5 scenarios at three load levels and the results are presented in Table 4-4. The size limits of DG units selected for installation in candidate bus locations like case 1 The power losses of the base case (in KW) in light, nominal and heavy load conditions are 55.91, 225.11 and 955.23, respectively. According to Table 4-4, it can be seen that scenario 5 is more effective in improving minimum voltage and reducing power loss than other scenarios. The effect of the number of DG installation locations on the power loss in all three load levels was studied and the results are presented in Table 5. The candidate bus locations considered for DG installations were 91, 91, 92 and 93. As in case 1, it can be seen that the reduction in power loss is reduced for the fourth DG, and therefore only three DGs are sufficient, which provides near-optimal power loss with a near-optimal size compared to other installations. Scenarios 2 to 5 were simulated for nominal load conditions using GA and RGA to compare the results obtained by HSA.

Table 4- The results of the 69 Shin system

Min vol	Loss reduction	Power loss	Swiches opend	Scenario
0.98	28.4	33.98	33,34,35,36	Scenario1
0.97	29.5	32.18	33,34,35,36	Scenario2
0.98	28.6	32.68	33,34,35,36	Scenario3
0.96	29.1	31.95	33,34,35,36	Scenario4

Table 5-Effect of the number of dg installations on power loss

	DG Number	1	2	3	4
light	size	0.43	0.91	0.87	0.97
	Power loss	23	17	16	18
	Loss reduction	52	60	62	61
Nominal	size	0.43	0.91	0.87	0.97

	Power loss	23	17	16	18
	Loss reduction	52	60	62	61
hheavy	size	0.43	0.91	0.87	0.97
	Power loss	23	17	16	18
	Loss reduction	52	60	62	61

According to Table 6, it can be seen that the performance of the proposed method is better compared to GA and RGA regarding the quality of the solutions of all scenarios.

Table 6-Comparison of the simulation results of the 69 Shin system

	DG Number	1	2	3	4
light	size	0.43	0.91	0.87	0.97
	Power loss	23	17	16	18
	Loss reduction	52	60	62	61
Nominal	size	0.43	0.91	0.87	0.97
	Power loss	23	17	16	18
	Loss reduction	52	60	62	61
hheavy	size	0.43	0.91	0.87	0.97
	Power loss	23	17	16	18
	Loss reduction	52	60	62	61

6. Discussion

In this Article, a new method for reconfiguration and simultaneous installation of D units in the distribution system is proposed. In addition, different loss reduction methods (only network reconfiguration, only DG installation, DG installation after reconfiguration) were also simulated to determine the excellent feature of the proposed method. The proposed method and other methods were tested on 33-bus and 96-bus systems in three different load levels, i.e. light, nominal and heavy. The results show that the reconfiguration method and simultaneous DG installation reduce power loss and improve the profile. Voltage is more effective compared to other methods. The effect of the number of DG installation locations on reducing power loss at different load levels was studied. The results show that the percentage of power loss reduction is improved as the number of DG installation locations increases from one to four, but The improvement rate will decrease when the number of locations increases from one to four at all load levels. Although the power reduction percentage ratio for DG size is the highest when the number of DG installation locations is three. The results obtained using From the proposed method with the results of genetic algorithm (GA) and modified genetic algorithm (RGA) has been compared. The calculation results showed that the performance of the proposed method is better than GA and RGA. New approaches and new algorithms can be used to improve.

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