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Genetik Algoritma ile Elektrik Dağıtım Ağının Kayıplarının Azaltılmasında Dg Yerleştirme and Tekrar Yapılandırma Birleştirmesi

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Özet. Dağıtım ağları elektriksel ağların en yoğun parçasıdır. Düşük voltaj ve geniş alan elektrik kayıplarının en büyük payına sebep olur. Bu ağların kayıplarını en aza indirmek için farklı yaklaşımlar tavsiye edilmiştir. Dağıtım ağının yeniden düzenlenmesi ve DGler yerleştirilmesi bu makalede kullanılan etkili metotlardır. Dağıtım ağının dairesel konfigürasyonu onaylamak için etkili bir metot, yeniden düzenleme uygulaması ve GA tarafından DG yerleştirmesi için bir kodlama, dairesel ağlar için bir enerji akım metodu ve sonuç değerlendirmek için bir fonksiyon bu makalede tanımlanmıştır. A33 bus dağılım ağı test ağı ve GA tarafından yeri ve kapasitesi belirlenen DGlerin sayısı olarak kullanılmıştır. Bölgelerdeki ağların konfigürasyonunun etkileri ve DGlerin kapasiteleri tanımlanmış ve DGlerin yerleştirilmesi için en iyi konfigürasyon verilmiştir. Sonuçta DGlerin sayılarının ve kapasitelerinin artırılmasının ağ kayıplarındaki etkileri çalışılmıştır.

Anahtar Kelimeler: Dağıtım ağı optimizasyonu, kayıp azaltma, yeniden yapılandırma, DG yerleştirme, genetik algoritma

Combining Dg Placement and Reconfiguration to Reducing Losses of Electrical Distribution Network by Genetic Algorithm

Abstract. Distribution networks are the most extensive part of electrical networks. Low voltage and wide area cause them to have the most portions of electrical losses. Different approaches are suggested in order to reduce losses of these networks. Reconfiguration of distribution network and DGs placement are effective methods which are used in this paper. An effective method for recognizing radial configurations of distribution network, a coding strategy for implementation of reconfiguration and DG placement by GA, a power flow method for radial networks and a fitness function for evaluating solutions are described in this paper. A 33 bus distribution network is used as test network and Numbers of DGs, their locations and capacities of them are determined by GA. Effect of configuration of network on locations and capacities of DGs is described and the best configuration for DGs placement is introduced. At last effects of increase in numbers and capacities of DGs on losses of network are studied.

Keywords: Optimization of distribution network, Loss reduction, Reconfiguration, DG placement, Genetic Algorithm (GA)

1. INTRODUCTION

Electrical distribution networks are the most extensive part of electrical networks. Low voltage and wide area cause them to have the most portions of losses. Reconfiguration of electrical

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distribution network and DGs placement are effective loss reduction methods which are used in this paper. These networks are designed and planned to have low investment and operation costs. They are designed by some mesh and are operated in radial form. In fact, reserve lines are one of useful contrivances in these networks. Reserve lines are used in reconfiguration, which cause loss reduction and voltage profile correction. Many researches about reconfiguration of electrical distribution network have been done. Some of them are mentioned in the literature. An advanced method based on refined genetic algorithm for reconfiguration of electrical distribution network is presented in [1].The constraints of line current are not included in the objective function in this paper. The genetic string for reconfiguration of electrical distribution network in [2] is made of all closed switches, so the strings are too long and comparisons of them are difficult in this paper. An initiative reconfiguration by genetic algorithm is presented in [3]for a radial network. Each solution depends on all previous solutions in this paper. Binary PSO method is used for reconfiguration in [4]. Binary coding causes long strings in large networks, so it is not proper coding strategy. Reconfiguration and DG placement by PSO method are implemented separately in [5], but the effect of their implementation at the same time is not studied in this paper. The effects of load models on locations and capacities of DGs are presented in [6], but the effects of configurations of distribution network on locations and capacities of DGs are not studied in this paper. Reconfiguration and DG placement are used to reduce the losses of distribution network in [7] but the proper numbers and capacities of DGs are not studied in this paper. A proper power flow method for radial distribution networks, based on backward- forward method is presented in [8]. The presented power flow method is so useful and acceptable. A sensitivity analysis is used to determine the locations of DGs in [9]. Then reconfiguration and capacity finding are done simultaneously by harmony search method. Implementation of reconfiguration, DG placement and capacity finding, simultaneously, is not studied in this paper. The next section is about genetic algorithm and implementation of optimization problem. Then an objective function for optimization problem is introduced and a proper power flow method is presented. Test system, proper radial configurations and proper numbers of DGs are the subjects of next sections. Then reconfiguration and DG placement are implemented separately. Implementation of Reconfiguration, DG placement and finding the proper capacities of DGs simultaneously as a unit optimization problem (the proposed method), the effects of increase in numbers and capacities of DGs on losses, are the last sections. MATLAB software is used for simulations.

2. GENETIC ALGORITHM AND IMPLEMENTATION OF OPTIMIZATION PROBLEM

Genetic Algorithm is a powerful intelligence method which is used in this paper. At first, GA produces some possible incidental solutions, then operators such as crossover and mutation are used to produce newer solutions. Coding strategy is so important to form a GA string. The integer numbers of all open switches produce a GA string for reconfiguration in this paper. By combining the integer numbers of open switches, bus numbers of DGs and their capacities, a GA string for implementation of reconfiguration and DG placement as a unit optimization problem (the proposed method) is made. Equation (1) shows a sample string which is made of 5 open switches and 4 DGs.

$$\left[X^1, X^2, \ldots, X^{12}, X^{13}\right] \tag{1}$$

3. FITNESS FUNCTION

Solutions generated by GA are evaluated by a fitness function. The fitness function used in this paper is shown by (2) [2].

$$f_{FITNESS}=P_{LOSSES}+W_1 S(K)+W_2 V(K)+W_3 S_A(K) \tag{2}$$

where

$$S(K) = \frac{Number\ of\ substations\ above\ capacity\ limit}{Number\ of\ substations}$$

$$V(K)=\frac{Number\ of\ buses\ voltage\ above\ or\ below\ limit}{number\ of\ buses}$$

$$S_A(K)=\frac{Number\ of\ lines\ above\ capacity\ limit}{number\ of\ solutions}$$

W_1 , W_2 and W_3 are defined by their importance in the optimization problem. Each solution generated by GA is evaluated by the fitness function after a power flow run.

4. RADIAL NETWORK POWER FLOW

Because of special features of distribution networks such as radial structure, high portions of R/X, unbalanced loads, large numbers of branches and nodes and etc., classic power flow methods such as Newton-Raphson and Gauss-Seidel are not acceptable. Because of simple structure of these networks, nonlinear power flow equations can be solved easily by backward-forward power flow method. Following steps are required for this method:

1) Define an initial voltage for all nodes.
2) Define the nodes which are at the end of the radial network.
3) Define the path to the reference node for all end nodes.
4) Backward: move from the end nodes to the reference node to calculate the currents of upper lines of end nodes by (3).
5) Forward: move from the reference node to the end nodes to calculate the voltage of nodes by (4).
6) Check the stop criteria. If the stop criteria are not satisfied, go back to step 4.

$$I = \left(\frac{S}{V}\right)^* = \left(\frac{P+jQ}{V}\right)^* \tag{3}$$

$$V_m = V_n - Z_{mn} * I_{mn} \tag{4}$$

It must be attention that the current of each node passing all upper branches between that node and reference node. In (4)node *m* is below node *n* in the path. All DGs are modeled as PQ with constant power factor and accuracy of 0.00001 is stop criterion for voltage convergence of all nodes in this paper.

5. TEST NETWORK

A 33 bus radial distribution network is used for simulations in this paper. This network has 5 loops and 37 switches. 5 open switches are needed for radial configuration (1 switch per loop).The losses of network is 202.7 KW and open switches are 33 to 37 which are shown by dotted lines in Figure 1 at initial configuration [10].

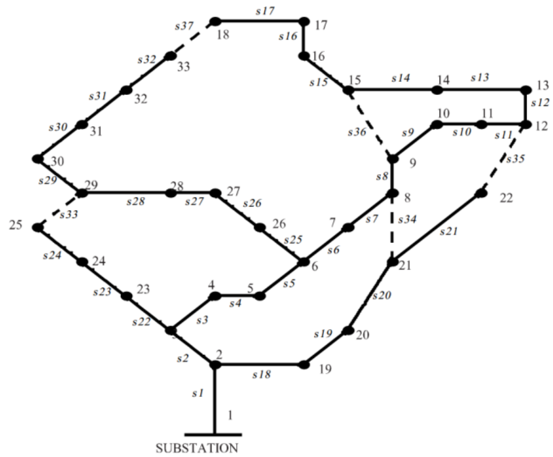

Figure 1. 33 bus network

6. RADIAL CONFIGURATIONS

Bus incidence matrixÂ is used to determine whether GA solutions are radial or not. This matrix has one row for each branch and one column for each node with an entrya_{ij}in row$i$and column$j$according to the following rules:

$a_{ij} = 0$, if branch i is not connected to node$j$

$a_{ij} = 1$, if branch i is directed away from node j

$a_{ij} = -1$, if branch i is directed toward node j

A reference node must be chosen. The column corresponding to the reference node is omitted from Â and the resultant matrix is a square branch-to-node matrix and expressed by A. If the determinant of A is equal to 1 or -1, then the system is radial. Else if that is equal to zero, this means that either the system is not radial, or groups of loads are disconnected from the service [11].

7. DG PLACEMENT

The numbers, capacities and locations of DGs are defined by DG placement study. Installations of DGs improve the voltage profile and decrease the losses of network. A 33 bus distribution network is used for DG placement study in this paper.

8. DEFINE THE NUMBERS OF DGS

DG placement is a costly act in a distribution network. Usually about half demand of network is supplied by DGs and remain is supplied by infinite bus. 3.7 MW is the demand of network at initial conditions. So2 MW is the maximum permitted capacity for installation of DGs. At first, one DG by maximum capacity of 2 MW is assumed and location and proper capacity of it is defined by proposed GA. Then numbers of DGs are increased and 2 MW is divided between them. Table 1 shows the results. It shows that increase in numbers of DGs cause decrease in losses of network. As numbers of DGs increase, their loss reduction ability decrease. So according to Table 1, 3 or 4 DGs are enough for test network. 4 DGs are assumed in this paper.

Table 1. Finding the number of DGs by GA

DG number	Locations of DGs				Losses (KW)
	Capacities of DGs (KW)				
0	-				202.7
	0				
1	29				65.864
	1771.4				
2	11		30		33.43
	999.46		999.67		
3	14	27		31	29.095
	665.89	665.78		665.98	
4	14	25	30	32	24.965
	499.5	499.24	499.65	499.95	

9. EFFECTS OF NETWORK CONFIGURATION ON DGS LOCATIONS AND LOSSES

According to last section, 4 DGs are appropriate for test network. Following scenarios are used to study the effects of network configuration on DGs placement and losses:

I. Initial condition (before reconfiguration and before DG placement).

II. Only reconfiguration (without DG placement).

III. DG placement at initial configuration.

IV. Reconfiguration, then DG placement.

V. DG placement at initial configuration, then reconfiguration

VI. Implementation of reconfiguration and DG placement simultaneously as a unit optimization problem (proposed approach).

DG placement means determining locations and capacities of 4 DGs simultaneously in all above scenarios. Table 2 shows the results of above scenarios by GA. Comparing the results of scenario Ⅰ and Ⅱ shows that reconfiguration can reduce the losses of network about 63.168 KW and change the losses of 202.7 KW to 139.502 KW. This energy saving is earned by reconfiguration which has no cost or low cost. Comparing the results of scenario Ⅰ and Ⅲ shows that installation of DGs at initial configuration cause 177.735 KW energy saving. It is seen that DG placement is an effective loss reduction technic. It is a costly act and a long time is needed for restoration of investment costs. Effect of initial configuration on locations of DGs and losses of network is clear by comparing the results of scenarios Ⅲ and Ⅳ. It is seen that before DG placement, the losses of reconfigured network is less than initial configuration but after DG placement, the reconfigured network has more losses than initial configuration. So the configuration of network is so important for DG placement. Scenario Ⅵ is used to determine the best configuration of network for DG placement. Implementation of reconfiguration and DG placement simultaneously as a unit optimization problem (the proposed approach) is carried out in this scenario. It is seen that losses of this scenario is less than others.

If DG placement and reconfiguration carry out separately, Transposition of implementation of them is effective on DGs locations, their capacities, configuration and losses of network. This important issue is seen by comparing the results of scenarios Ⅲ, Ⅳ and Ⅴ. Comparing the results of scenarios Ⅱ, Ⅲ and Ⅴ shows that reconfiguration is an effective loss reduction technic in different load patterns, whether DGs are installed or not. Reconfiguration is used for different purposes such as load restoration, phase unbalanced correction and loss reduction. Only loss reduction capability of it is studied in this paper.

10. EFFECT OF CAPACITIES OF DGS ON THEIR LOCATIONS AND LOSSES OF NETWORK

Implementation of reconfiguration and DG placement simultaneously as a unit optimization problem was the best loss reduction technic introduced in the last sections. Table 3 shows the results of this approach whereas the capacities of DGs increase in 100 KW steps. It shows that increase in capacities of DGs cause decrease in losses of network. As capacities of DGs increase, their loss reduction ability decrease. Also it is seen that maximum capacities of DGs are effective on their locations, used capacities of them and configuration of network. DG placement is a costly act. So, usually half demand of distribution network is supplied by DGs and remain is supplied by reference bus. The last 2 rows of Table 3 show that whole capacities of large DGs are not used. So installation of DGs with large capacities is not logical, if investment costs are important. Whole demand of independent networks must be supplied by DGs. So Table 3 is useful for these networks.

11. EFFECT OF INCREASE IN NUMBERS AND CAPACITIES OF DGS ON THEIR LOCATIONS AND LOSSES OF NETWORKS

Usually numbers of DGs are limited. In this section, the maximum numbers of them are assumed 8 and instead of assigning the maximum capacity of each one, the maximum sum of their capacities are assigned and are increased in 400 KW steps. Implementation of reconfiguration and DG placement simultaneously as a unit optimization problem by above assumptions are shown in Table 4. It is seen that in all capacities, the losses of Table 4 are less than Table 3. Decrease in losses of network is clearer in large capacities of DGs. Table 4 shows that as the capacities of DGs increase, their loss reduction ability decrease. Table 3 and Table 4 show that configuration of network and locations of DGs are affected by numbers of DGs and their capacities.

Table 2. Effect of network configuration on DG location and losses by GA

<table>
<tr><th rowspan="3">scenarios</th><th colspan="6">DGs locations</th><th rowspan="3">Losses (KW)</th></tr>
<tr><th colspan="6">Used capacity of DGs (KW)</th></tr>
<tr><th colspan="6">Open keys</th></tr>
<tr><td rowspan="3">I.</td><td>-</td><td colspan="2">-</td><td colspan="2">-</td><td>-</td><td rowspan="3">202.7</td></tr>
<tr><td>-</td><td colspan="2">-</td><td colspan="2">-</td><td>-</td></tr>
<tr><td>33</td><td>34</td><td colspan="2">35</td><td>36</td><td>37</td></tr>
<tr><td rowspan="3">II.</td><td>-</td><td colspan="2">-</td><td colspan="2">-</td><td>-</td><td rowspan="3">139.532</td></tr>
<tr><td>-</td><td colspan="2">-</td><td colspan="2">-</td><td>-</td></tr>
<tr><td>7</td><td>9</td><td colspan="2">14</td><td>32</td><td>33</td></tr>
<tr><td rowspan="3">III.</td><td>14</td><td colspan="2">25</td><td colspan="2">30</td><td>32</td><td rowspan="3">24.965</td></tr>
<tr><td>499.5</td><td colspan="2">499.24</td><td colspan="2">499.65</td><td>499.95</td></tr>
<tr><td>33</td><td>34</td><td colspan="2">35</td><td>36</td><td>37</td></tr>
<tr><td rowspan="3">IV.</td><td>16</td><td colspan="2">25</td><td colspan="2">30</td><td>31</td><td rowspan="3">26.362</td></tr>
<tr><td>499.69</td><td colspan="2">499.93</td><td colspan="2">499.66</td><td>499.73</td></tr>
<tr><td>7</td><td>9</td><td colspan="2">14</td><td>32</td><td>33</td></tr>
<tr><td rowspan="3">V.</td><td>14</td><td colspan="2">25</td><td colspan="2">30</td><td>32</td><td rowspan="3">18.668</td></tr>
<tr><td>499.5</td><td colspan="2">499.24</td><td colspan="2">499.65</td><td>499.95</td></tr>
<tr><td>7</td><td>8</td><td colspan="2">10</td><td>27</td><td>35</td></tr>
<tr><td rowspan="3">VI.</td><td>14</td><td colspan="2">25</td><td colspan="2">30</td><td>32</td><td rowspan="3">18.638</td></tr>
<tr><td>499.87</td><td colspan="2">499.91</td><td colspan="2">499.87</td><td>499.97</td></tr>
<tr><td>7</td><td>8</td><td colspan="2">10</td><td>27</td><td>35</td></tr>
</table>

Table 3. Reconfiguration, finding the locations and capacities of 4 DGs simultaneously by GA

<table>
<tr><th rowspan="3">Maximum capacity of each DG (KW)</th><th colspan="8">DGs locations</th><th rowspan="3">Losses (KW)</th></tr>
<tr><th colspan="8">Used capacity of each DG (KW)</th></tr>
<tr><th colspan="8">Open keys</th></tr>
<tr><td rowspan="3">500</td><td colspan="2">14</td><td colspan="2">25</td><td colspan="2">30</td><td colspan="2">32</td><td rowspan="3">18.638</td></tr>
<tr><td colspan="2">499.87</td><td colspan="2">499.91</td><td colspan="2">499.87</td><td colspan="2">499.97</td></tr>
<tr><td>7</td><td colspan="2">8</td><td colspan="2">10</td><td colspan="2">27</td><td>35</td></tr>
<tr><td rowspan="3">600</td><td colspan="2">14</td><td colspan="2">25</td><td colspan="2">30</td><td colspan="2">32</td><td rowspan="3">12.587</td></tr>
<tr><td colspan="2">599.83</td><td colspan="2">599.81</td><td colspan="2">599.91</td><td colspan="2">599.81</td></tr>
<tr><td>7</td><td colspan="2">8</td><td colspan="2">10</td><td colspan="2">21</td><td>25</td></tr>
<tr><td rowspan="3">700</td><td colspan="2">8</td><td colspan="2">18</td><td colspan="2">25</td><td colspan="2">30</td><td rowspan="3">8.876</td></tr>
<tr><td colspan="2">699.79</td><td colspan="2">699.85</td><td colspan="2">699.95</td><td colspan="2">699.65</td></tr>
<tr><td>5</td><td colspan="2">13</td><td colspan="2">34</td><td colspan="2">35</td><td>36</td></tr>
<tr><td rowspan="3">800</td><td colspan="2">6</td><td colspan="2">12</td><td colspan="2">25</td><td colspan="2">32</td><td rowspan="3">7.2567</td></tr>
<tr><td colspan="2">779.33</td><td colspan="2">549.17</td><td colspan="2">799.88</td><td colspan="2">799.97</td></tr>
<tr><td>4</td><td colspan="2">8</td><td colspan="2">14</td><td colspan="2">21</td><td>34</td></tr>
<tr><td rowspan="3">900</td><td colspan="2">7</td><td colspan="2">12</td><td colspan="2">25</td><td colspan="2">32</td><td rowspan="3">6.7114</td></tr>
<tr><td colspan="2">703.07</td><td colspan="2">562.9</td><td colspan="2">899.45</td><td colspan="2">847.38</td></tr>
<tr><td>4</td><td colspan="2">8</td><td colspan="2">14</td><td colspan="2">21</td><td>34</td></tr>
</table>

Table 3. Reconfiguration, finding the locations and capacities of 8 DGs simultaneously by GA

Maximum Sum of capacities of DGs (KW)	Open keys / locations of DGs / Capacity of each DG								Losses (KW)
2000	Open keys	7	8	10	14	26			17.871
	locations of DGs	9	13	17	25	29	30	31	33	
	Capacity of each DG	140.1	265.42	152.96	299.05	328.35	330.64	310.15	173.33	
2400	Open keys	6	8	13	27	35			10.186
	locations of DGs	7	11	15	24	25	29	30	32	
	Capacity of each DG	327.7	274.3	253.92	135.28	341.15	165.93	430.57	471.14	
2800	Open keys	5	8	12	34	35			4.8808
	locations of DGs	7	8	10	14	24	25	30	32	
	Capacity of each DG	368.88	185.56	215.76	307.64	282.06	58.623	460.38	393.47	
3200	Open keys	4	9	20	21	36			2.4458
	locations of DGs	6	8	12	14	24	25	30	32	
	Capacity of each DG	416.76	307.08	320.03	198.33	442.21	503.91	529.15	482.51	
3600	Open keys	4	8	12	20	21			2.2674
	locations of DGs	6	8	12	14	24	25	30	32	
	Capacity of each DG	365.35	329.41	280.77	311.08	501.69	488.07	520.32	480.25	

Whole capacities of DGs are used by the strategy proposed in this section, so investment costs are not waste.

12. CONCLUSION

Reconfiguration is an effective loss reduction technic for electrical distribution networks. Simulation results showed that implementation of it by GA cause energy saving in different load patterns, whether DGs are installed or not. This energy saving has no cost or low cost. DG placement was another loss reduction technic used in this paper. It was implemented by GA in different configurations of test network and results showed that transposition of implementation of reconfiguration and DG placement, are effective on locations and capacities of DGs and final configuration and losses of network. Simulations showed that implementation of reconfiguration and DG placement simultaneously as a unit optimization problem (proposed method) is the best technic for planning of distribution networks. Increase in numbers or capacities of DGs or increase in both of them, cause decrease in losses of distribution network. As capacities of DGs increase, their loss reduction ability decrease. Locations of DGs, used capacities of them and final configuration of network are affected by numbers of DGs and their capacities.

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