Curtailment of losses in Distribution Systems

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Abstract Loss reduction can only augment the system performance which is a challenge nowadays as the load demand on the system increases. Network reconfiguration is an option to reduce the loss of the system. If distributed generators can be placed further in reconfigured network, the loss of the system further reduces. In this paper an attempt has been made to reconfigure the network efficiently and place the distributed generators in reconfigured network optimally using “Hybrid artificial bee colony and Cuckoo Search (ABC-CS) algorithm” with a target to slash power loss and to improve the voltage profile of the network. The power loss minimization and load balancing index based objective function is used so that the operating constraints like voltage, current rating of feeder, and radial configuration of the network are satisfied. The proposed method is implemented on the MATLAB working platform. The suggested method is tested on a standard 33-node radial distribution network and the outcomes obtained by proposed approach are juxtaposed with other published methods.

Keywords- Network Reconfiguration; Distributed Generation; Fuzzy Logic; PSO; ABC-CS

I. INTRODUCTION

Due to increase of load demand, distribution networks are facing higher system losses causing poor voltage regulation [1]. Any distribution network has a number of interconnected radial circuits and the design of any distribution should be made cost effective during the peak load demand. The nature of distribution systems is usually radial [2]. Effective load flow of distribution systems can give proper investigation [3]. Loss enhancement is the main concern of the planners, which has motivated the research of loss reduction of distribution networks [4]. If the system loss is reduced, the system voltage profile as well as the stability of the system will be upgraded [5]. There are two types of switches in distribution system named as sectionalizing switch and tie-line switch [6]. By closing the tie-line switch and opening the sectionalizing switch, the configuration of the system will be different without disturbing the supply to the consumers. [7]. After reconfiguration of any distribution network, the system loss will be reduced [8]. The operation condition of the system enhanced due to transfer of load from one feeder to another [9].

Since a few parts of the distribution network are overloaded during the peak time of the day and these are under loaded at other times of the day [10]. The structure reconfiguration of the network is the only possibility to balance the load of the system as well to minimize the loss of the system. If DG is further placed to the reconfigured network, this will give additional relief for loss reduction [11].

The main motive of this paper is to reconfigure the distribution network and place DG sources in the reconfigured network to enhance the system performance. The objective function is optimized by an established hybrid ABC-CS algorithm to get better outcomes. The organization of the paper is summarized as follows. Section 2 briefs some of the latest research works reported in network reconfiguration and DG placement. In section 3, network reconfiguration and DG placement have been carried out. The results and the comparison of the proposed method are presented in section 4. Section 5 presents the conclusions followed by references.

II. RELATED WORKS

Doagou-Mojarrad et al. [18] suggested an interactive fuzzy satisfying technique based mostly on “Hybrid Shuffled Leaping Frog algorithm (HSLFA)”. They solved the drawback of the Multi-objective optimum placement and size of DG units within the distribution network. The proposed method had been implemented on a 69-node distribution network. Kavousi-Fard and Akbari-Zadeh [19] presented a multi-objective “Improved Shuffled...
Frog Leaping Algorithmic (ISFLA)” to reconfigure distribution feeder. The total cost of MW loss was very important and hence total active power losses considered as a main factor. The objective functions consisting of system average interruption frequency index (SAIFI), system average interruption duration index (SAIDI), average energy not supplied (AENS) and the total active power losses was optimized. The proposed method was implemented on a typical distribution system. Ugranl and Karatepe [20] had examined different DG unit penetration levels using an optimality criterion to minimize losses with the help of load uncertainty. Since there was the complexity of the multiple DG construct, they developed artificial neural network based optimal DG unit placement. They tested their method on 30-node system. Rao et al. [21] used a meta-heuristic “Harmony Search Algorithmic (HSA)” to reconfigure the network as well as to place the DG unit with an aim to reduce the power loss of the system and enhance the voltage profile of the system. They implemented the suggested method on 33-node and 69-node distribution networks. Imran et al. [22] applied a novel method o reconfigure the network as well as to place DG units in distribution system using Fireworks Algorithm (FWA) securing the radial nature of the network. They had considered six different eventualities during this process to get the enhanced performance of the system. Tolabi et al. [23] had suggested a hybrid method to place multiple DGs optimally to reduce losses, improve voltage profile and to get the better feeder load balancing in power distribution systems. They had Improved Analytical (IA) method to choose the optimum candidate locations for multiple-DG. Bees Algorithmic (BA) was applied at the same time to reconfigure and establish the optimum capability for installation of DG units. Dahalan et al. [24] had suggested a technique to reconfigure the network optimally and to place the DG unit optimally using EP method to cut down the system’s loss and uplift the voltage profile by satisfying the operative constraints. They tested their method on 33-node and 69-nodedistribution systems and showed a nice improvement of the outcomes in terms of power loss reduction and overall voltage profile of the system. Esmaeilian and Fadaeinedjad [25] proposed a novel hybrid technique, which enclosed meta-heuristic and heuristic algorithms to attenuate energy loss in distribution systems by network reconfiguration and integration of DGs. They had used forward and backward power flow method. Different varieties of load pattern had been used. To demonstrate the effectiveness of the proposed technique, they had used 33-node and 83-node distribution networks. Rajaram et al. [26] used a modified plant growth simulation to reduce the real power loss of the system. They integrated the DGs in the system before and after network reconfiguration dealing the objectives and constraints separately. They had used 33-node distribution networks to show the effect of their proposed algorithms. Murty and Kumar [27] used “voltage stability index (VSI)” method to place DG. They had placed single DG unit in 12-node, modified 12-node, 69-node and 85-node RDNs. They had juxtaposed their methods with the “novel power loss sensitivity” and “power sensitivity index (PSI)”. Bala and Ghosh [28] suggested a method to assimilate upto three DGs both in radial and meshed distribution networks using hybrid ABC-CS algorithms. They also proposed hybrid Fuzzy-PSO load flow technique of radial and meshed distribution system. A new voltage stability index had also been suggested. They placed three DG units in 33-node and 69-node RDNs as well as 85-node and 119-node MDNs. They had also compared their methods with other published methods. Bala and Ghosh [29] proposed a method to integrate distributed generations (DGs) in radial distribution networks (RDNs) using ABC algorithm. The appropriate nodes of RDN was calculated by loss sensitivity index. The optimal sizing of DGs was performed by using the ABC algorithm. The method was tested on 33-node and 69-node RDNs. The results obtained using ABC algorithm were compared with other algorithms. Bala and Ghosh [30] presented a method to integrate distributed generations (DGs) in radial distribution networks (RDNs) using FF algorithm. The results obtained via Firefly algorithm had also been juxtaposed with that PSO and GA algorithm.

III. PROPOSED METHODOLOGY FOR DG PLACEMENT SIMULTANEOUS WITH NETWORK RECONFIGURATION

A method to reconfigure distribution network as well as three DG units placement is proposed in this paper so that better loss minimization and improvement of system performance can be obtained. The proposed method uses a new dimensional objective function which is to be optimized using the established ABC-CS algorithm using the load flow available in [28]. The objective function is formulated based on power loss minimization, load balancing index, radial nature of system and loss reduction during DG installation with operating constraints. By using this method, we obtain an efficient distribution network with minimum loss. The architecture of the proposed method is shown in Figure 1.
The flow of process of the suggested method has been shown in Fig. 1 for optimal network reconfiguration and DG placement. In most of the research work either they concentrate on DG placement or network reconfiguration.

3.1 Network Reconfiguration with DG Placement

In the proposed method the best reconfiguration of distribution network is carried out with the help of objective function minimization of power loss and load balancing index. The operating constraints like voltage, current rating of feeder, and radial structure of system are satisfied. The DG units are placed on reconfigured network.

3.1.1 Power Loss Minimization

The power loss of a line connecting buses in between \( k \) and \( k+1 \) after network reconfiguration can be calculated. Refer to “(1)”. \[ P_{\text{Loss}}(m, m+1) = \frac{R_m}{V_m^2} \left( P_m^2 + Q_m^2 \right) \] (1)

Therefore, the total power loss for all feeders is given by (2).

\[ P'_{\text{Total Loss}} = \sum_{m=1}^{n} P'_{\text{Loss}}(m, m+1) \] (2)

The difference of power losses before and after reconfiguration of network termed as the net power loss reduction of the system is given by (3).

\[ \Delta P'_{\text{Loss}} = \sum_{m=1}^{n} P_{\text{Total Loss}}(m, m+1) - \sum_{m=1}^{n} P'_{\text{Total Loss}}(m, m+1) \] (3)

where \( P_m' \) = Real power of bus \( m \) after reconfiguration

\( V_m' \) = Voltage at bus \( m \) after reconfiguration

\( Q_m' \) = Reactive power of bus \( m \) after reconfiguration

\( R_m \) = Resistance between \( m \) and \( m+1 \)

\( P_{\text{Loss}}(m, m+1) \) = Losses in line connecting \( m \) and \( m+1 \)

\( P_{\text{Total Loss}}(m, m+1) \) = Total loss of feeder before reconfiguration

\( P'_{\text{Total Loss}}(m, m+1) \) = Total loss of feeder after reconfiguration

3.1.2 Load Balancing Index

The degree of loading among feeders is known as the load balancing index (LBI). If part of the loads heavily loaded feeders is transferred to the lightly loaded feeders, the loading margin will be increased. The LBI of feeder is given by (4).
\[ LBI = \sum_{m \in B} \left( \frac{I_{m,r}}{I_{m,\text{max}}} \right)^2 \quad (4) \]

Where \( B \) = set of network branches forming loops
\( L_m \) = Length of branch \( m \)
\( I_{m,r} \) = Current capability of branch \( m \) for feeder reconfiguration pattern \( r \)
\( I_{m,\text{max}} \) = maximum current capability of branch \( m \)

### 3.1.3 Radial Structure of System

The structure of network after the reconfiguration should be maintained as radial. Here “A” is considered as the bus incidence matrix. If its determinant “A” matrix is equal to zero, the network is not radial. If (5) is satisfied, the network becomes radial.

\[ \det(A) = 1 \quad \text{or} \quad -1 \quad (5) \]

### 3.1.4 Loss Reduction Using DG Installation

Incorporation of optimal DG in distribution network results in reduction of losses in lines and improvement of voltage profile. The loss when DG placed in the distribution network is given by (6).

\[ p_{DG}^{\text{Loss}} = \frac{R_m}{V_m^2} \left( P_m^2 + Q_m^2 \right) - \frac{R_m}{V_m^2} \left( P_m^2 + Q_m^2 - 2P_mP_g - 2Q_mQ_g \right) \quad (6) \]

Therefore, the net power loss reduction of the network is the difference of power loss before and after DG allocation is given by (7).

\[ \Delta P_{\text{Loss}}^{DG} = \frac{R_m}{V_m^2} \left( P_m^2 + Q_m^2 - 2P_mP_g - 2Q_mQ_g \right) \quad (7) \]

Here, the positive value of (7) gives reduction of system’s loss while the negative value gives enhancement of system’s loss.

### 3.1.5 Formation of Objective Function

The objective for the problem is formulated in such a way to get the maximum loss reduction of the system.

The objective function is given by (8).

\[ \text{Objective Function, } F = \max \left( \frac{\Delta P_{\text{Loss}}^R}{LBI} + \Delta P_{\text{Loss}}^{DG} \right) \quad (8) \]

Subjected to \( V_{min} \leq V_m \leq V_{max} \)

\[ |I_{m,r}| \leq |I_{m,r,\text{max}}| \]

\[ \sum_{n=1}^{n} P_G \leq \sum_{n=1}^{n} (P_t + P_{\text{Loss,m}}) \]

Once the objective function is formulated the next step is to utilize the objective function in the optimization algorithm to get the optimal reconfiguration of the system and optimal DG size to be placed. The method to obtain the location of DG is available in [28]. The flow chart of the proposed method is shown in Fig. 2.
The necessary relations for cost of energy loss and cost of DG are available in [27]. The details of ABC-CS are available in [28].

**IV. SIMULATION RESULTS FOR TEST SYSTEM**

The proposed method has been implemented in the following system configuration.

Operating System: Windows 8
Processor: Intel Core i3-3210
System Frequency: 3.19 GHz
RAM: 4 GB
MATLAB 2013a
The experimental results for the test system (33-node) is given in this section. The four type of cases i.e., Base case network (Case 1), Reconfiguration (Case 2), DG installation in Base network [28] (Case 3) and DG installation in reconfigured network (Case 4) are examined. Table 1 shows the outcomes for four different cases.

From Table 1, it can be observed that the losses of the system are 202.32 kW, 100.15 kW, 63.30 kW and 49.15 kW respectively for the cases 1, 2, 3, and 4. This shows that, the power loss decrease is very high in the case 4 i.e., simultaneous reconfiguration and DG placement, which shows the performance and advantage in the presented technique than the other cases. In Table 1, the development in the voltage profile and reduction of loss for case 4 are higher than the case 2 and 3. This shows that only reconfiguration or only DG installation does not produce the desired results of maximizing power loss reduction and voltage profile improvement. The improvement in least voltages (node number) of the system for case 1, case 2, case 3 and case 4 are 0.9136 (18), 0.9788 (16), 0.9788 (30) and 0.9894 (28) respectively. From this, it can be seen that development in least voltage of the network for case 4 is the highest.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Different Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case 1</td>
</tr>
<tr>
<td>Switches Opened</td>
<td>33, 34, 35, 36, 37</td>
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<tr>
<td>Power Loss (kW)</td>
<td>202.32</td>
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<tr>
<td>Minimum Voltage (p.u.)</td>
<td>0.9136 (18)</td>
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<tr>
<td>VSI</td>
<td>0.8341 (18)</td>
</tr>
<tr>
<td>Number of DGs</td>
<td>-</td>
</tr>
<tr>
<td>DG Location</td>
<td>-</td>
</tr>
<tr>
<td>DG Size (MW)</td>
<td>-</td>
</tr>
<tr>
<td>Cost of Energy Loss ($/kWh)</td>
<td>106339.392</td>
</tr>
<tr>
<td>Cost of DG ($/h)</td>
<td>-</td>
</tr>
</tbody>
</table>
The reconfigured network obtained for case 2 from base network shown in Fig. 3 is depicted in Fig. 4. Fig. 5 shows the three DG placement in the base network. Fig. 6 shows the three DG placement in the network obtained in case 2. The voltage profile curves for the four cases are shown in Fig. 7.

Figure 3. Base Configuration of Test System (Case 1)

Figure 4. Reconfigured Network for Test System (Case 2)
Figure 5. DG Placement for Test System (Case 3)

Figure 6. Simultaneous DG placement and network reconfiguration for Test System (Case 4)
From Figure 7, it is clear that the voltage profile of case 4 is better than other cases (Case 2 and Case 3).

4.1. Comparison of Proposed Work with Existing Works

The comparison of the proposed method with other existing methods is shown in Table 2 for the Test system (33-node RDS). Table 2 show that the proposed method has achieved better results in each and every aspect like power loss reduction as well the voltage profile improvement from the detailed results given in the section shows that proposed simultaneous reconfiguration with DG placement using hybrid ABC-CS algorithm is the best method for radial distribution network.

<table>
<thead>
<tr>
<th>Different Cases</th>
<th>Parameters</th>
<th>Proposed Method</th>
<th>[23]</th>
<th>[24]</th>
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<tr>
<td>Case 2</td>
<td>Switches Opened</td>
<td>13, 19, 21, 24, 30</td>
<td>7, 14, 9, 32, 28</td>
<td>28, 20, 17, 10, 14</td>
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<tr>
<td></td>
<td>Power Loss (kW)</td>
<td>100.15</td>
<td>139.98</td>
<td>136.19</td>
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<td></td>
<td>Min. Voltage (p.u.)</td>
<td>0.9443</td>
<td>0.9413</td>
<td>0.9380</td>
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<td>Case 3</td>
<td>DG Size (MW)</td>
<td>2.92</td>
<td>1.7937</td>
<td>2.825</td>
</tr>
<tr>
<td></td>
<td>Power Loss (kW)</td>
<td>63.3</td>
<td>88.68</td>
<td>97.65</td>
</tr>
<tr>
<td></td>
<td>Min. Voltage (p.u.)</td>
<td>0.9788</td>
<td>0.9680</td>
<td>0.9529</td>
</tr>
<tr>
<td>Case 4</td>
<td>Switches Opened</td>
<td>13, 19, 21, 24, 30</td>
<td>7, 14, 11, 32, 28</td>
<td>7, 9, 14, 32, 37</td>
</tr>
<tr>
<td></td>
<td>DG Size (MW)</td>
<td>2.53</td>
<td>1.6841</td>
<td>2.942</td>
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<tr>
<td></td>
<td>Power Loss (kW)</td>
<td>49.15</td>
<td>67.11</td>
<td>44.28</td>
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<tr>
<td></td>
<td>Min. Voltage (p.u.)</td>
<td>0.9894</td>
<td>0.9713</td>
<td>0.9701</td>
</tr>
</tbody>
</table>
V. CONCLUSION

Reconfiguration of distribution network is carried out using a new methodology in the proposed method with simultaneous installation of DG units. The performance evaluation of the proposed method have been carried out using the three cases like only network reconfiguration, only DG installation, simultaneous reconfiguration and DG installation and outcomes are compared to the available methods. The effectiveness of proposed method is tested using a 33-bus radial distribution system. The proposed method gives better loss reduction, ease-of-use, and applicability.

REFERENCES


Author Biographies


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