Research Article

Enhancing Distribution System Performance via Distributed Generation Placement and Reconfiguration Based on Improved Symbiotic Organisms Search

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Minimal power loss is highly desired for an efficient and economical operation in distributed systems. This paper presents an improved symbiotic organisms search (ISOS) for system reconfiguration (SR) and distributed generation placement (SR-DGP) simultaneously. The proposed ISOS combined the simple quadratic interpolation (SQI) strategy into SOS to improve the search process. The ISOS was adopted to define the optimal system topology, location, and capacity of distributed generators (DGs) to minimize power losses. The proposed ISOS was evaluated on the 33-node and 69-node systems. The proposed ISOS successfully reduced the power losses by 73.1206% and 84.2861% for the 33-bus and 69-bus. Moreover, ISOS was also compared with other approaches, where ISOS obtained better results than other approaches for all test systems. Hence, ISOS showed its effectiveness in dealing with the SR-DGP problem.

1. Introduction

There is a momentous amount of power loss associated with the distribution system. An inefficient power loss results in the system performing inefficiently as well as a poor voltage profile. To improve efficiency and advance the voltage profiles, the system needs to be reconfigured properly. Furthermore, distribution generation (DG) can contribute to lowering power losses and improving the voltage profiles and system capacity by integrating local power sources such as wind turbines, solar photovoltaic (PVC), and diesel generators. It is nevertheless imperative that system reconfiguration (SR) and DG placement (DGP) should be carried out in a systematic manner since it can result in ineffective and undesirable network performance. After reconfiguring the distributed system, it is imperative to maintain the radial topology of the feeders. It is also important to determine the DGs placement so as to minimize power losses while maintaining constraints. Therefore, it is very critical to solve the SR-DGP problem properly to improve the system’s performance [1].

Numerous studies have examined the SR of the distribution system to minimize power loss. It has been reported that metaheuristic algorithms can be used to reconfigure the distribution system in recent studies such as bacterial foraging optimization (BFO) [2], genetic algorithm (GA) [3–5], cuckoo search algorithm (CSA), fireworks algorithm (FWA) [6], harmony search algorithm (HSA) [7], heuristic rules-based fuzzy multiple objectives [8], and particle swarm optimization (PSO) [9, 10]. To improve the effectiveness of the distribution system, several studies have combined both SR and DGP in recent years. By deploying a fuzzy-bees technique in [11], power losses were reduced, the voltage profile was enhanced, and feeder load balancing in the distribution system was balanced through reconfiguration and distribution of multiple DGs. In [12], the authors employed the gravitational search algorithm (GSA) to define DG uncertainties and reconfiguration. In [13], an adaption shuffled frog leaping algorithm (ASFLA) has been adopted for dealing with the coordination of DG allocation and network reconfiguration in several cases of 33-node and 69-
node systems. To optimize the voltage stability index (VSI) and power losses, an enhanced CSA [14] was implemented based on graph theory. A combination of gray wolf optimizer and PSO was used in [15] to address reconfiguration problems while taking DGs into consideration. The heuristic algorithm used in [16] provided some promising results for network reconfiguration involving the allocation of DGs. According to Badran et al. [17], the firefly (FF) could be used to optimize reconfiguration and DG outputs. For reconfiguration with DGs distribution, Raut and Mishra [18] applied a combination of levy flights and a sine-cosine algorithm (SCA). In [19], DGP and system reconfiguration were achieved using HSA in 33-node and 69-node networks, in which voltage profiles and power loss reduction optimization were objectives. VSI and loss sensitivity factor (LSF) were employed to calculate the DG positions. Harmony search algorithm (HSA) was introduced by Rao et al. [20] to reconfigure and determine the optimal DGs placement. LSF was also adopted to find the DG positions. For optimizing the integration of reconfiguration with DG allocation, an improved equilibrium optimization algorithm (IEOA) [21] was proposed. This technique was verified on 33-node and 69-node systems with various load scenarios. For dealing with DG placement and reconfiguration, a search group algorithm (SGA) was applied to four distribution networks [22]. A similar problem was studied by the marine predators algorithm (MPA) [23]. A literature review indicates that there have been only a few studies conducted for defining the optimal configuration simultaneously with the DGs placement. By using this approach, maximum loss reduction can be achieved. It may be difficult to solve such a combined optimization problem because it includes several types of variables and constraints and as a result, there is no perfect optimization method to solve this problem.

In this study, we have developed an improved symbiotic organisms search (ISOS) for dealing with the SR-DGP problem to obtain the minimum power losses. To advance the quality of the original SOS, the ISOS was implemented by combining simple quadratic interpolation (SII). We applied ISOS to determine the SR-DGP in the 33-node and 69-node systems. Based on numerical results, it has been demonstrated that a combination of SR-DGP substantially enhanced the system's power losses and voltage profile. ISOS was also more efficient in terms of obtaining optimal solution quality than other compared methods according to comparison results.

In summary, this paper makes the following contributions:

(i) A new ISOS was proposed to handle the SR-DGP problem for minimizing system power losses.
(ii) The ISOS was tested on the 33-node and 69-node systems. After the SR-DGP application, the system performance was improved regarding power losses and voltage profile.
(iii) As shown by the outcome evaluations, ISOS gained high solution quality compared to other techniques.

2. Problem Formulation

The SR-DGP objective aims to minimize power losses by optimizing the network topology, locations, and capacities of DGs, which may be given in the following equation:

\[
OF = \min(P_L) = \min \left( \sum_{l=1}^{N_{br}} R_l I_l^2 \right),
\]

where \( R_l \) is the resistance of the \( l \)th branch, \( I_l \) is the current passing through that branch, and \( N_{br} \) is the number of branches in a distributed system.

The SR-DGP problem needs to satisfy the following constraints:

(i) Power balance:

\[
P_S + \sum_{m=1}^{N_{DG}} P_{DG,m} = \sum_{l=1}^{N_{Bus}} P_{L,l} + \sum_{n=1}^{N_{DM}} P_{DM,n}
\]

(ii) Bus voltage constraints: the voltage at buses \( (V_k) \) may be limited as follows:

\[
V_{\text{min},k} \leq V_k \leq V_{\text{max},k}; \quad k = 1, \cdots, N_{\text{Bus}}
\]

(iii) Power flow constraints: the power flowing in the \( l \)th branches must not exceed the limit \( I_{\text{max},l} \):

\[
|S_l| \leq |S_{\text{max},l}|; \quad l = 1, \cdots, N_{\text{br}}.
\]

(iv) DG constraints: the output of the \( m \)th DG unit should be limited as follows:

\[
P_{DG_{\text{min}},m} \leq P_{DG,m} \leq P_{DG_{\text{max}},m}; \quad m = 1, \cdots, N_{DG}.
\]

(v) DG penetration constraints: the penetration of all DGs follows the given condition [19]:

\[
0.1 \times \sum_{m=2}^{N_{DG}} P_{DM,m} \leq \sum_{m=1}^{N_{DG}} P_{DG,m} \leq 0.6 \times \sum_{m=2}^{N_{DG}} P_{DM,m}.
\]

(vi) Radial topology constraint: after reconfiguration, all loads must be supplied and the radial structure must be secured [24, 25]:

\[
\det(Y) = \begin{cases} 
1 \text{ or } -1 & \text{ (radial system)} \\
0 & \text{ (not radial)}
\end{cases}
\]
in which \( Y \) denotes a matrix resembling the connection of buses and branches in the system:

\[
Y_{ij} = \begin{cases} 
1 & \text{if branch } i \text{ connects from bus } j \\
-1 & \text{if branch } i \text{ connects to bus } j \\
0 & \text{otherwise.} 
\end{cases} 
\]

3. Application of ISOS Algorithm to the SR-DGP Problem

3.1. Original SOS. The SOS has been developed based on symbiotic interactions between two creatures in a natural ecosystem [26]. This method begins the exploration phase by constructing a population called an ecosystem, where each organism in the ecosystem represents a solution. The ecosystem is modified for each iteration via three symbiotic stages: mutualism, commensalism, and parasitism.

In the mutualism stage, the \( n^{th} \) organism is chosen at random from the ecosystem to associate with the \( m^{th} \) organism via mutualistic connections. New organisms are created as follows [26]:

\[
\begin{align*}
O_{m}^{\text{new}} &= O_{m} + \text{rand}(0, 1) \times (O_{\text{best}} - MV \times bf_{1}), \\
O_{n}^{\text{new}} &= O_{n} + \text{rand}(0, 1) \times (O_{\text{best}} - MV \times bf_{2}), \\
MV &= \frac{O_{i} + O_{j}}{2},
\end{align*}
\]

where \( O_{\text{best}} \) is the best organism in the ecosystem, vectors \( O_{m} \) and \( O_{n} \) are the \( m^{th} \) and \( n^{th} \) organisms in the ecosystem, respectively, \( MV \) denotes the average of the \( m^{th} \) and \( n^{th} \) organisms, representing a mutualistic relationship; \( bf_{1} \) and \( bf_{2} \) (benefit factors) are chosen at random as either 1 or 2.

The fitness values are estimated for organisms. New organisms are updated in the following equations:

\[
\begin{align*}
O_{m} &= \begin{cases} 
O_{m}^{\text{new}} & \text{if } f(O_{m}^{\text{new}}) < f(O_{i}), \\
O_{m} & \text{otherwise,} 
\end{cases} \\
O_{n} &= \begin{cases} 
O_{n}^{\text{new}} & \text{if } f(O_{n}^{\text{new}}) < f(O_{n}), \\
O_{n} & \text{otherwise,}
\end{cases}
\]

In the commensalism stage, the \( m^{th} \) organism is likewise chosen randomly from the population to connect with the \( n^{th} \) organism, equivalent to the mutualism step. Through commensalism interaction, the \( m^{th} \) organism gets advantages, whereas the \( n^{th} \) organism is neither damaged nor profited. A new organism can be defined as follows [26]:

\[
O_{m}^{\text{new}} = O_{m} + \text{rand}(-1, 1) \times (O_{\text{best}} - O_{n}).
\]

The new organism can be updated according to equation (10).

In the parasitism communication of two diverse organisms in the parasitism stage, one organism (i.e., parasite) gets benefits while the other (i.e., host) is negatively affected. During this period, the \( n^{th} \) organism takes over the parasite’s role. By replicating the vector \( O_{m} \), a Parasite_Vector (PV) is generated. Several PV vector elements are randomly altered to develop a new candidate solution \( (O_{\text{PV}}) \) [26]. The \( n^{th} \) organism is picked at random from the existing population to act as a host. Both PV and \( O_{n} \) vectors have their fitness values calculated. The \( O_{\text{PV}} \) vector is updated or discarded as follows:

\[
O_{n} = \begin{cases} 
O_{\text{PV}} & \text{if } f(O_{\text{PV}}) < f(O_{n}), \\
O_{n} & \text{otherwise.}
\end{cases}
\]

3.2. SQI Strategy. The efficiency of an optimization method is based on its exploitation and exploration. Having global exploration capability indicates that the optimization algorithm is effectively utilizing the entire search space. Local exploitation ability refers to the ability of the optimization algorithm to search for the best solution near a new solution that has already been discovered. However, a metaheuristic algorithm may become stuck in a local optimum and fail to converge because of its stochastic nature. To enhance the search ability of SOS, the SQI method is integrated with SOS. By using SQI, a new set of solution vectors is generated that lie on a point of minima quadratic curve that passes through three randomly selected solution vectors. Hence, SQI is able to accelerate the algorithm’s convergence [27]. After the parasitism phase at each iteration, the \( d^{th} \) dimension of a new candidate organism can be defined based on a three-point SQI as follows [28]:

\[
O_{m}^{\text{new}} = f_{k}\left(\frac{(O_{m,d})^{2} - (O_{n,d})^{2}}{f_{k}(O_{m,d} - O_{n,d}) + f_{m}(O_{n,d} - O_{k,d}) + f_{n}(O_{k,d} - O_{m,d})}\right),
\]

where \( O_{n} \) and \( O_{k} \) are the two organisms randomly selected from the population, \( f_{m}, f_{n}, \) and \( f_{k} \) denote fitness function values for \( m^{th}, n^{th}, \) and \( k^{th} \) organisms, respectively, and \( D \) is the dimension of the problem, and \( d = 1, 2, \ldots, D. \)

The fitness values are computed for the organism \( O_{m}^{\text{new}}. \)
The updating of the new organism can be defined as follows:

\[
O_{m} = \begin{cases} 
O_{m}^{\text{new}} & \text{if } f(O_{m}^{\text{new}}) < f(O_{m}), \\
O_{m} & \text{otherwise.}
\end{cases}
\]

3.3. Application of ISOS to SR-DGP Problem. In the population of ISOS, each organism \( O_{i} (i = 1, \ldots, N_{P}) \) serves as a solution vector, which consists of variables of opened
switches positions and locations and DG units sizes as follows:

\[ O_i = \{SW_1, \ldots, SW_{N_{SW}}, LDG_1, \ldots, LDG_{N_{DG}}, PDG_1, \ldots, PDG_{N_{DG}}\}, \]  

(16)

where \(N_{SW}\) is the number of opened switches.

Each organism is randomly generated in its boundaries, in which the opened switch’s positions and DG unit’s locations are natural numbers. Thus, the control variables for opened switches positions \( (SW_i) \), locations \( (LDG_i) \) and sizes \( (PDG_i) \) of DG units are constructed using the given formula:

\[
SW_i = \text{round} \left[ SW_{\min,i} + \text{rand}(0, 1) \times (SW_{\max,i} - SW_{\min,i}) \right], \\
LDG_i = \text{round} \left[ LDG_{\min,i} + \text{rand}(0, 1) \times (LDG_{\max,i} - LDG_{\min,i}) \right], \\
PDG_i = PDG_{\min,i} + \text{rand}(0, 1) \times (PDG_{\max,i} - PDG_{\min,i}) 
\]

(17)

where \(N_{SW}\) indicates the total number of opened switches.

Every fitness function value for each organism of ISOS is calculated as follows:

\[ F_T = OF + K_P \sum_{i=1}^{N_S} \left( V_i - V_{i_{\text{lim}}} \right)^2 + K_P \sum_{k=1}^{N_F} \left( I_k - I_{k_{\text{lim}}} \right)^2 + K_P (PE_{DG} - PE_{DG_{\text{lim}}})^2. \]  

(18)

in which \(K_P\) represents penalty constants for inequality constraint violations. If the dependent variables (bus voltages, feeder capacity, and DGs penetration) violate the constraints, a method is applied to adjust the variables towards their bound:

\[ x_{\text{lim}} = \begin{cases} x_{\min} & \text{if } x < x_{\min} \\ x_{\max} & \text{if } x > x_{\max} \\ x & \text{otherwise.} \end{cases} \]  

(19)

in which \(x\) symbolizes the \(V_i, I_k, \) and \(PE_{DG}\) values; \(x_{\text{lim}}\) denotes the limitations of \(V_i, I_k, \) and \(PE_{DG}\).

The steps for applying the ISOS approach to the SR-DGP problem are given as follows:

Step 1: the data of the SR-DGP problem is declared
Step 2: ISOS parameters (NP and maxIter) are defined
Step 3: the population \(O\) is initialized
Step 4: the fitness values are calculated using equation (18) for each organism in the population $O$. Set the iteration to 1 ($\text{Iter} = 1$)

Step 5: the best organism is defined

Step 6: identify the best solution

Step 7: perform the mutualism phase

Step 8: perform the commensalism phase

Table 1: Comparisons of ISOS and other techniques in solving 33-node system.

<table>
<thead>
<tr>
<th>Items</th>
<th>Opened switches</th>
<th>$P_{DG}$ (kW)/(node)</th>
<th>Power losses (kW)</th>
<th>Power loss reduction (%)</th>
<th>Minimum voltage magnitude (pu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original case</td>
<td>33-34-35-36-37</td>
<td>—</td>
<td>202.66</td>
<td>—</td>
<td>0.9131</td>
</tr>
<tr>
<td>ISOS</td>
<td>7-14-9-30-28</td>
<td>539/(33)</td>
<td>54.4785</td>
<td>73.1206</td>
<td>0.9678</td>
</tr>
<tr>
<td>SOS</td>
<td>7-14-9-31-28</td>
<td>841/(31)</td>
<td>55.2824</td>
<td>72.7239</td>
<td>0.9689</td>
</tr>
<tr>
<td>FF [17]</td>
<td>8-9-28-32-33</td>
<td>648/(32)</td>
<td>73.95</td>
<td>63.51</td>
<td>0.9735</td>
</tr>
<tr>
<td>ISCA [18]</td>
<td>7-9-14-28-31</td>
<td>510/(13)</td>
<td>66.81</td>
<td>67.03</td>
<td>0.9611</td>
</tr>
<tr>
<td>FWA [19]</td>
<td>7-11-14-28-32</td>
<td>615/(29)</td>
<td>67.11</td>
<td>66.89</td>
<td>0.9713</td>
</tr>
<tr>
<td>HSA [20]</td>
<td>4-7-10-28-32</td>
<td>558/(31)</td>
<td>73.05</td>
<td>63.95</td>
<td>0.9713</td>
</tr>
<tr>
<td>GA [20]</td>
<td>7-10-28-32-34</td>
<td>—</td>
<td>75.13</td>
<td>62.92</td>
<td>0.9766</td>
</tr>
<tr>
<td>RGA [20]</td>
<td>7-9-12-27-32</td>
<td>—</td>
<td>74.32</td>
<td>63.33</td>
<td>0.9691</td>
</tr>
<tr>
<td>EOA [21]</td>
<td>8-27-33-34-36</td>
<td>651/(14)</td>
<td>61.48</td>
<td>69.66</td>
<td>—</td>
</tr>
<tr>
<td>IEOA [21]</td>
<td>7-10-13-27-31</td>
<td>669/(17)</td>
<td>57.40</td>
<td>71.67</td>
<td>—</td>
</tr>
</tbody>
</table>

Step 9: perform the parasitism phase

Step 10: perform the SQI method

Step 11: if $\text{Iter} < \text{maxIter}$, increase the iteration ($\text{Iter} = \text{Iter} + 1$) and proceed to Step 5. Otherwise, the algorithm is stopped

Finally, the ISOS application to the SR-DGP problem is given in Figure 1.
4. Simulation Results

The ISOS algorithm was carried out on Matlab 2019b. For each test case, the ISOS method was executed in thirty trials independently. The ISOS control parameters were set as follows: \( \text{NP} = 50 \) and \( \text{maxIter} = 200 \). The ISOS performance was compared with other techniques in previous papers.

4.1. 33-Node System

Initially, the ISOS technique was applied to the 33-node system with 37 branches and 33 nodes, as shown in Figure 2. The line and load data for the 33-node system can be found in Supplementary Table S1. For the original case, the system contains 202.677 MW of power loss [29]. Three DGs were located in the system with a maximum capacity of 300 kW. Table 1 shows the results acquired from the ISOS method for this system.

From Table 1, the network configuration was obtained with the opened switches: 7-14-9-30-28. Concurrently, the integrations of DG units were defined at buses 33, 12, and 25 and their capacities were 739 kW, 469 kW, and 1020 kW, respectively. The ISOS acquired minimal power losses of 54.4785 kW; i.e., a 73.1206% reduction compared with the original case. Furthermore, the voltages at load buses were also enhanced, which can be seen in Figure 3. This showed that the SR-DGP using ISOS significantly impacted the voltage improvement and power loss decrease.

Table 1 also gives the outcomes obtained by ISOS and other techniques in the literature for this system.
Compared with other methods, the proposed ISOS acquired the lowest power losses. It may be shown that the power losses of 54.4785 kW produced by the ISOS was better than SOS, FF [17], ISCA [18], FWA [19], HSA [20], GA [20], RGA [20], EOA [21], and IEOA [21]. Thus, the ISOS approach can provide a good-quality solution for this system. The ISOS and SOS convergence curves are shown in Figure 4. ISOS converges to a better value than SOS, which indicated its good performance regarding convergence ability.

4.2. 69-Bus System. ISOS method was employed in the 69-node system with 73 branches and 69 nodes, as shown in Figure 5. The line and load data for the 69-node system can be found in Supplementary Table S2. For the original case, minimum voltage amplitude and power losses were 0.9092 pu and 225.03 kW [29], respectively. The results attained by ISOS for the 69-bus system are given in Table 2.

The opened switches: 69-70-14-55-61 were defined by the ISOS to generate the optimum topology of the 69-bus system. Moreover, DG units with capacities of 475 kW, 28

<table>
<thead>
<tr>
<th>Items</th>
<th>Opened switches</th>
<th>$P_{DG}$ (kW)/(node)</th>
<th>Power losses (kW)</th>
<th>Power loss reduction (%)</th>
<th>Minimum voltage magnitude (pu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original case</td>
<td>69-70-71-72-73</td>
<td>—</td>
<td>225</td>
<td>—</td>
<td>0.9092</td>
</tr>
<tr>
<td>ISOS</td>
<td>69-70-14-55-61</td>
<td>475/(64)</td>
<td>35.3549</td>
<td>84.2861</td>
<td>0.9806</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1400/(61)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>301/(69)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOS</td>
<td>69-70-13-55-63</td>
<td>544/(27)</td>
<td>36.3982</td>
<td>83.8224</td>
<td>0.9803</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1435/(61)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>251/(60)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FF [17]</td>
<td>12-19-57-61-69</td>
<td>1232/(61)</td>
<td>40.30</td>
<td>82.08</td>
<td>0.9816</td>
</tr>
<tr>
<td></td>
<td></td>
<td>452/(62)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>100/(61)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISCA [18]</td>
<td>12-19-57-63-69</td>
<td>410/(62)</td>
<td>39.73</td>
<td>82.34</td>
<td>0.9798</td>
</tr>
<tr>
<td></td>
<td></td>
<td>461/(65)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>1127/(61)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FWA [19]</td>
<td>13-55-63-69-70</td>
<td>275/(62)</td>
<td>39.25</td>
<td>82.55</td>
<td>0.9796</td>
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<tr>
<td></td>
<td></td>
<td>415/(65)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1066/(61)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HSA [20]</td>
<td>13-17-58-61-69</td>
<td>352/(60)</td>
<td>40.3</td>
<td>82.08</td>
<td>0.9736</td>
</tr>
<tr>
<td></td>
<td></td>
<td>452/(62)</td>
<td></td>
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<tr>
<td>GA [20]</td>
<td>10-15-45-55-62</td>
<td>—</td>
<td>46.5</td>
<td>73.38</td>
<td>0.9727</td>
</tr>
<tr>
<td>RGA [20]</td>
<td>10-14-16-55-62</td>
<td>—</td>
<td>44.23</td>
<td>80.32</td>
<td>0.9742</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1463/(61)</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>278/(66)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>362/(12)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>IEOA [21]</td>
<td>12-57-63-69-70</td>
<td>518/(26)</td>
<td>36.3986</td>
<td>83.82</td>
<td>—</td>
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<td></td>
<td></td>
<td>1400/(61)</td>
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</table>

Figure 5: The 69-node system.
1400 kW, and 406 kW were located at buses 64, 61, and 12, respectively. Compared to the base case, the minimal power losses was 35.3549 kW, which is corresponding to a reduction of 84.2861%. The voltages at load buses were improved as shown in Figure 6. The minimum voltage in the system was enhanced from 0.9092pu to 0.9806pu. Accordingly, SR-DGP using ISOS significantly enhanced the voltage profile and reduced the power loss of this system.

Table 2 also indicated a comparison between ISOS and other techniques for the 69-node system. As seen in Table 2, the minimal power loss of 35.3549 kW attained by ISOS is better than those attained by SOS, FF [17], ISCA [18], FWA [19], HSA [20], GA [20], RGA [20], EOA [21], and IEOA [21]. The convergence characteristics of ISOS and SOS are depicted in Figure 7. This figure showed that ISOS converged to better results than SOS, as shown in Figure 7. Therefore, ISOS is very effective for dealing with SR-DGP in the 69-bus system.

5. Conclusion

This study has successfully implemented the ISOS method to solve the SR-DGP problem for minimizing power loss. The ISOS effectiveness has been validated on the 33-node and 69-node systems. It was found that SR-DGP using ISOS led to a reduction of power loss and an improvement of voltage profile compared to the original case. The power loss reductions for 33-node and 69-node were 73.1206% and 84.2861%, respectively. Also, the findings indicated that ISOS delivered higher solution quality with regard to power loss reduction than other techniques, as seen from the outcome evaluations. ISOS also showed better convergence characteristics than SOS for both test systems. Thus, ISOS provided a viable solution for DG placement issues and managing network reconfiguration in distribution systems.

Data Availability

The system data used to support the findings of this study are included within the supplementary information file.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Supplementary Materials

The line and load data for 33-node and 69-bus systems can be found in Supplementary Tables S1 and S2 in Supplementary document. (Supplementary Materials)

References


