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# Integrated Index Vector Method and Hybrid Ant Lion Chaotic Evolutionary Programming Optimization (HALCEP) Technique for Loss Minimization in Distribution System



**Abstract:** - Distribution system is the final section of the electrical power system, apart from the transmission and generation system. The distribution system acts as the interface that connects the high-voltage network to the low-voltage consumer service point. Consequently, the distribution system contributes the most of the overall losses in the electrical power system. Hence, evolutionary computation was introduced to accomplish a reduction of the previously said losses. The evolutionary computation involves optimization techniques to allocate distributed generation (DG) to the distribution system. Unfortunately, several optimization techniques are not capable of achieving accurate results and are trapped at local optima. This paper presents the Integrated Index Vector Method and Hybrid Ant Lion Chaotic Evolutionary Programming Optimization (HALCEP) technique for loss minimization in a distribution system. In this study, Evolutionary Programming (EP), Ant Lion Optimization (ALO) and HALCEP optimization engines are developed. The validation process was simulated on the IEEE 33-bus radial distribution system (RDS) model. Comparative studies were performed to gain a clear observation of the advantage of the developed HALCEP over the conventional EP and the ALO techniques, effectively showing its capability to outperform them.

**Keywords:** Distribution system; optimization techniques; evolutionary programming; ant lion optimization; loss minimization.

## I. INTRODUCTION

The electrical power system is divided into three subsystems; generation, transmission and distribution system. The distribution system is connected from the transmission line at the substation. About 70% of the losses in the power system are situated at the distribution system. Hence the distribution system became the zone of main focus to improvise as to elevate the efficiency to supply electrical power. The balance of 30% losses is mostly occurred at in transmission system. As the distribution system is directly connected to the consumers, an efficient system is necessary with most of capital investments are spent here.

Distributed generation (DG) is a compensation device, having significantly lower power generation than generator units in the generation sector while commonly installed in the distribution system. There are 4 types of DGs available where each of them has different operations. DG Type 1 injects real power, while Type 2 injects real power by consuming reactive power. Type 3 is capable to inject both real and reactive power, and lastly Type 4

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injects reactive power only [1]. DG installation will affect several parameters of the power system, which includes voltage profile, line losses and system reliability [2].

The installation of DG is done on the effort to adjust with the rising profile of electrical power demand, to achieve energy saving which is mainly caused by development of industrial and residential areas [3]. Allocation of DG with optimal sizing and in optimal locations is also important to achieve minimal power losses. Either of these parameters can be identified by using optimization methods and techniques. Examples of them are traditional evolutionary programming (EP) [4], ant lion optimizer (ALO) [5], chaotic bat algorithm [6], index vector method [7], power flow tracing method [8], ant colony algorithm [9] and flower pollination algorithm [10]. Furthermore, there are improvised new techniques that are recently developed for improved optimization; quantum-inspired EP [11], immune-based optimization method [12], hybrid neural network algorithm [13], swarm EP algorithm [14] and multiagent immune EP [15].

This paper presents the integrated Index Vector method and Hybrid Ant-Lion Chaotic-Evolutionary Programming optimization (HALCEP) technique. The proposed HALCEP optimization technique embedded the ant lion operators into the traditional EP algorithms. The algorithm development and validation of this technique was done with MATLAB software on IEEE 33-bus radial distribution system (RDS). Comparative study of HALCEP against its parents, the conventional EP and ALO provided significant results. This phenomenon is experienced in all the planned cases for DG installation.

## II. PROBLEM FORMULATION

### A. Fitness Function

Fitness function is a crucial component in this study. In this study, minimization of loss is the chosen objective function. When comparing with the transmission system, the distribution system has a considerably lower voltage profile that became the main cause of losses. These losses are mostly comprised of copper losses and can be identified with the following expression:

$$P_{loss} = \sum_i^n I_i^2 R_i \quad (1)$$

$I_i$  : Current  
 $R_i$  : Resistance  
 $n$  : Number of buses

The objective function for the entire optimization process is the loss minimization as can be mathematically presented in equation (2).

$$\begin{aligned} \text{Objective function} &= \min (P_{loss}) \\ &= \min \left( \sum_i^n I_i^2 R_i \right) \end{aligned} \quad (2)$$

### B. Constraints

The constraint used in this study is:

- Sizing range of DG, due to its low generation property:

$$60 \text{ MW} \leq P_{DG} \leq 3000 \text{ MW}$$

### III. METHODOLOGY

#### A. Index vector method

The Index Vector method [1] identifies the bus locations that are optimal for DG allocation. Calculations are done by the following equation:

$$index[n] = \frac{1}{V(n)^2} + \frac{I_q(k)}{I_p(k)} + \frac{Q_{eff}(n)}{Q_{total}} \quad (3)$$

- $I_p(k)$  : Real value of current in  $k^{th}$  branch
- $I_q(k)$  : Imaginary value of current in  $k^{th}$  branch
- $Q_{eff}(n)$  : Effective load
- $V(n)^2$  : Voltage at  $n^{th}$  bus
- $Q_{total}$  : Total reactive load
- $n$  : Bus number

The resulting index values for each bus then will be used to select the suitable bus for DG allocations. The selection is prioritized for bus with the highest index value. The flowchart for index calculation is shown in Figure 1. The steps of Index Vector method algorithm are:

- Step 1* : Initialize the 33-bus radial distribution system and run load flow.
- Step 2* : The values of voltages and branch currents from the load flow are used to calculate the index values.
- Step 3* : Total of 33 index values are obtained for each 33 bus respectively.
- Step 4* : Sort the indexes from highest to lowest values.
- Step 5* : The bus with the highest Index vector value is prioritized for DG allocation.

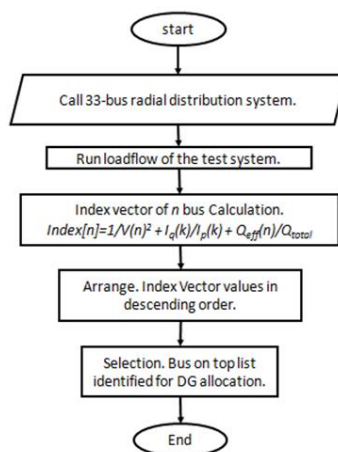


Figure 1: The flowchart of Index Vector for identification of optimal bus location for DG installation.

#### B. Evolutionary Programming (EP)

EP is a traditional optimization technique to obtain optimum solution by repeated iterations of population evolution and producing new generations. This population individual fitness are calculated and then implemented

in a mutation function, hence evolving them. In the case of this study, the optimum solution is to identify the optimum DG sizing in order to minimize losses value. The flowchart of EP algorithm is shown in Figure 2. EP optimization steps are presented as follows:

*Step 1* : Initialization; 20 individuals of DG sizes will be randomly generated for all the control variables. The general equation can be represented in equation (4).

$$Parent\ population = \begin{bmatrix} x_{11}, x_{12}, x_{13}, \dots, x_{1k} \\ x_{21}, x_{22}, x_{23}, \dots, x_{2k} \\ \dots \\ \dots \\ x_{n1}, x_{n2}, x_{n3}, \dots, x_{nk} \end{bmatrix} \quad (4)$$

*Step 2* : Check the fitness (losses); sizing that has lower fitness than set fitness is recorded in the initial population.

*Step 3* : Stop initializing when 20 individuals in population is reached.

*Step 4* : The fitness 1 (power losses) are calculated using the DG sizing values of the parent's population.

*Step 5* : Mutation process; evolving the parent's population to produce offspring population based on Gaussian mutation approach as shown in equation (5).

$$X_{i+m,j} = X_{i,j} + N(0, \beta(X_{j\ max} - X_{j\ min})\left(\frac{f_i}{f_{max}}\right)) \quad (5)$$

The parameters are:

$X_{i+m,j}$  : Products of mutations (offspring)

$X_{i,j}$  : The parents

$N$  : Random Gaussian parameter with mean  $\mu$  and variance,  $\gamma^2$

$\beta$  : scale of mutations,  $0 < \beta < 1$

$X_{j\ max}$  : for each vector the highest random number

$X_{j\ min}$  : the minimum random number of each vector

$f_i$  : fitness the random number  $i^{\text{th}}$ ,  
 $f_{max}$  : fitness of maximum random number

- Step 6 : The fitness 2 are calculated using the DG sizing values of the offspring's population.
- Step 7 : Combination; parent and offspring population are merged and the total of 40 individuals are sorted in ascending order of their fitness values respectively.
- Step 8 : Selection; the best 20 individuals of minimum fitness are chosen from the combination process for new generation of population in the next iteration.
- Step 9 : Convergence is checked using the stopping criterion of smallest difference in the fitness values defined in (6). If convergence is not achieved, the steps 4-8 are repeated iteratively.

$$Fitness_{max} - Fitness_{min} \leq 0.001 \quad (6)$$

- Step 10 : Record the optimal solution.

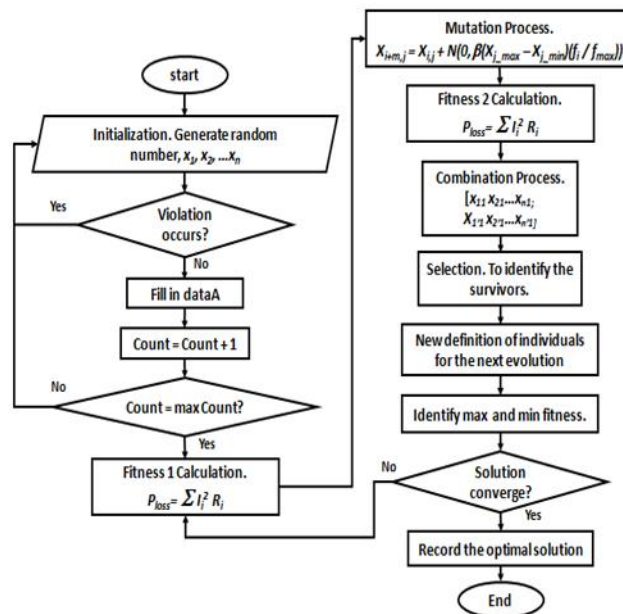


Figure 2: The flowchart of EP for minimum losses.

### C. Ant Lion Optimizer (ALO)

ALO [5] was developed from the behavior of ant lions to catch prey. A selected ant lion lays a trap around it and ants will have random walks in it until the ant lion catches its prey. The exploration capability of the ants' random

walks was observed beneficial for identifying the optimal solution. The flowchart of ALO algorithm is shown in Figure 3. ALO optimization steps are done by:

*Step 1* : Initialization; generate random positions (DG sizes) of ant lions in the initial population.

*Step 2* : The fitness 1 (power losses) are calculated using the DG sizing values of the ant lion population.

*Step 3* : Sort the population according to lowest fitness value to highest fitness value.

*Step 4* : Record the ant lion with best fitness as elite ant lion.

*Step 5* : By roulette wheel, select ant lion to set trap for catching ants using equation (7).

$$\text{Min boundary, } c_i^t = \text{Antlion}_i^t + c_i^t \quad (7)$$

$$\text{Max boundary, } d_i^t = \text{Antlion}_i^t + d_i^t$$

*Step 6* : Slide the ants down the trap by scaling down the boundary of the trap defined in (8).

$$C^t = \frac{c^t}{I}, D^t = \frac{d^t}{I} \quad (8)$$

$$\text{While } I = 10^w \left( \frac{t}{T} \right), w = \begin{cases} 2, & t > 0.1T \\ 3, & t > 0.5T \\ 4, & t > 0.75T \\ 5, & t > 0.9T \\ 6, & t > 0.95T \end{cases}$$

*Step 7* : Mutation; ants' random walk process around the selected ant lion using the equation (9). This process also includes normalization of the random walk with the DG sizing boundary defined in (10).

$$X(t) = \{0, \text{cumsum}(2r(t_1) - 1), \dots, \text{cumsum}(2r(t_n) - 1)\} \quad (9)$$

While  $r(t) = 1$  if  $\text{rand} > 0.5$ ,  $r(t) = 0$  if  $\text{rand} < 0.5$ .

$$X_i^t = \frac{(X_i^t - a_i) \times (d_i^t - c_i^t)}{(b_i - a_i)} + c_i^t \quad (10)$$

The parameters are:

$a_i$  : Min value of random walk of  $i^{\text{th}}$  variable.

$b_i$  : Max value of random walk of  $i^{\text{th}}$  variable.

$c_i^t$  : Min boundary value of  $i^{\text{th}}$  variable in the  $t^{\text{th}}$  iteration.

$d_i^t$  : Max boundary value of  $i^{\text{th}}$  variable in the  $t^{\text{th}}$  iteration.

*Step 8* : Elitism; the random walks from both ant lion by roulette wheel and elite ant lion are summed and average value is obtained to maintain the best solution as defined in equation (11).

$$Ant_i^t = \frac{R_A^t + R_E^t}{2} \quad (11)$$

$R_A^t$  : Random walk near ant lion by roulette wheel at  $t^{\text{th}}$  iteration.

$R_E^t$  : Random walk near elite ant lion at  $t^{\text{th}}$  iteration.

*Step 9* : The fitness 2 is calculated using the DG sizing value of the ants' random walk.

*Step 10* : Catching prey; if the ant's fitness is lower than the selected ant lion's fitness, the ant lion updates its position (DG sizing) to the position of the ant.

*Step 11* : The convergence is checked by the preset of max iteration. The steps 5-11 are repeated iteratively until max iteration is reached.

*Step 12* : Record the optimal solution.

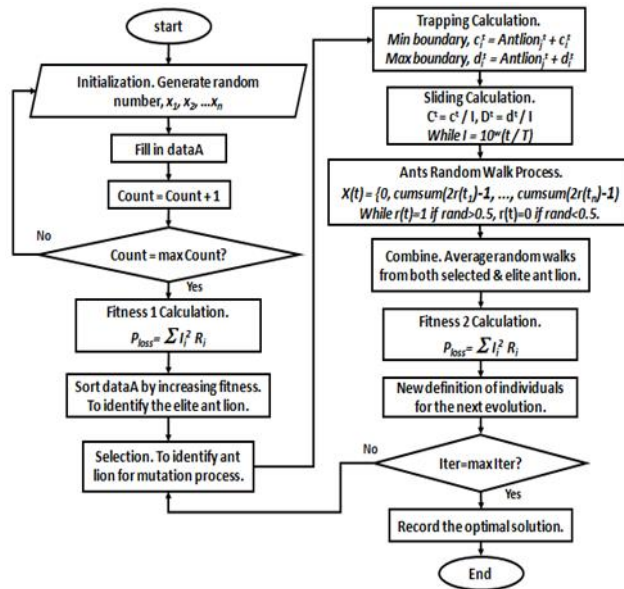


Figure 3: The flowchart of ALO for min losses.

D. Proposed Hybrid Ant Lion Chaotic Evolutionary Programming (HALCEP) technique

The HALCEP is a newly developed technique, integrating both EP and ALO in its development. The EP initialization step is implemented due to its chaotic property of population generation, allowing a solution to be identified from multiple approaches. Paired with ALO mutation process which benefits from its exploration capability and converge onto the best individual in the population to obtain the optimal solution. The flowchart of HALCEP algorithm is shown in Figure 4. The detailed HALCEP algorithm development is as the following steps:

Step 1 : Initialization; 20 individuals of DG sizes will be randomly generated for all the control variables. The general equation can be represented in equation (4).

$$Parent\ population = \begin{bmatrix} x_{11}, x_{12}, x_{13}, \dots, x_{1k} \\ x_{21}, x_{22}, x_{23}, \dots, x_{2k} \\ \dots \\ \dots \\ x_{n1}, x_{n2}, x_{n3}, \dots, x_{nk} \end{bmatrix} \quad (4)$$

Step 2 : Check the fitness (losses); sizing that has lower fitness than set fitness is recorded in the initial population.

Step 3 : Sort the population according to lowest fitness value to highest fitness value.

Step 4 : Record the ant lion with best fitness as elite ant lion.

Step 5 : By roulette wheel, select ant lion to set trap for catching ants using equation (7).

$$Min\ boundary, c_i^t = Antlion_i^t + c_i^t \quad (7)$$



Max boundary,  $d_i^t = Antlion_i^t + d_i^t$

Step 6 : Slide the ants down the trap by scaling down the boundary of the trap defined in (8).

$$C^t = \frac{c^t}{I}, D^t = \frac{d^t}{I} \tag{8}$$

$$\text{While } I = 10^w \left(\frac{t}{T}\right), w = \begin{cases} 2, & t > 0.1T \\ 3, & t > 0.5T \\ 4, & t > 0.75T \\ 5, & t > 0.9T \\ 6, & t > 0.95T \end{cases}$$

Step 7 : Mutation; ants' random walk process around the selected ant lion using the equation (9). This process also includes normalization of the random walk with the DG sizing boundary defined in (10).

$$X(t) = \{0, \text{cumsum}(2r(t_1) - 1), \dots, \text{cumsum}(2r(t_n) - 1)\} \tag{9}$$

While  $r(t) = 1$  if  $\text{rand} > 0.5, r(t) = 0$  if  $\text{rand} < 0.5$ .

$$X_i^t = \frac{(X_i^t - a_i) \times (d_i^t - c_i^t)}{(b_i - a_i)} + c_i^t \tag{10}$$

The parameters are:

$a_i$  : Min value of random walk of  $i^{\text{th}}$  variable.

$b_i$  : Max value of random walk of  $i^{\text{th}}$  variable.

$c_i^t$  : Min boundary value of  $i^{\text{th}}$  variable in the  $t^{\text{th}}$  iteration.

$d_i^t$  : Max boundary value of  $i^{\text{th}}$  variable in the  $t^{\text{th}}$  iteration.

Step 8 : Elitism; the random walks from both ant lion by roulette wheel and elite ant lion are summed and average value is obtained to maintain the best solution as defined in equation (11).

$$Ant_i^t = \frac{R_A^t + R_E^t}{2} \quad (11)$$

$R_A^t$  : Random walk near ant lion by roulette wheel at  $t^{th}$  iteration.

$R_E^t$  : Random walk near elite ant lion at  $t^{th}$  iteration.

*Step 9* : The fitness 2 is calculated using the DG sizing value of the ants' random walk.

*Step 10* : Catching prey; if the ant's fitness is lower than the selected ant lion's fitness, the ant lion updates its position (DG sizing) to the position of the ant.

*Step 11* : The convergence is checked by the preset of max iteration. The steps 5-11 are repeated iteratively until max iteration is reached.

*Step 12* : Record the optimal solution.

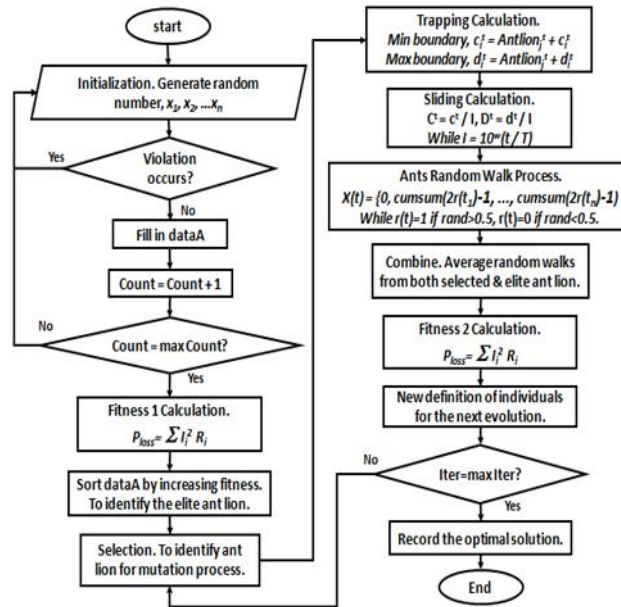


Figure 4: The flowchart of HALCEP for min losses.

#### IV. RESULT AND DISCUSSION

This section describes the results and discussion of the study. All the three optimization techniques were used to solve the DG installation, implemented on the IEEE 33-bus radial distribution system. The DGs used in this study was Type 1 DG, which injects real power in the system. There are 4 scenarios with each have 4 cases respectively that have been considered for each optimization technique:

*Scenario 1* : Base load condition.

- Scenario 2* : 150% active power load increase at all buses.
- Scenario 3* : 150% reactive power load increase at all buses.
- Scenario 4* : 150% all load increase at all buses.
- Base case* : No DG is installed in the test system.
- Case 1* : Only one DG is installed in the test system.
- Case 2* : Three DGs are installed in the test system.
- Case 3* : Five DGs are installed in the test system.

#### A. Index Vector Computation

Initially index vector calculation involving all the buses was conducted. Indices of all buses were conducted. The results are tabulated in Table 1. According to the consideration of scenarios and cases, the results are sorted from highest index value to lowest and the best 5 bus locations were selected as the optimal location for DG installation, which are tabulated in Table 2.

Table 1: Bus locations and their respective index values.

Bus no	Index Vector			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
1	1	1	1	1
2	1.6331	1.436	1.9326	1.6358
3	1.4942	1.3623	1.7148	1.5103
4	1.748	1.5502	2.0757	1.7714
5	1.5721	1.4369	1.8184	1.6034
6	1.4405	1.3788	1.6093	1.4949
7	1.656	1.5433	1.9081	1.7173
8	1.6659	1.5594	1.9173	1.7334
9	1.4768	1.4332	1.649	1.5535
10	1.4908	1.4548	1.664	1.5766
11	1.8321	1.6879	2.1639	1.92
12	1.7538	1.639	2.0462	1.8436
13	1.7696	1.6631	2.0632	1.8698
14	1.8813	1.7506	2.2151	1.9863
15	1.3497	1.3858	1.4442	1.4557
16	1.5252	1.5082	1.7013	1.634
17	1.5312	1.5171	1.7081	1.6439
18	1.6539	1.6041	1.8845	1.7682
19	1.4696	1.3248	1.6916	1.473
20	1.4782	1.3371	1.7007	1.486
21	1.48	1.3397	1.7028	1.4887
22	1.4818	1.3421	1.7047	1.4913
23	1.6178	1.4531	1.8931	1.6383
24	1.6236	1.4926	1.8608	1.6527

25	1.6315	1.5043	1.8691	1.665
26	1.5295	1.4423	1.7385	1.5861
27	1.5339	1.4495	1.7428	1.5934
28	1.471	1.4245	1.6427	1.5449
29	1.76	1.6397	2.0505	1.8446
30	1.6968	1.6076	1.9488	1.7859
31	1.6636	1.5913	1.9025	1.7624
32	1.6907	1.6168	1.9348	1.7923
33	7.8019	6.1323	9.395	7.8008

Table 2: The selected best 5 bus locations and their respective index values.

Scenario 1		Scenario 2		Scenario 3		Scenario 4	
Bus no	Index	Bus no	Index	Bus no	Index	Bus no	Index
33	7.8019	33	6.1323	33	9.395	33	7.8008
14	1.8813	14	1.7506	14	2.2151	14	1.9863
11	1.8321	11	1.6879	11	2.1639	11	1.92
13	1.7696	13	1.6631	13	2.0632	13	1.8698
29	1.76	29	1.6397	29	2.0505	29	1.8446

*B. Evolutionary Programming (EP)*

EP is the first optimization technique, used to identify the optimal sizing for the DG installation. The locations for the DGs to be installed were identified from the results of index vector method. Table 3 shows the optimal DG sizing for bus 33, bus 14, bus 4, bus 11 and bus 13 accordingly. Significant reduction in losses was observed by comparing base case value with the other three cases. The lowest loss achieved is in Scenario 1: Case 3, which is 0.0691 MW.

Table 3: Bus locations, losses and DG sizing for EP.

		Base case (MW)	Case 1 (MW)	Case 2 (MW)	Case 3 (MW)
Scenario 1	Loss	0.1684	0.1098	0.0778	0.0691
	DG1	-	0.9754	0.4945	0.2872
	DG2	-	-	0.6908	0.1783
	DG3	-	-	0.5482	0.1537
	DG4	-	-	-	0.5717
	DG5	-	-	-	0.8024
Scenario 2	Loss	0.3153	0.2103	0.1237	0.0937
	DG1	-	1.6651	1.5951	0.7227
	DG2	-	-	0.5767	0.7534
	DG3	-	-	1.4921	0.6515
	DG4	-	-	-	0.0727
	DG5	-	-	-	0.6316
Scenario 3	Loss	0.2305	0.172	0.1388	0.1302
	DG1	-	0.9196	0.4945	0.2872
	DG2	-	-	0.6908	0.1783

Scenario 4	DG3	-	-	0.5482	0.1537
	DG4	-	-	-	0.5717
	DG5	-	-	-	0.8024
	Loss	0.3785	0.2745	0.1951	0.1545
	DG1	-	0.9196	1.595	0.7227
	DG2	-	-	0.5766	0.7534
	DG3	-	-	1.4919	0.6515
	DG4	-	-	-	0.0727
	DG5	-	-	-	0.6316

C. Ant Lion Optimizer (ALO)

ALO is the next optimization technique used to identify the DG optimal sizing for installation. The locations for the DGs to be installed were identified from the results of index vector method similar to the previous technique. Table 4 illustrates the optimal buses are bus 33, bus 14, bus 4, bus 11 and bus 13 accordingly. Significant reduction in losses was observed by comparing base case value with the other three cases. The lowest loss achieved is in Scenario 1: Case 3, which is 0.0687 MW.

Table 4: Bus locations, losses and DG sizing for ALO.

		Base case (MW)	Case 1 (MW)	Case 2 (MW)	Case 3 (MW)
Scenario 1	Loss	0.1684	0.1084	0.0723	0.0687
	DG1	-	1.0595	0.8108	0.4692
	DG2	-	-	0.5338	0.3167
	DG3	-	-	0.5938	0.351
	DG4	-	-	-	0.3529
	DG5	-	-	-	0.5211
Scenario 2	Loss	0.3153	0.2032	0.1022	0.1003
	DG1	-	1.063	1.0596	0.6887
	DG2	-	-	0.7562	0.6424
	DG3	-	-	0.9529	0.7856
	DG4	-	-	-	0.4703
	DG5	-	-	-	0.5066
Scenario 3	Loss	0.2305	0.1694	0.1338	0.1339
	DG1	-	1.0467	0.877	0.4692
	DG2	-	-	0.5138	0.3709
	DG3	-	-	0.6987	0.5755
	DG4	-	-	-	0.3893
	DG5	-	-	-	0.3807
Scenario 4	Loss	0.3785	0.2628	0.1629	0.1519
	DG1	-	1.089	1.0882	0.6106
	DG2	-	-	0.8457	0.48
	DG3	-	-	0.8994	0.5889
	DG4	-	-	-	0.4303
	DG5	-	-	-	0.9975

*D. Proposed Hybrid Ant Lion Chaotic Evolutionary Programming (HALCEP)*

The proposed algorithm found the optimal bus for DG allocations and the optimal sizing of DGs. The locations for the DGs to be installed were identically identified from the results of index vector sizing method. Table 5 shows the optimal buses are bus 33, bus 14, bus 4, bus 11 and bus 13 accordingly. Significant reduction in losses was observed by comparing base case value with the other three cases. The lowest loss achieved is in Case 3, which is 0.7571 MW. Hence, this technique is superior to both of the previous techniques.

Table 5: Bus locations, losses and DG sizing for HALCEP.

		Base case (MW)	Case 1 (MW)	Case 2 (MW)	Case 3 (MW)
Scenario 1	Loss	0.1684	0.1084	0.0721	0.0682
	DG1	-	1.0592	0.8518	0.5308
	DG2	-	-	0.42	0.2104
	DG3	-	-	0.6461	0.329
	DG4	-	-	-	0.3608
	DG5	-	-	-	0.6199
Scenario 2	Loss	0.3153	0.2023	0.102	0.0908
	DG1	-	1.0776	1.0893	0.6175
	DG2	-	-	0.7589	0.3268
	DG3	-	-	1.0057	0.7826
	DG4	-	-	-	0.4101
	DG5	-	-	-	1.0153
Scenario 3	Loss	0.2305	0.1694	0.133	0.1293
	DG1	-	1.0501	0.8176	0.3694
	DG2	-	-	0.4994	0.3102
	DG3	-	-	0.5993	0.2567
	DG4	-	-	-	0.3385
	DG5	-	-	-	0.805
Scenario 4	Loss	0.3785	0.2628	0.1628	0.1517
	DG1	-	1.0889	1.0719	0.5538
	DG2	-	-	0.7218	0.2371
	DG3	-	-	0.8989	0.3019
	DG4	-	-	-	1.0235
	DG5	-	-	-	0.994

*E. Conclusion*

The objective of this study is to do a comparison of all three optimization techniques; EP, ALO and the proposed HALCEP. The Table 6 highlights that the proposed new technique achieved the best solution at all scenarios and cases, with the least losses at 0.0682 MW in Scenario 1: Case 3. This implies the proposed HALCEP technique excellence performance in finding optimal solution, out-performing both of the EP and ALO techniques.

Table 6: Comparison of losses for all three techniques.

		EP (MW)	ALO (MW)	HALCEP (MW)
Scenario 1	Case 1	0.1098	0.1084	0.1084
	Case 2	0.0778	0.0723	0.0721
	Case 3	0.0691	0.0687	0.0682

Scenario 2	Case 1	0.2103	0.2032	0.2023
	Case 2	0.1237	0.1022	0.102
	Case 3	0.0937	0.1003	0.0908
Scenario 3	Case 1	0.172	0.1694	0.1694
	Case 2	0.1388	0.1338	0.133
	Case 3	0.1302	0.1339	0.1293
Scenario 4	Case 1	0.2745	0.2628	0.2628
	Case 2	0.1951	0.1629	0.1628
	Case 3	0.1545	0.1519	0.1517

## V. CONCLUSION

This paper presents the Integrated Index Vector method and Hybrid Ant Lion Chaotic Evolutionary Programming (HALCEP) for DG allocation for loss minimization. In this study, the Index Vector method, EP and ALO were integrated to form the proposed new HALCEP technique. This proposed technique was implemented in the IEEE 33-bus radial distribution system and resulted that HALCEP outperformed EP and ALO in terms of DG allocation for loss minimization.

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