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Reliability Enhancement and Low Leakage in Radial Distribution Systems Using Big Bang Crunch (BBC) Optimization Algorithm

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Abstract: By developing a new algorithm based on the outcomes of previous studies, an issue with reconfiguring Electrical Distribution Systems is addressed. This work contributes to by significantly reducing power loss and improving the accuracy of distribution systems with high voltage stability. Consequently, the customer-oriented reliability measures known as the System-Average-Interruption-Duration-Index, System-Average-Interruption-Frequency-Index, and Energy-Not-Supplied measures have been calculated. Meanwhile, the Big Bang Crunch (BBC) optimization algorithm is used to guarantee an increased distribution system stability and decreased loss. The simulation analysis validates and tests the suggested methodology based on measurements of power loss, voltage profile, and reliability using an IEEE-33 bus distribution system. Then, for the identical distribution network, the outcomes of these Harmony Search and Non-Dominated Sorting Genetic Algorithm approaches are compared. The assessment resulted in the conclusion that the proposed Non-Dominated Sorting Genetic Algorithm might be more efficient in resolving the power distribution systems reconfiguration problem. From the evaluation, it is analyzed that the SAIDI value is reduced to 0.63738 hr/yr, the SAIFI and ENS value also reduced to 0.00752 faults/Yr, 0.8594 kWhr/year by using the BBC technique.

Keywords: Electrical Distribution Systems, Power Loss, Energy-Not-Supplied, Non- Dominated Sorting Genetic Algorithm Harmony Search.

1. Introduction

By using the generating stations, the electrical energy is generated and distributed to the consumers through the transmission and distribution systems. An electrical distribution system comprises a group of interconnected radial networks, where the large amount of losses can happen due to the supply of low voltage level power to the consumer. Also, it is considered as one of the main problem in the power distribution systems. Hence, the distribution system is need to be properly reconfigured for resolving the power loss issues. Typically, reconfiguration is defined as one of the most significant method used designing and planning the power distribution system. It consists of two different switches such as, closed type switches and open type switches (tie switches). Moreover, the reconfiguration performed by opening and closing the system switches, where the status of switches can modify the architecture of distribution system. The main objective of reconfiguration EDS method [1, 2] is to minimize the power losses, and to maintain load balance for service recovery. The power systems can provide the continuous power supply to the consumers without any interruption of supply, where the accuracy assessments are used to enhance the continuity of supply by reducing the interruption of services [3]. Some of the indices are also used to enhance the accuracy of a distribution system, which includes SAIDI, SAIFI, and ENS. To solve the problems related to reconfiguration due to varying load time for long duration schedule an idea is discussed in. In robust configuration method [4, 5], all the optimal decisions and losses on configured network are derived in two steps. To calculate the reduced loss of distribution network through reconfiguration, a model named as, multi objective approach is used in work [6-8]. During the process of reconfiguration, the variation in voltage profile effects the load schedule time. Due to the scatter search property, the node depth representation network is only used in the radial distribution networks, where the FNSG technique could be employed for solving the reconfiguration problem. A reactive power compensation algorithm based on an artificial immune system is used in the conventional work. In the existing works, the different types of optimization techniques are used to solve the reconfiguration problem in the distribution system. Also, it used various IEEE bus systems to implement and test the models for analyzing its efficacy. The proposed work intends to enhance the

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performance of distributed systems based on the factors of increased voltage profile, improved reliability, and reduced power loss. Also, it used an efficient optimization technique, named as, BBC for efficiently solving the reconfiguration problems with better system performance. Moreover, it is used to determine that the switches that to be opened to reduce the power losses and to enhance the reliability indicators and voltage profile. The radial reconfiguration distribution network is tested on IEEE 33 bus system using MATLAB simulations.

2. Related Works

Hashem, et al [9] objects to increase the reliability of radial power distribution systems by using an enhanced Equilibrium Optimization (EO) technique. The purpose of this work was to minimize the energy loss and increase the reliability of radial systems by deploying a hybrid optimization approach. Here, the objective function was constructed to minimize the measures of SAIFI, SAIDI, ENS, ASUI, and NSI by optimizing the power exchange at the initial level. In addition to that, an IEEE-33 bus system could be used for testing and validating the performance of this system under different load models. The primary advantages of this work [10] were reduced power loss, increased efficiency, and optimal performance. Alam, et.al [11] presented a comprehensive analysis on the optimal placement of reclosers in the radial power distribution systems. A GA-based optimization technique is used to construct this bidirectional power flow. Pattabiraman, et al [12] implemented a Binary-Particle-Swarm-Optimization (BPSO) technique for minimizing the reliability indices by computing the best optimal solution to optimally place the switches. Here, the objective function was computed to increase the high reliability of power distribution. During optimization, the best possible parameters were obtained with reduced convergence time and increased speed. Moreover, the IEEE-33 and 69 bus system was used to validate and test the performance of this system under changing load dynamics. The key benefits of this work [13] were reduced power loss, system loss, and voltage deviation with better performance outcomes. Taluker, et al [14] implemented a new Teaching-Learning based Optimization (TLBO) technique for ensuring the increased reliability and minimized system loss in the radial distribution systems. The purpose of this work was to balance the load by properly reconfiguring the network with reduced values of the reliability indices. Here, the IEEE-33 bus system was used to validate the performance of this work by using the Gauss-Seidal load flow model.

Pau, et al [15] suggested an automation schemes for maximizing the reliability of the radial distribution grids by optimally placing the switching devices. This work was developed based on an Integer-Linear-Programming (ILP) model, where the multi-objective optimization technique was utilized to improve the performance of SAIDI and SAIFI. Moreover, it identified the global optimum value to obtain the suitable solution to solve the switching placement problem. Galias, et al [16] utilized a tree structured deterministic algorithms for improving the reliability of radial distribution networks based on an optimal switching placement. Here, the tree structured algorithm was mainly used to sectionalize the switching devices for improving the performance of reliability indices. Bhadoria, et al [17] implemented an iterative searching method for increasing the reliability of distribution systems. Here, the objective function was computed to reduce the total system loss based on the most gainful location and minimal sizing of capacitors. Moreover, an IEEE-34 bus-system was used to test the performance of this system using the line data and bus data. Also, the results were evaluated and compared with and without capacitors. The advantages of this work were increased system reliability and reduced power loss with optimized performance rate.

Sultana, et al [18] intended to increase the reliability and quality of the radial distribution systems by optimally placing the controlled switches. For this purpose, a multi-objective NLP based optimization technique was deployed, which computes the objective function with minimized interruption cost, and high system reliability. Moreover, the performance of this system has been validated and compared by using various bus systems such as IEEE-13, 58, and 123. Teja, et al [19] deployed a network reconfiguration problem by optimizing the power flow for improving the performance of distribution networks. Here, the power loss and reliability analyzes have been conducted for analyzing the performance of reconfiguration algorithm. Yet, it limits with the problems of complex computational operations, inefficient placement, and high loss of power.

3. Proposed Methodology

The original contribution of this work is to efficiently reduce the power loss, enhance the reliability and voltage profile measures by properly reconfiguring the distribution systems. For this purpose, an efficient optimization techniques are implemented to obtain the best solution for solving the reconfiguration problems. Among other power flow models, the main purposes of using the forward-backward algorithm are recursive in nature, highly efficient, and better performance outcomes. The working model of the proposed system is shown in Fig 1. Moreover, the radiality constraint is formulated for enabling the topological and other flexibilities in teh distribution systems. Because, it helps to solve the optimization problems with ensured feasibility and optimality. In the proposed work, it is used to test the power flow analysis. During simulation, the radial reconfiguration distribution network is tested on IEEE 33 bus system using MATLAB simulations.

3.1. Problem Formulation

Problem formulation technique deals with the mathematical modelling of a system which meets the desired objective of the given problem with a set of decision variables and constraints. The main purpose of reconfigured network is to ultra-low power leakage and to enhance the threshold level of voltage and accuracy of a system by means of indicators- SAIDI, SAIFI and ENS.

$$\text{Min } \mathbf{f_1} = \sum_{\mathbf{ij}\in\Omega_l} \mathbf{R_{ij} I_{ij}^2} = \sum_{\mathbf{ij=1}}^{\Omega_l} \mathbf{P_L^{ij}} \tag{1}$$

Where, $\mathbf{R_{ij}}$- Resistance of branch $\mathbf{ij} \in \Omega_\mathbf{l}$, $\mathbf{I_{ij}}$- Current magnitude through branch $\mathbf{ij} \in \Omega_\mathbf{l}$, $\Omega_\mathbf{l}$- Number of branches in a network, and $\mathbf{P_L^{ij}}$- Real power leakage in first branch. The design task given in equation (1) reduces the total active power leakage in reconfiguration network. The below equations gives the constraint of active and reactive power flow balance of each node.

$$\sum_{\mathbf{ji}\in\Omega_l} \mathbf{P_{ji}} - \sum_{\mathbf{ij}\in\Omega_l}\left(\mathbf{P_{ij}} + \mathbf{R_{ij} I_{ij}^2}\right) + \sum_{\mathbf{ji}\in\Omega_{sw}} \mathbf{P_{ji}^{sw}} - \sum_{\mathbf{ij}\in\Omega_{sw}} \mathbf{P_{ij}^{sw}} + \mathbf{P_i^S} = \mathbf{P_i^D} \quad \forall \mathbf{i} \in \Omega_\mathbf{b} \tag{2}$$

$$\sum_{\mathbf{ji}\in\Omega_l} \mathbf{Q_{ji}} - \sum_{\mathbf{ij}\in\Omega_l}\left(\mathbf{Q_{ij}} + \mathbf{X_{ij} I_{ij}^2}\right) + \sum_{\mathbf{ji}\in\Omega_{sw}} \mathbf{Q_{ji}^{sw}} - \sum_{\mathbf{ij}\in\Omega_{sw}} \mathbf{Q_{ij}^{sw}} + \mathbf{Q_i^S} = \mathbf{Q_i^D} \quad \forall \mathbf{i} \in \Omega_\mathbf{b} \tag{3}$$

$$\text{Min } \mathbf{f_2} = \sum_{\mathbf{i=1}}^{\Omega_b - \mathbf{g}} \mathbf{V_{Di}} \tag{4}$$

$$\mathbf{V_{Di}} = (\mathbf{1} - \mathbf{V_i})^\mathbf{2} \tag{5}$$

Where, $\mathbf{V_{Di}}$- Voltage-Deviation-load-bus I, $\mathbf{V_i}$ – Voltage-magnitude at node i$\in \Omega_b$, Ω_b- No.of nodes in a network, and **g**-No. of generator nodes in network. Equation (6) is the constraint representing voltage magnitude limit of switchable nodes. The switch ij is the closed voltage magnitude of both nodes. If the Switch is in open position, the nodal voltage can be varying with respect to their operational limits.

$$\left|\mathbf{V_j^{sqr}} - \mathbf{V_i^{sqr}}\right| \leq \left(\overline{\mathbf{V}}^2 - \underline{\mathbf{V}}^2\right)\left(\mathbf{1} - \mathbf{y_{ij}}\right) \quad \forall \mathbf{ij} \in \Omega_{sw} \tag{6}$$

Equation (7) shows the constraint of the voltage-magnitude-limits of nodes.

$$\underline{\mathbf{V}}^2 \leq \mathbf{V_i^{sqr}} \leq \overline{\mathbf{V}}^2 \quad \forall \mathbf{i} \in \Omega_b \tag{7}$$

Where, $\mathbf{V_i^{sqr}}$- Square of $\mathbf{V_i}$, $\overline{\mathbf{V}}$- Max-voltage-magnitude, $\underline{\mathbf{V}}$-Min-voltage-magnitude, $\mathbf{y_{ij}}$- Switch**ij** $\in \Omega_{sw}$status, where $\mathbf{y_{ij}} = \mathbf{1}$ if switch 'ij' is closed; $\mathbf{y_{ij}} = \mathbf{0}$,otherwise, and Ω_{sw} - Number of switches in a network.

$$\text{Min } \mathbf{f_3} = \sum_{\mathbf{k}\in\Omega_b} \mathbf{P_k^D U_k} \tag{8}$$

Equation (8) reduces the ENS value by limiting the SAIDI and SAIFI value.

$$\frac{\sum_{\mathbf{k}\in\Omega_b} \mathbf{U_k N_k}}{\sum_{\mathbf{k}\in\Omega_b} \mathbf{N_k}} \leq \overline{\mathbf{SAIDI}} \tag{9}$$

$$\frac{\sum_{\mathbf{k}\in\Omega_b} \mathbf{U_k \lambda_k}}{\sum_{\mathbf{k}\in\Omega_b} \mathbf{N_k}} \leq \overline{\mathbf{SAIFI}} \tag{10}$$

The constraint (9) and (10) gives the maximum limit of the system SAIFI and SAIDI values in the network. Where, $\mathbf{P_k^D}$-The average active power load connected at load-point k, $\mathbf{U_k}$-Average-Annual-Outage time of node $\mathbf{k} \in \Omega_b$, $\mathbf{N_k}$-No. of users connected at node $\mathbf{k} \in \Omega_b$, $\boldsymbol{\lambda_k}$- Average-Failure-Rate of node $\mathbf{k} \in \Omega_b$, $\overline{\mathbf{SAIDI}}$-Max. average interruption duration index[h/year], $\overline{\mathbf{SAIFI}}$ –Max. average interruption frequency index[faults/year], and ENS-The overall energy not abounding by the structure.

3.2 Reliability Indices

Reliability indicators are the one of the important factor to be considered for the economical design and operation of EDS. The main objective of electrical power distribution system is to supply the continuous power supply to the consumer. Hence, a reliability indicator helps to supply continuous power supply to the system by reducing the interruption in services. Reliability indicator factors are tested and calculated at each and every point of user connection and at every load nodes. For the assessment of reliability indicator, the equation is given by,

$$\boldsymbol{\lambda_k} = \sum_i \boldsymbol{\lambda_i} \tag{11}$$

$$\boldsymbol{U_k} = \sum_i \boldsymbol{\lambda_i} \boldsymbol{r_i} \tag{12}$$

$$\boldsymbol{r_k} = \frac{U_k}{\lambda_k} = \frac{\sum_i \lambda_i r_i}{\sum_i \lambda_i} \tag{13}$$

Where,$\boldsymbol{\lambda_i}$ and $\boldsymbol{r_i}$ values are obtained from the network components, it is statistical or predictive data, $\boldsymbol{\lambda_i}$ - expected failure rate, and $\boldsymbol{r_i}$- Time taken to restore each module 'i' located between nodes k and their sources. n-time of each module 'i' located between each node k and its source. Enhancement of reliability indicators is only possible by minimizing the restitution time of each individual component and also by decreasing the number of nodes that are exaggerated due to fault. As the estimation of restoration time at each and every node is complex, this paper discusses alternative basic reliability indicator systems like SAIFI, SAIDI and ENS.

1) SAIFI

It helps to evaluate during a period of fixed time periods, the standard amount of interruptions experienced by a consumer. Mathematically, it is given as,

$$\boldsymbol{SAIFI} = \frac{\sum \lambda_k N_k}{\sum N_T} \tag{14}$$

Where, $\boldsymbol{\lambda_k}$- Average failure rate of node $\boldsymbol{k} \in \Omega_b$, $\boldsymbol{N_k}$-Number of users connected at node$\boldsymbol{k} \in \Omega_b$, and$\boldsymbol{N_T}$ - Total number of customers served.

$$\text{SAIFI}=\frac{\boldsymbol{TotalNumberofCustomerInterruptions}}{\boldsymbol{TotalNumberofCustomersServed}} \tag{15}$$

SAIFI is improved by reducing the number of interruption. This can be done by provide proper maintenance cycle and use efficient protective equipments.by minimizing the total number of interruptions in a system by using economical protective devices and by implementing proper maintenance period cycle.

2) SAIDI

This index helps to calculate the average time of an interruption during long period period of time. Mathematically it is given as,

$$\boldsymbol{SAIDI} = \frac{\sum U_k N_k}{\sum N_T} \tag{16}$$

Generally, it is expressed in hrs of interruption/year or interruption/year. Where, $\boldsymbol{U_k}$-Average annual outage time of node$\boldsymbol{k} \in \Omega_b$.

$$\text{SAIDI}=\frac{\boldsymbol{SumOfAllCustomerInterruptionDurations}}{\boldsymbol{TotalNumberofCustomersServed}} \tag{17}$$

SAIDI can be further enhanced similar to SAIFI by minimizing the total duration or number of interruptions.

3) Energy-not-Supplied-Index

This the one of the energy oriented indicator. Mathematically, it is expressed as,

$$\boldsymbol{ENS} = \sum_{k\in\Omega_k} \boldsymbol{P_k^D U_k} \tag{18}$$

Where, $\boldsymbol{P_k^D}$- At load-point k, the average active power load.

3.3 Big Bang Crunch (BBC) Optimization

The BBC is a recent evolving population technique that, in general, has the advantages of a faster convergence rate and less computation. According to this model's definition, the crunching phase entails the convergence operator that accepts a large number of inputs and generates a single output in accordance with the objective function. For the purpose of discovering the innovative solution based on the center of mass, which is calculated using the following equation, the randomly dispersed solutions are reconfigured in the great crunch phase:

$$\widehat{\boldsymbol{p^s}} = \frac{\sum_{h=1}^{P} \frac{1}{F_f^h} \widehat{p^h}}{\sum_{h=1}^{P} \frac{1}{F_f^h}} \tag{19}$$

Where, $\boldsymbol{P}$ is the size of population, $\boldsymbol{F_f^h}$ denotes the fitness function, and $\boldsymbol{p^s}$ shows the location in the d-dimensional search space where the fitness function is assessed. Then, the space border is regarded as the total of all members' Euclidean distances, as calculated below:

$$\frac{X_W \text{ in } k^{th} \text{ interation}}{X_W \text{ in } (k+1)^{th} \text{ interation}} > 1 \quad (20)$$

Where, X_W is the space boundary. Based on the creation of an undirected logical network (L_p) with n vertices and m edges, the model's best solution is estimated. Following that, according to the pheromone concentration from τ_{mn} to τ_{mx}, each ant in the population conceals the same amount of pheromone at each edge. Additionally, it only permits the top ants to pheromone with their trails, allowing for an improved solution to be found after the maximum number of repetitions. Setting the initial pheromone concentration to τ_{mx} greatly enhances the ant's capacity for exploration. Then, using the following equation, the set of neighbors $V(a,b)$ are determined for the edges containing vertices of Y_a, Y_b:

$$V(a,b) = \{Y|_{y \in Y_p}, (a,y) \in Z_s \wedge (b,y) \in Z_s\} \quad (21)$$

Where, Z_s is the set of edges, Y_s is the set of vertices $Y_s = \{y_1, y_2, \ldots, y_s\}$, $y(a,b)$ denotes any particular vertex. The ants choose the following edges based on pheromone concentration, and the edge selection probability designates any certain vertex. The ants select the following edges based on the pheromone concentration and the chance of edge selection. (σ_{ab}) of an ant at vertex $y_{a-1,h}$ *to* $y_{a,b}$ is calculated as follows:

$$\sigma_{ab}(i) = \frac{\left[\tau_{(y_{a-1,h} \text{ to } h_{a,b})}(i)\right]^{\delta} . \left[g_{y_{a,b}}(i)\right]^{\omega}}{\sum_{r=1}^{\sigma_a}\left[\sigma_{(y_{a-1,h} \text{ to } y_{a,r})}(i)\right]^{\delta} . \left[g_{y_{a,r}}(i)\right]^{\omega}} \quad (22)$$

Where, $\tau_{(y_{a-1,h} \text{ to } y_{a,b})}$ is the pheromone value of edge. The symbol δ and ω denotes the weight parameters used to compute the relevance of pheromone and heuristic values. The function $g_{y_{a,b}}$ defines the heuristic value of the vertex $(y_{a,b})$ computed by using the following equation:

$$g_{y_{a,b}}(i) = \frac{R_Q^{a,b} \ \& \ U = bst_a}{|R_Q^{a,b}|} \quad (23)$$

Where, $R_Q^{a,b}$ represents the partition pertaining to all classes. Moreover, the pheromone quality is computed as follows

$$\tau_{(y_{a,r}, y_{a-1,h})}(i+1) = \varepsilon * \tau_{(y_{a,r}, y_{a-1,h})}(i) + \frac{E^{+}_{best}}{10} \quad (24)$$

Where, E^{+}_{best} denotes the path quality, where the pheromone concentration is increased by the best ants. The new candidate set(p^{new}) is estimated by using the following equation:

$$p^{new} = \widehat{p^s} + \frac{r_1 * \tau_{(y_{a,r}, h)}}{i} \quad (25)$$

Where, $\widehat{p^s}$ is the center of mass, r_1 and i are the random number and iterations, correspondingly.

4. Results and Discussion

The suggested IEEE 33 test system in the proposed paper is tested using MATLAB software. An IEEE 33 bus system consists of 33 buses, 32 sectionalizing (normally closed) switches and 5 tie line (Normally opened) switches.

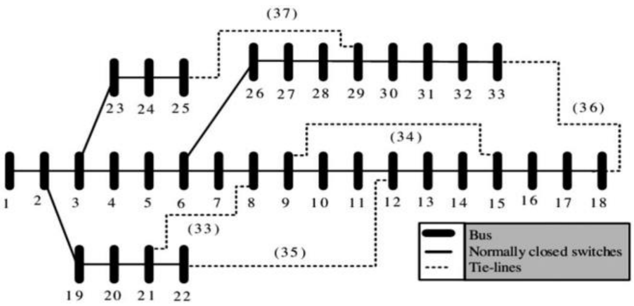

Fig. 1. IEEE 33 Bus Test System

Among other bus standards, the main advantages of IEEE 33 bus system are reduced cost, low loss, maximum loadability index, and efficiency. The simulation of IEEE 33 bus test system is carried out mainly in two different types namely- case 1: Base case, case 2: After reconfiguration.

CASE I: Analysis in Base Case

For the analysis in base case, the forward and backward algorithm is tested for power flow analysis. Table 3 and table 4 discusses about the results obtained in load flow without changing the topography of the network. It is observed that the total P, Q losses and voltage deviation are 210.0594 kW, 142.5320kVAR and 0.1328 respectively. The accuracy indicators are observed as 12.6528 h/year, 0.1342fault/year and 2.599 kWhr/year. Based on the results of Table 3 and Table 4, the power flow analysis is validated for the IEEE 33 bus system with the reliability indices. The obtained results indicate that the loss factor is efficiently reduced in these base cases.

Table 3. Base case of IEEE 33 bus test system

Bus no	Voltage in p.u.	Angle in degrees	Individual 'P' loss	Individual 'Q' loss
2	0.99660	0.00020	13.93	7.20670
3	0.00150	0.00150	30.321	15.44340
4	0.00240	0.00240	17.092	8.70480
5	0.00340	0.00340	15.80910	8.05180
6	0.95250	0.00130	32.07550	27.68910
7	0.94460	-0.00520	6.33570	20.94300
8	0.92460	-0.01100	23.23670	16.76970
9	0.91470	-0.01420	9.54050	6.85430
10	0.90540	-0.01720	8.50340	6.05050
11	0.90530	-0.01720	0.00500	0.00160
12	0.90510	-0.01710	0.01560	0.00520
13	0.98140	0.00090	0.82190	0.64670
14	0.98020	0.00030	0.16970	0.22340
15	0.97990	0.00020	0.01620	0.01440
16	0.97950	0.00000	0.02210	0.01610
17	0.97870	-0.00050	0.03820	0.05100
18	0.95180	0.00120	0.05560	0.04360
19	0.99420	-0.00070	2.85400	2.72350
20	0.97420	-0.00730	22.9695	20.69730
21	0.96870	-0.01000	5.42090	6.33300
22	0.95950	-0.01530	8.03930	10.62950
23	0.95500	-0.01620	4.31980	2.95170
24	0.94680	0.01850	7.07860	5.58960
25	0.94240	-0.01980	2.01240	1.57470
26	0.94230	-0.01980	0.00690	0.00350
27	0.94210	-0.01980	0.00960	0.00490
28	0.93810	-0.00190	3.88290	3.42350
29	0.93700	-0.00210	0.12550	0.10930
30	0.93500	-0.00000	1.64780	0.83930
31	0.89720	-0.02160	5.95370	5.88400
32	0.98100	-0.01230	0.99890	1.16420
33	0.98070	-0.01240	0.01300	0.02030

Table 4. Power flow in Base case

SAIDI [h/year]	SAIFI [faults/year]	ENS [kWhr/year]	P loss [kW]	Q loss [kVAR]	Voltage deviation
12.6528	0.1342	2.5994	210.0594	142.5320	0.1328

CASE II: Analysis after Reconfiguration

The same network is analyzed by applying BBC optimization algorithm the switches 7,9,12, 15, 22 are to be in open condition where as other switches in closed condition. Real power loss is reduced to 68.9327 kW, reactive power loss is minimized to 85.2242 kVAR and the voltage deviation is also minimized to 0.0337. In this reconfigured network, the SAIDI value is reduced by 0.63738 hr/yr, the SAIFI and ENS value also reduced by 0.00752 faults/Yr, 0.8594 kWhr/year. Based on the results shown in Table 5, the comparative analysis of existing GA and proposed BBC optimization techniques. From the evaluation, it is proved that the overall performance of the reconfigured network is highly improved after deploying BBC optimization mechanism.

Table 5: Comparison of existing GA and proposed BBC radial based Reconfigured Network

Method	Min Fitness	Tie switches	Voltage deviation	P loss kW	Q loss kVAR	ENS kWhr/Yr	SAIDI [h/year]	SAIFI [faults/year]
GA	0.8594	7 12 9 15 22	0.0337	68.9327	85.2242	0.8594	0.63738	0.0075255
BBC	0.9379	7 12 10 15 23	0.0356	73.0006	87.6278	0.9379	0.6569	0.0075

Table 6 presents the comparative analysis of existing [20], and proposed approaches for the IEEE 33 bus systems. The different types of parameters considered in this evaluation are power loss, loss reduction, minimum voltage, voltage node, and computational time.

Table 6. Comparative analysis

Items	Base Case	SFS	SSOE	MSSOE	Proposed
Power loss (kW)	202.69	139.55	139.55	139.55	128.6
Loss reduction (%)	NA	31.15	31.15	31.15	30.6
V_{min} (pu)	0.9131	0.9378	0.9378	0.9378	0.9378
Voltage node	18	32	32	32	32
Computational time (s)	NA	NA	0.2496	0.2330	0.2168

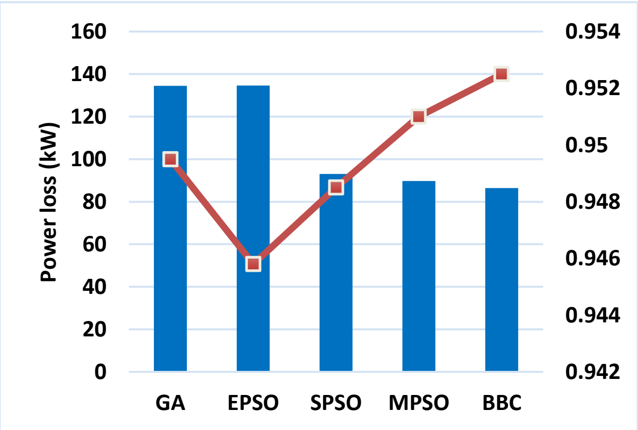

Fig. 2. Power loss analysis

Figure 2 compares the conventional and proposed optimization techniques with respect to the parameters of power loss (kW) and minimum voltage profile (p.u.) for three different load conditions. Then, its corresponding graphical illustrations are shown in Fig 4 and Fig 5 respectively, which includes the techniques of Genetic Algorithm (GA), Enhanced Particle Swarm Optimization (EPSO), Selective Particle Swarm Optimization (SPSO), and Modified Particle Swarm Optimization (MPSO). Based on the obtained results, it is identified that the proposed BBC optimization technique outperforms the other techniques with improved performance results.

5. Conclusion

In this paper, an optimization method used to reconfigure the EDS (Electrical distribution system) has been discussed. The main objective of this paper is to reduce the power loss, to enhance the voltage profile and to improve the accuracy indicators by formulating the existing distribution system by reconfiguration method. BBC optimization algorithm is used to find out the optimal switches to be opened during reconfiguration. The suggested reconfiguration methodology is tested on IEEE 33 bus test using MATLAB for two different cases - namely for base case, for reconfiguration of distributed system. The test results give the reduced power losses, increased voltage profile and improved reliability. In this reconfigured network, the SAIDI value is reduced to 0.63738 hr/yr, the SAIFI and ENS value also reduced to 0.00752 faults/Yr, 0.8594 kWhr/year by using the BBC technique. Similarly, the voltage deviation is minimized to 0.0356 and the and the reliability indices ENS,SAIDI, SAIFI improved to 0.9379 kWhr/year, 0.6569 hr/year and 0.0075 faults/year by using the BBC technique.

In future, this work can be enhanced by implementing a hybridized meta-heuristics based optimization algorithm for solving the reconfiguration problem.

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