Network Reconfiguration to improve Reliability indices and Efficiency in Distribution Systems with An efficient hybrid Big Bang-Big Crunch algorithm systems

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Abstract—*Failure statistics show that distribution networks engage the most contribution the customer unavailability services. Because optimal reconfiguration of distribution systems has many advantages. Sothis paper presents an efficient hybrid Big Bang-Big Crunch optimization (HBB-BC) algorithm to solve the single-objective reconfiguration of improve the objective functions of the problem such as system average interruption frequency index, system average interruption duration index, average energy not supplied, in distribution systems. So that each objective is calculated in this optimization process. The HBB-BC is a powerful algorithm and has fast convergence. This algorithm using the Particle congestion Optimization (PSO) capacities improves the susceptibility of the Big Bang- Big Crunch (BB-BC) algorithm for better discovery. In addition, the HBB-BC uses a mutation operator after position updating to avoid local optimum and to explore new search areas. The effectiveness of the proposed algorithm is show on balanced test distribution systems. The simulation results are compared with the other solution obtained by other approach.*

Keywords— Big Bang-Big Crunch, Distribution system reconfiguration (DFR), Particle Swarm Optimization, single-objective optimization

I. INTRODUCTION

The distribution system is an important part that provides final links between the utility and the customers. That makes the most individual involvement to the unavailability of supply to the users [1]. Indeed, most of the failures occur in the voltage level of distribution [2]. Distribution feeder reconfiguration is one of the most important strategies between reliability improvement schemes [3-5]. The reliability in a distribution system can be improved by network reconfiguration, which is done by closing normally-open switches and opening normally closed switches [5]. These switches have a very important role in reducing interruption durations in the event of a system failure. Distribution systems are typically acted as radial networks because in radial structure coordination of the protective schemes is simple and the fault level is lower than meshed structure. The reconfiguration of a distribution system is performed by changing open/close status of sectionalizing and tie switches [6].Network reconfiguration is done in order to achieve a radial operating structure that optimizes certain objectives while satisfying operational constraints without islanding of any load(s) [5].

A great deal of work has been done on network reconfiguration (also known as feeder reconfiguration) in distribution systems mainly in the context of active power loss reduction because the cost of MW loss occupies considerable amount of operating cost in the system and therefore small amount achieved from loss reduction is still attractive for electric power utilities. But Very little has been paid attention to reliability improvement by feeder reconfiguration [7-17]. Lopez et al. [18] suggested a new technique for solving distribution feeder reconfiguration problem based on online evaluations. Similar work for loss reduction was done in [19].In fact, in the mentioned works, the most attention has been paid on the loss reduction as a good criterion for the total cost. In other works in association with the loss objective function are also considered as objective function. In [20] Nikname introduced two methods based on the norm2 technique to solve the multi objective distribution feeder reconfiguration (mdfr) problem.

This paper presents an efficient method to solve the problem of single-objective reconfiguration to improve reliability indices distribution systems using HBB-BC algorithm with fuzzy objective function. The objective considered are minimization of system average interruption frequency (SAIFI) and the system average interruption duration (SAIDI) and average energy not supply (AENS) in the feeders.

II. PROBLEM DESCRIPTION

1.1. Distribution feeder reconfiguration

Reliability indices are statistical aggregation of reliability data for a well-defined set of loads. A primary feeder originates from a substation and passes through major load centers. The lateral distribution connected the individual load points to the main feeder with distribution transformers at their ends. Many distribution systems used in practice have a single-circuit main feeder and defined as radial distribution system. A radial distribution system consist of series component (lines, cables, transformers) to load points. So high currents can cause the overhead lines to sag which will reduce the ground clearance and increase the probability of occurring an electric break. Therefore, any planning strategy which can reduce the branch current will have a positive influence on the reliability of the system. Distribution feeder reconfiguration can reduce the magnitude of the branch currents by changing the topology of the network and as the direct result, reduce the total power losses of the system sufficiently. Also distribution feeder reconfiguration enhances the reliability of the system in another way. By decreasing the total power losses in the system, the load ability of the feeder is increased such that the reliability of the system is enhanced. There for according to the above descriptions, distribution feeder reconfiguration can be supposed as a failure rate reduction strategy. Before running the reconfiguration to the system, any line I has an initial failure rate of λ^{init} .

1.2. Problem formulation

1.2.1. Objective functions

Minimization of the system average interruption frequency index (f1):

The system average interruption frequency index (SAIFI) is the average number of the interruption that a customer would experience [2], and SAIFI is measured in units of interruption per customer.

Minimization of the system average interruption duration index (f2):

The system average interruption duration index (SAIDI) is generally used as a reliability indicator by the electric power utilities. In definition, SAIDI is equal to the average outage duration time which each customer experiences. [3], and SAIDI is measured in units of time.

Minimization of energy not supplied index (f3):

One of the important parameters required in the evaluation of load and energy oriented indices is the average load point busbar [1].

Minimization of the average not supplied (f4) the average energy not supplied (AENS)

Minimization of the power losses (f5)

1.2.2. Decision variables

X= [Tie,Sw]

Sw= [Sw_1, Sw_2,….,S_{wnsw}]

Tie= [Tie_1, Tie_2,……,Tie_{Ntie}]

Xb= [$x_{b,1}$, $x_{b,2}$,…...$x_{b,n}$]

Xd= [$x_{d,1}$, $x_{d,2}$,…...$x_{d,n}$]

Xw= [$x_{w,1}$, $x_{w,2}$,…..$x_{w,n}$]

Xg= [$x_{g,1}$, $x_{g,2}$…….$x_{g,n}$]

1.2.3. Limits and constraints

Limits associated with the capacity of the distribution lines:

$$p_{ij,\min}^{line} < p_{ij}^{line} < p_{ij,\max}^{line} \quad (1)$$

Distribution power flow equations:

$$\text{Pi} = \sum_{i=1}^{N_{bus}} \cos(\theta_{ij} - \delta_i + \delta_j) \quad (2)$$

$$Q_i = \sum_{i=1}^{N_{bus}} V_i V_j V_{ij} \sin(\theta_{ij} - \delta_i + \delta_j) \quad (3)$$

This equation is a load flow equation which is considered as an equality constraint.

Having a radiality network requires: as mentioned before, the distribution system generally are designed as radial networks. Accordingly, during the reconfiguration, this quality of the system should be preserved. If a loop is formed in the network, then one of the tie or sectionalizing switches in the loop should be opened such that the radiality of the network is protected.

Bus voltage constraints:

$V_{min} \le v_i \le V_{max}$

Feeder current limitation:

$\left|I_{f,i}\right| \le I_{f,i}^{\max}$ i=1, 2,…..,Nf

III. PROPOSED HYBRID BIG BANG-BIG CRUNCH ALGORITHM

In this method, the HBB-BC algorithm uses the PSO capacities as introduced in [23] and a mutation operator to improve the exploration ability of the BB-BC algorithm and avoid the trapping into the local optimum.

The PSO algorithm was initially proposed by Kennedy and Eberhart [21] in 1995. It was inspired by the social behavior of bird flocking and fish schooling. PSO consists of a swarm of particles as candidate solutions for the optimization problem. Each particle adjusts its trajectory toward its own best previously visited position (local best) and the global best position of the swarm found (global best). In HBB-BC algorithm similarly in addition to the center of mass, the local best and the global best are also used to generate the new candidates as [23]:

$$A_i^{(k+1,j)} = \alpha_2 A_i^{c(k)} + (1-\alpha_2)(\alpha_3 A_i^{gbest(k)} + (1-\alpha_3) A_i^{lbest(k,j)}) + \frac{r_j \alpha_1 (A_{i\max} - A_{i\min})}{k+1} \quad \begin{cases} i = 1,2,\ldots,m \\ j = 1,2,\ldots,N \end{cases}, \qquad (4)$$

Where $A_i^{lbest(k,j)}$ is the best position of the j th particle up to the iteration k and $A_i^{gbest(k)}$ is the global best position up to the iteration k ; α_2 and α_3 are adjustable parameters controlling the effect of the global best and local best on the new position of the candidates, respectively. A discrete solution is achieved by using the Eq. [23].

$$A_i^{(k+1,j)} = round\,(\alpha_2 A_i^{c(k)} + (1-\alpha_2)(\alpha_3 A_i^{gbest(k)} + (1-\alpha_3) A_i^{lbest(k,j)}) + \frac{r_j \alpha_1 (A_{i\max} - A_{i\min})}{k+1}) \qquad (5)$$

where $round(X)$ is a function which rounds the elements of X to the nearest integers.

Now, we use the mutation operation to prevent the HBB-BC from trapping into the local optimum and to explore new search areas as follow:

$$A_i^{(k+1,j)} = round\,(A_{i\min} + rand\,() \times (A_{i\max} - A_{i\min})) \quad if \quad rand\,() < P_m \qquad (6)$$

Here, $rand()$ is the uniformly generated random number within the interval of [0,1] and P_m is mutation probability.

a. Application of the HBB-BC algorithm to distribution system reconfiguration

In the proposed algorithm, the control variable is an integer that represents the number of switch that should be opened to maintain a feasible radial configuration. Therefor the number of control variables for HBB-BC is equal to the number of tie-switches of the system. To form an individual, information about the fundamental loops and the switches number in each fundamental loop is required. In radial networks by closing all tie-switches the fundamental loops are determined. The number of fundamental loops (N_L) is obtained as follows:

$$N_L = N_{br} - N_b + 1, \qquad (7)$$

where N_b is the total number of buses of the network. N_L is equal to the number of tie-switches of the system.

The HBB-BC algorithm is applied for the problem of multi-objective network reconfiguration as follow:

Step 1: Describe the input data: In this step, the input data including the initial network configuration, line impedance, the number of fundamental loops and the switches number in each loop, the number of population, limiting parameter of the size of the search space (α_1), adjustable parameters (α_2, α_3), mutation probability (P_m) and the number of iterations are defined.

Step 2: produce the initial population: for initialization of each individual, one switch is randomly chosen from each fundamental loop to be open.

Step 3: Check the radiallity of the network and being all loads in service for each individual: to check whether radiallity is maintained as well as all loads being in service, graph theory can be used. If in a tree, those vertices that their degree is equal to 1 with all edges connected to them are deleted and this procedure is repeated, finally all vertices are deleted. If the network graph is not the tree, it means that network is not radial or at least one load has been isolated. In this state, the value of fitness function is considered zero.

Step 4: perform the load flow: A direct approach proposed in [24] is used for load flow solution. This approach is efficient for large scale distribution systems. At this point the voltage and current constraints are checked if there is a deviation from the provisions of the objective function for the arrangement of a number too large to be replaced. the value of the objective function using an acceptable reliability for each radial structure is evaluated. The objective function of the indices SAIFI, SAIDI reliability indices or AENS is in season radial is described.

Step 5: Calculate the center of mass ($A_i^{c(k)}$) using Eq. (12) and determine the best position of each particle ($A_i^{lbest(k,j)}$) and the global best position ($A_i^{gbest(k)}$).

Step 6: calculate new candidates according to Eq. (15). Then, apply the mutation operation to prevent the HBB-BC from trapping into the local optimum.

Step 7: Repeat steps 3–6 until a termination criterion is satisfied. In this paper, the stopping criterion is considered number of iteration. Furthermore, if the maximal iteration number is satisfied, algorithm is terminated.

IV. SIMULATION RESULTS

The proposed algorithm was implemented in MATLAB 7.8.0 (R2009a) on a Intel(R) Core(TM)2 2.67-GHz PC with 2-GB RAM, and tested on two distribution systems. The first is the Baran and Wu distribution test system, the second is a 69-bus IEEE distribution system. The HBB-BC parameters used in this paper to optimize the single objective fitness function to improve reliability indices for all two systems and the simulation results are compared with the reference [25] are summarized in Table 1 which determined by trial and error method by using computer simulations.

Table 1.Parameters of the HBB-BC

Network studied	Objective function	α_1	α_2	α_3	N	P_m
33 bus	SAIFI	1	0/4	0/8	15	0/1
	SAIDI	1	0/4	0/8	20	0/1
	AENS	1	0/4	0/8	25	0/2
69 bus	SAIFI	1	0/4	0/8	20	0/1
	SAIDI	1	0/4	0/8	30	0/2
	AENS	1	0/4	0/8	35	0/2

Table. 2 Results obtained by optimizing the SAIFI for case study.

Methods	SAIDI	SAIFI	AENS	Power losses (kW)	Minimum voltage(p.u)	Open switches
Initial state	9/6743	1/2246	1/9169	202/677	0/9131	33-34-35-36-37
Proposed HBB-BC	8/7508	1/0315	1/7377	159/508	0/9258	10-14-16-27-33
ISFLA[26]	9/3979	1/1550	1/8653	196/504	0/9167	33-13-35-36-37

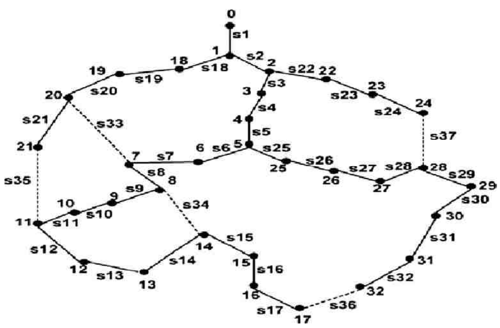

Fig. 1:Baran and Wu distribution test system

The Baran and Wu distribution test system is a hypothetical 12.66 kV system including two-feeder substation, 32 buses, and 5 looping branches as shown in Fig. 1. The line and load data of the system are given in [5]. Total loads for the base configuration are 3715 kW and 2300 kVAR. Power losses and minimum bus voltage in the initial configuration are 202.677 kW and 0.913 p.u, respectively.

At first, the objective functions including minimization of SAIFI (f1) and SAIDI (f2) and AENS (f3), and the result of single objective optimization of the active power losses (f4) . The results obtained by using HBB-BC algorithm are compared with ISLFA algorithm.According to Tables 2 and 3 and 4, the results for optimization of the first, the second and the third objectives are separately shown. The satisfying performance of HBB-BC in comparison to the other algorithms can be deduct easily. However, it can be seen from these tables that the best switching statues corresponding to the optimal solutions of SAIDI and AENS objective functions the same. In fact, this result shows that SAIDI and AENS objective functions have similar behavior in increasing and decreasing process in a way that improving one.

Therefore the amount of SAIFI index before reconfiguration is 1/2246 (failure/customer/yr). The amount of SAIFI after reconfiguration has improved to 1/0315 (failure/customer/yr). Also the impact of the reconfiguration on SAIDI and AENS indexes, in the minimum power loss and bus voltage has been studied, would result to the improvement of the other one. As shown in the tables, the algorithm can be find the best solutions for each objective function.

In Table 2, it may be observed that the proposed algorithm is applicable in minimization of SAIFI.

Figs. 3 and 4 and 5 show the SAIFI and SAIDI and AENS indexes of the Baran and Wu distribution test system decrease after reconfiguration and have been improved by the proposed HBB-BC algorithm.

The proposed algorithm is implemented 50 times for each objective function separately as well as single objective fitness function and the statistics of the different objective functions are shown in Table 5. Test results represent effectiveness of the proposed algorithm to find global optimum configuration with a short execution time.

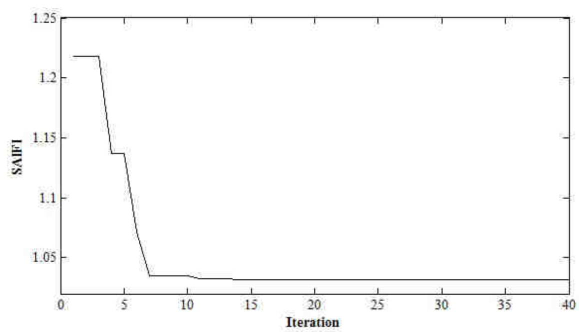

Fig. 2. Convergence characteristic of the SAIFI objective fitness function for case study.

Table. 3 Results obtained by optimizing the SAIDI of the buses for case study

Methods	SAIDI	SAIFI	AENS	Power losses (kW)	Minimum voltage(p.u)	Open switches

Initial state	9/6743	1/2246	1/9169	202/677	0/9131	33-34-35-36-37
Proposed HBB-BC	8/6461	1/0436	1/7131	157/818	0/9265	9-16--27-33-34
ISFLA[26]	9/4492	1/1981	1/8690	204/011	0/9090	33-34-35-16-37

Table.4 Results obtained by optimizing the AENS of the buses for case study.

Methods	AENS	SAIFI	SAIDI	Power losses (kW)	Minimum voltage(p.u)	Open switches
Initial state	1/9196	1/2246	9/6743	202/677	0/9131	33-34-35-36-37
Proposed HBB-BC	1/7131	1/0436	8/6461	157/818	0/9265	9-16--27-33-34
ISFLA[26]	1/8690	1/1981	9/4492	204/011	0/9090	33-34-35-16-37

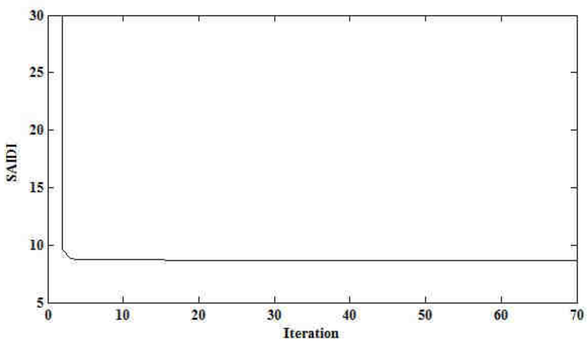

Fig. 3. Convergence characteristic of the SAIDI objective fitness function for case study.

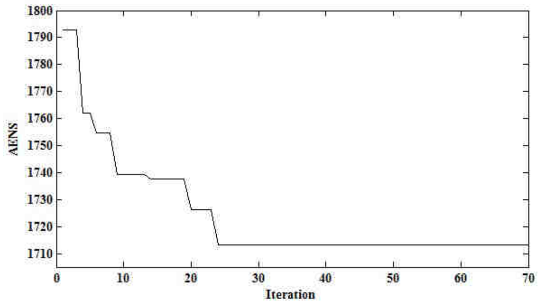

Fig. 4. Convergence characteristic of the AENS objective fitness function for case study.

V. CONCLUSION

A Hybrid Big Bang-Big Crunch optimization (HBB-BC) algorithm for multi-objective reconfiguration of balanced distribution systems in fuzzy framework has been presented in this paper. In HBB-BC algorithm PSO capacities and mutation operation is used to improve the exploration ability of the BB-BC algorithm and avoid local optimum. In the proposed algorithm, minimization of, system average interruption frequency (SAIFI) and the system average interruption duration (SAIDI) and average energy not supply (AENS) in the feeders buses and total real power losses in the feeders are considered as the objective functions. First each objective iscalculated with first parameters that was introduced and then minimized with the help of HBB-BC algorithm. The simulation results on Small and large-sized distribution systems represent the effectiveness of the proposed algorithm to find global optimum configuration and also depict that the average execution time of this algorithm is significantly short. Regarding the results, proposed algorithm can be applied to solve the problem of distribution system reconfiguration for practicalnetworks.

Table. 5 Statistics obtained for different objectives after 50 trials.

Objective functions	Average of objective function value	Standard deviation	Worst solution		Best solution		CPU time (s)
			objective function value	Open switches	objective function value	Open switches	
SAIFI	1.0315	0	1/0315	10-14-16-27-33	1/0315	10-14-16-27-33	3.05
SAIDI	8/6461	0	8/6461	9-16-27-33-34	8/6461	9-16-27-33-34	2.48
AENS	1/7131	0	1/7131	9-16-27-33-34	1/7131	9-16-27-33-34	7

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