Bio-Geography based High Speed Contingency Selection in Static Security Analysis of Power System

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ABSTRACT
Operating the Power system is one of the major tasks for the electrical engineers. Due to increase in habituation on the consumption of electricity, the grandness of preventing the voltage collapse is increasing. The power system evaluation is processed to withstand the system during dangerous contingencies and to holdout to a normal or acceptable operating point, which is required for security analysis. To secure the power system a fast and accurate operation has to be performed. In this paper, Biogeography Based Optimization (BBO) algorithm is proposed for contingency selection in Static Security Analysis of Power System. The Proposed method is realized with IEEE-30 bus system. Also Efficiency and performance of the proposed method is validated with classical selection of contingencies based on Differential Evolution algorithm.
Keywords : BBO algorithm, IEEE-30 bus system, Static security, Power Flow Index and Voltage Violation Index.

1. Introduction

The definition of the term *'Security'* given by NERC(1997), is the ability of electric systems to withstand sudden disturbances such as electric short circuits or unanticipated loss of system components [1]. The system is said to be operationally "secure" if there is low probability of outage or blackouts [2],[3]. Security assessment is the analysis process carried out to find whether the system remains fairly in the secure state even in case of disturbances to the system [4]. Security analysis is classified into two categories as Static Security Analysis, which deals only with the post contingency steady state case and Transient Security Analysis, which considers the parameters related to time(rotor angle stability).

Security analysis involves simulation of power system elements outages, such as generating units, transmission lines and transformers [2],[4]. System security analysis is broadly classified into three major stages namely, contingency analysis, system monitoring and security constrained optimal power flow [5]. Contingency is defined as the loss of transmission lines, generator malfunction which leads to branches overload and bus voltage limit violation [6],[7]. Hence, contingency analysis is considered as the important stage in security analysis. In the planning stage of power system, contingency analysis provides the details of need for new transmission line or generation expansion due to growth in load [8],[9]. By definition, Contingency selection is the list of critical contingencies that can occur in the system [10]. The conventional approach for contingency selection includes the use of sensitivity factors and AC power flow methods [11]. Sensitivity factors based method provides approximate solutions with less computation time [12]. The AC power flow method provides accurate solution with more computational time [13],[15]. So the AC power flow method is not suitable for online applications [16]. Instead of Conventional approach, the Contingencies can be selected based on their severity indices either in terms of power flow violations or voltage limit violations. Biogeography-based optimization (BBO) is one of the population-based algorithm, suggested by Dan Simon. It is based on the biogeography theory, which deals with the geographical distributions of organisms. Two factors such as Mutation and Migration is involved in biogeography algorithm. Migration operator is mainly useful in sharing the information among solutions [17],[18]. Differential Evolution (DE) is another powerful population-based algorithm used for global optimization problems was introduced by Storn and Price [14]. In Differential Evolution algorithm to determine the deviation in third randomly chosen individual the source used is the variations of two randomly selected individuals [19]. BBO algorithm is good at exploitation ability but poor in exploration ability. Conversely, DE algorithm is best at examining the optimization but poor at exploitation.

2.Biogeography-Based Optimization (BBO) algorithm

BBO is one of the population based Evolutionary algorithm(EA), which provides the optimized candidate solution stochastically and iteratively with regards to their suitability index. Mathematical model of this algorithm depends on the emigration of species from one enclave to another and immigration to enclave. The important aspect of BBO algorithm is that primitive population is not leftover at end of each generation. Each individual has a Habitat Suitability Index (HSI) which is similar to fitness function in other heuristic algorithm. Good solution will be sign of enclave with high HSI and a poor solution specify the island with low HSI. Habitat with high HSI has more number of species compared relatively to low HSI habitat. High HSI is static in species distribution and moreover low HSI is dynamic. Each individual has its own emigration rate μ and immigration rate λ. High HSI habitat have high emigration rate and low HSI habitat have high immigration rate. The emigration and immigration rate are the functions of number of species in the habitat. The variables that characterize the habitability is known as Suitability Index Variables(SIV). HSI is dependent variable and SIV is independent. The rate can be computed using,

$$\lambda_k = I\left(1-\frac{k}{n}\right) \qquad (1)$$

$$\mu_k = E\left(\frac{k}{n}\right) \qquad (2)$$

Where Iis the maximum immigration rate; E is the maximum emigration rate; $k$is species count in K^{th} individual; n is maximum species count.

Migration is stochastic operator where it exchanges the among solutions. This operator improves the quality of solution. Mutation is also a probabilistic strategy which modifies the suitability index variables based on mutation probability. This is suitable for both high and low HSI solution. In case of low HSI solution, this operator is used to acquire required information from the best solutions and thus providing an opportunity to improve the quality of solution. Thus, BBO is best at accomplishing the information of the present population.

3. Methodology

The proposed strategy is demonstrated on the IEEE-30 bus system as shown in Figure 1. The system constitutes 6 generators, 41 transmission lines and 24 load buses. The maximum and minimum voltage limit is taken as 0.95 and 1.05 p.u. respectively.

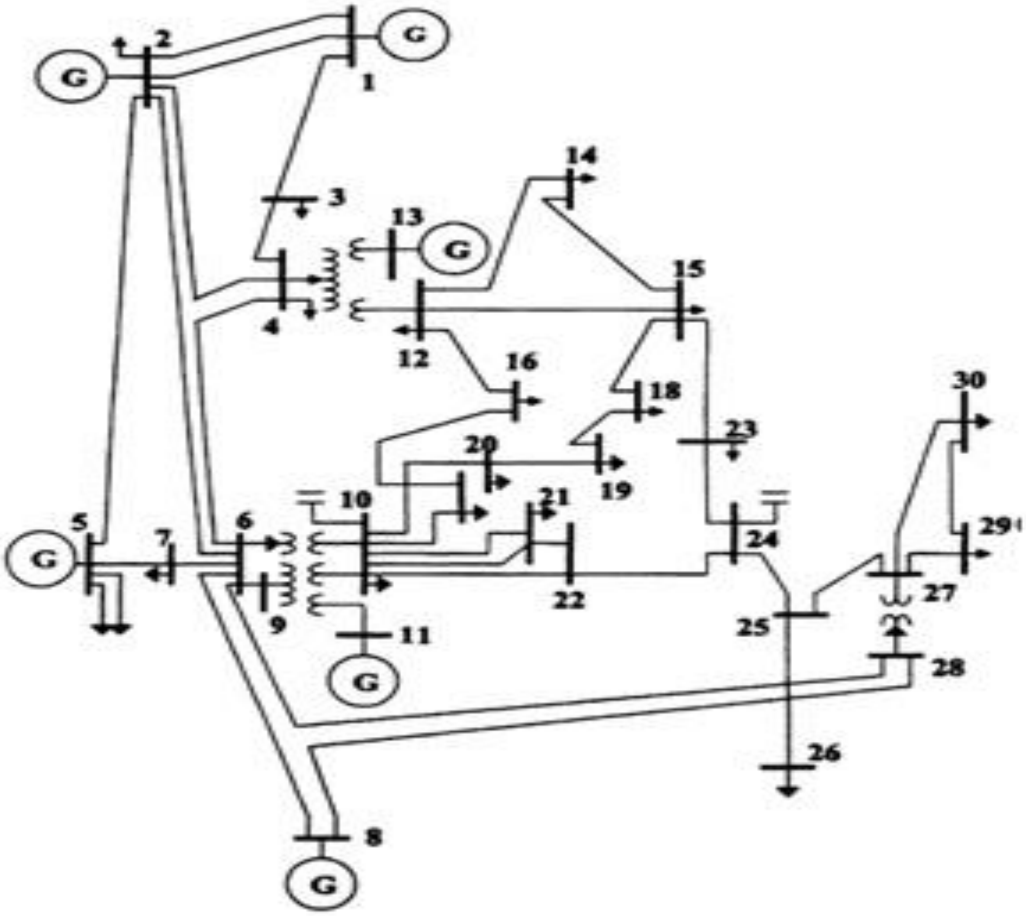

Figure 1. IEEE-30 bus system One line diagram

The moto of the work is to determine credible contingencies form the list of all possible contingencies for IEEE 30 bus system. This paper work envisages the salient features of BBO Optimization algorithm for the objective. The effectiveness of the algorithm for the problem considered and assessed by comparing the result with the conventional methods of contingency selection byFast Decoupled Load Flow method through the calculation of performance indices.The problem is to select the most credible contingency from the list of all possible contingencies.The process involved in the contigency selection is presented in the form of flowchart in figure 2. The solution for the above mentioned problem will be obtained by BBO algorithm using migration operator.

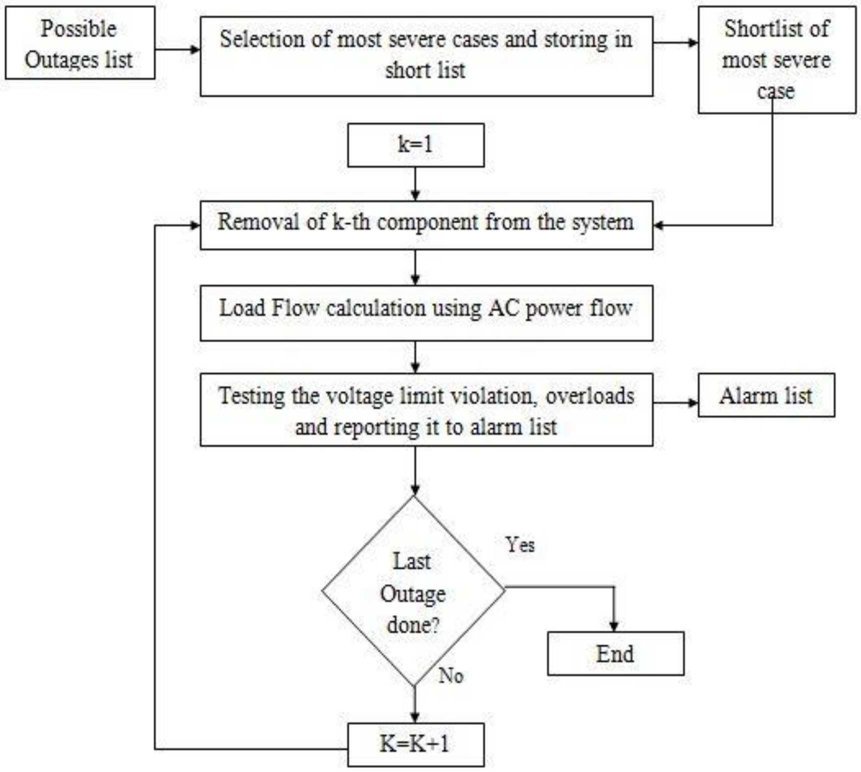

Figure 2. Flowchart for Contingency Selection.

3.2Index formulae

The Power Flow Index (P_{index}) can be obtained using equation (3)

$$P_{index} = \sum_{k=1}^{v} \frac{pfl(k)^2}{cpf(k)^2} \qquad (3)$$

where,

pfl = power flow at branch k
cpf = power capacity at branch k
v = number of overloaded branches

The Voltage Violation Index can be obtained using equation (4)

$$V_{index} = \sum_{k=1}^{n} (VIOL(k))^2 \times 10^4 \qquad (4)$$

$$VIOL = \begin{cases} V(k) - V_{max}, & \text{if } V(k) > V_{max}; \\ V_{min} - V(k), & \text{if } V(k) < V_{min}; \end{cases} \qquad (5)$$

where,

$VIOL(k)$ = voltage violation at bus k
$V(k)$ = voltage magnitude at bus k (pu)
V_{max} = maximum voltage allowed for bus k
V_{min} = minimum voltage allowed for bus k

n = number of buses with voltage violations
The formula of the capture ratio is:

$$\text{Capture Ratio} = \frac{K}{N} \times 100 \tag{6}$$

Where,
K - number of contingencies captured using assessed method
N - number of contingencies captured using exhaustive method(desired)
Parameters used in BBO algorithm is tabulated in Table 1.

Table 1. Mapping of problem parameters with BBO algorithm parameters

Algorithm Parameters	Problem Parameters
Species	Branches
Habitat Suitability Index	Power Flow violations and Voltage Violations
Suitability Index Variables	Branches under Contingency
Emigration rate Immigration rate	Least Vulnerable branches under Contingency to be removed. Highly Violated branches to be entered into the list.
Mutation	Random Changes between the branches.
Elite Selection	Sorting of Contingencies in descending order of violations in the branches.

Each species in an island has its Suitability Index based on which it can either emigrate or immigrate to other island. Similarly, this concept is applied to our problem where each line in the system has its HIS value calculated using eqn. 3 & 4. The security of the power system will be affected to the most case due to voltage instability, therefore the lines are ranked based on their voltage violation value and arranged in the descending order. The Flow Chart of Contingency Selection using BBO is presented in Figure 3.

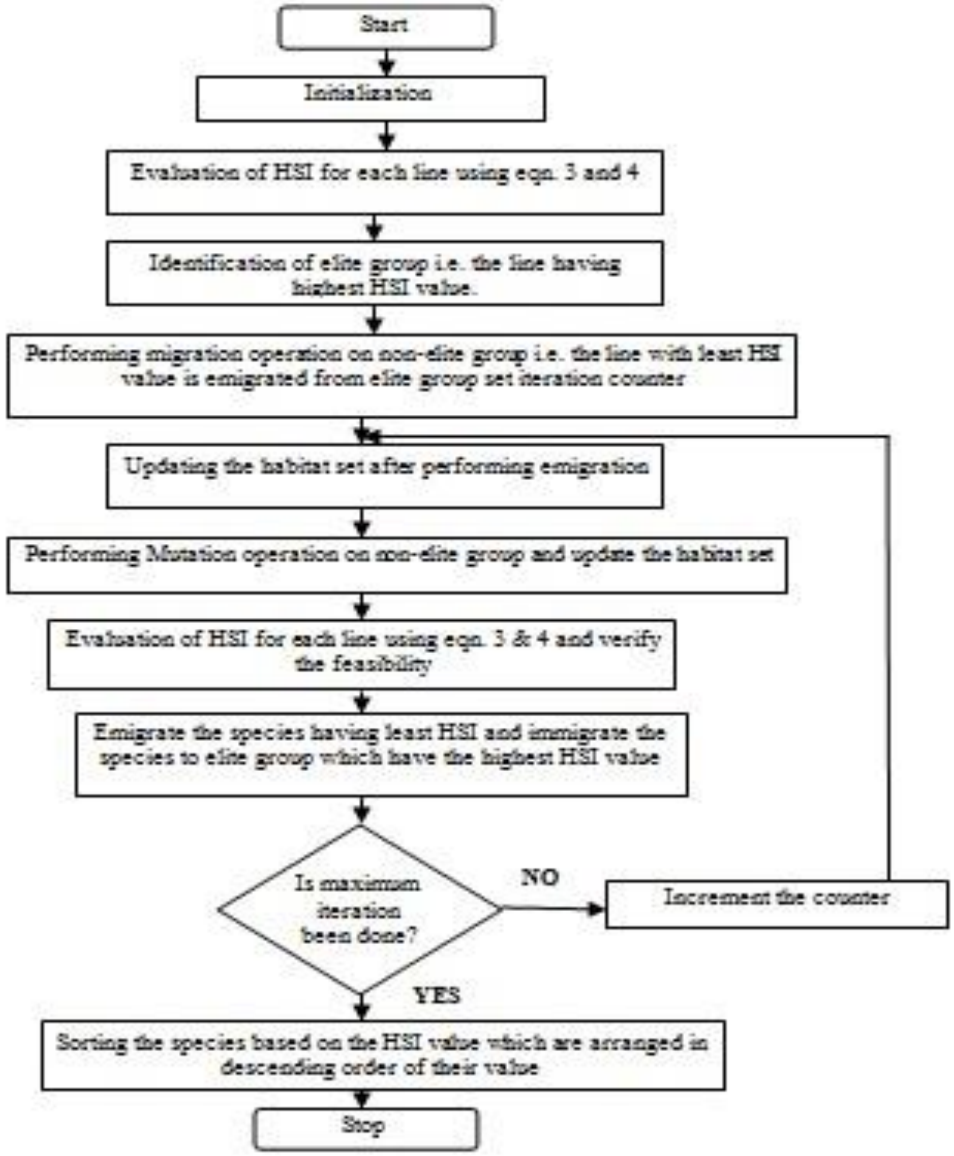

Figure 3.Flow Chart for Contingency Selection using BBO.

4. Result Analysis and Discussion

In the IEEE 30 bus system the transmission lines randomly removed in order to simulate the contingency effect. The overall effect of line contingency on the 30 bus system is assessed by Voltage Violation Index and Power Flow Index. Voltageindex based contingency ranking using FDLF Methodare listedin descending order and listed in Table 2. Power flow index based contingency ranking using FDLF classic approach listed in Table 3. The above mentioned task once again repeated for the proposed BBO algorithm to evaluate the security status of IEEE 30 bus system.Voltage index based contingency ranking using BBO is listed in Table 4. Power flow index based contingency ranking using BBO is listed in Table 5.

Table 2. V_{Index} based Contingency Ranking using FDLF.

Line No.	From bus	To bus	V_{index}	Ranking
36	28	27	177.5304	1
38	27	30	2.1227	2
4	3	4	1.2379	3
11	6	9	1.2206	4
18	12	15	1.2047	5
19	12	16	1.0835	6
7	4	6	0.875	7
30	15	23	0.8689	8
21	16	17	0.8325	9
9	6	7	0.8069	10
22	15	18	0.7661	11
34	25	26	0.7102	12
33	24	25	0.6891	13
32	23	24	0.6743	14
23	18	19	0.6421	15
37	27	29	0.6274	16
17	12	14	0.6057	17
14	9	10	0.5807	18
20	14	15	0.5719	19
41	6	28	0.5674	20
10	6	8	0.5631	21
29	21	22	0.5581	22
12	6	10	0.5444	23
39	29	30	0.5428	24
28	10	22	0.5236	25
40	8	28	0.4913	26
8	5	7	0.4838	27
31	22	24	0.4832	28
35	25	27	0.463	29
27	10	21	0.4604	30
24	19	20	0.3191	31
26	10	17	0.3087	32
25	10	20	0.2725	33
6	2	6	0.2424	34
5	2	5	0.2423	35
3	2	4	0.138	36
2	1	3	0.0852	37
13	9	11	0.0791	38
1	1	2	0	39
15	4	12	0	40
16	12	13	0	41

Table 3. P_{Index} based Contingency Ranking using FDLF

Line no	From bus	To bus	Pindex	Ranking
1	1	2	16.3035	1
5	2	5	11.0353	2
2	1	3	9.4474	3
4	3	4	9.239	4
15	4	12	6.7332	5
7	4	6	5.76	6
6	2	6	5.5902	7
10	6	8	5.1626	8
36	28	27	4.9347	9
3	2	4	4.1212	10
41	6	28	3.897	11
13	9	11	2.8611	12
25	10	20	2.8569	13
11	6	9	2.8292	14
9	6	7	2.0431	15
8	5	7	1.8937	16
18	12	15	1.8297	17
38	27	30	1.8209	18
19	12	16	1.8201	19
37	27	29	1.819	20
16	12	13	1.819	21
27	10	21	1.8185	22
22	15	18	1.8179	23
17	12	14	1.8178	24
30	15	23	1.8177	25
21	16	17	1.8163	26
39	29	30	1.8153	27
23	18	19	1.8149	28
31	22	24	1.8145	29
32	23	24	1.8144	30
28	10	22	1.8144	31
40	8	28	1.8143	32
24	19	20	1.8143	33
20	14	15	1.8136	34
29	21	22	1.8135	35
35	25	27	1.8127	36
33	24	25	1.8126	37
26	10	17	1.8121	38
12	6	10	1.8074	39
14	9	10	1.803	40
34	25	26	1.7579	41

Table 4.V_{Index} based Contingency Ranking usingBBO.

Line no	From bus	To bus	Vindex	Ranking
36	28	27	177.5304	1
38	27	30	2.1227	2
4	3	4	1.2379	3
11	6	9	1.2206	4
19	12	16	1.0835	5
7	4	6	0.875	6
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21	16	17	0.8325	8
9	6	7	0.8069	9
22	15	18	0.7661	10
33	24	25	0.6891	11
32	23	24	0.6743	12
23	18	19	0.6421	13
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40	8	28	0.4913	22
8	5	7	0.4838	23
31	22	24	0.4832	24
35	25	27	0.463	25
27	10	21	0.4604	26
24	19	20	0.3191	27
26	10	17	0.3087	28
25	10	20	0.2725	29
5	2	5	0.2423	30
3	2	4	0.138	31
2	1	3	0.0852	32
13	9	11	0.0791	33
15	4	12	0	34

Table 5. P_{Index} based Contingency Ranking usingBBO.

. Line no	From bus	To bus	Pindex	Ranking
21	16	17	11.0353	1
33	24	25	9.4474	2
10	6	8	9.239	3
37	27	29	6.7332	4
14	9	10	5.76	5
31	22	24	5.1626	6
7	4	6	4.1212	7
28	10	22	4.1212	8
8	5	7	3.897	9
25	10	20	2.8611	10
26	10	17	2.8569	11
13	9	11	2.8292	12
12	6	10	1.8937	13
19	12	16	1.8209	14
5	2	5	1.8209	15
39	29	30	1.819	16
27	10	21	1.819	17
11	6	9	1.8185	18
40	8	28	1.8163	19
41	6	28	1.8153	20
3	2	4	1.8153	21
23	18	19	1.8149	22
2	1	3	1.8149	23
15	4	12	1.8149	24
35	25	27	1.8145	25
4	3	4	1.8144	26
24	19	20	1.8144	27
38	27	30	1.8143	28
32	23	24	1.8135	29
36	28	27	1.8127	30
22	15	18	1.8126	31
29	21	22	1.8121	32
30	15	23	1.8074	33
9	6	7	1.803	34

Bio-Geography Based algorithm creates the species randomly, hence the repetition of species is inevitable. This natural phenomenon of Bio-Geography of species reflects in the proposed method also, which results in repetition of seven numbers of lines while calculating the index values. Hence, the repeated lines and their rankings has been ignored in the Table 3.

FDLF method has performed widely for contingency analysis due to its fast convergence with local optimum parameters in less numbers of iterations. The voltage index given in equation (4) reflects the cumulative impact of the contingency. It has been observed from the Table 2 that line no.36 runs between bus no 28 and 27 has produced strong impact on other bus voltages. Hence the line no 36 identified as most vulnerable line and given the rank 1 also listed in Table 2.

At the time of contingency, the powerflow definitely gets affected due to over burden of remaining lines. The powerflow index describes the cumulative impact on powerflow due to the line outage. The powerflow index values were listed in the Table 3 in descending order. The Table 3 given the 1st rank for line no.1.

The population based BBO algorithm randomly selects the species. It is equivalent to branches in IEEE 30 bus system in this paper also listed in Table 4 describes the result of BBO for voltage index. The values for Power flow index listed in Table 5 resembles the classic FDLF method.

Performance Evaluation

The efficiency and effectiveness of the proposed algorithm is measured using the formula described interms of "Capture Ratio". This is obtained by finding the ratio of number of most severe contingencies obtained using proposed method to the number of most severe contingencies captured.Using the exhaustive method given by equation 5. The capture ratio obtained by our proposed method is compared with the ratios obtained in [19]. The Result obtained from [19], DE and BBO performed on 30 bus system is tabulated in Table 6,7 and 8 respectively.

Table 6: Result obtained from [19] performed on 30 bus system

N	P	K	Capture ratio in %
5	5	2	40
	10	5	100
10	10	8	80
	15	10	100

(Include the term P in the equation
P=desired number of contingencies on trial in assessed method)

Table 7: Results obtained by DE performed on 30 bus system.

N	P	K	Capture Ratio in %
5	5	1	20
	10	1	20
10	10	3	30
	15	6	60

Table 8: Results obtained by BBO performed on 30 bus system

N	P	K	Capture Ratio in %
5	5	4	80
	10	4	80
10	10	9	90
	15	9	90

From Figure 4 itis observed that capture ratio of BBO method is higher than FDLF method and also from Table 9, it is evident that BBO takes less computation time compared to the FDLF method. For contingency analysis, it is very important that the methods should produce the results so quickly as possible.

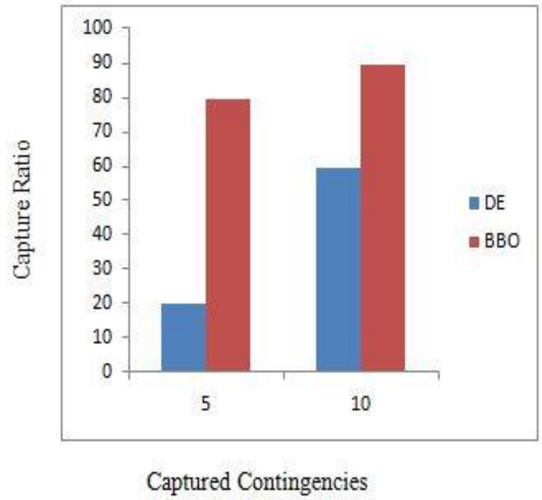

Figure 4. Capture Ratio Comparison graph

Table 9 Comparison of Computation Time

Methods	Computation Time (in seconds)
FDLF(exhaustive method)	1.61
BBO(proposed method)	0.46

6. Conclusion

The proposed technology expounds for the contingency selection based on the BBO algorithm that can be beheaded in real time for complex networks. The result obtained from the BBO showed their peculiarity. The superiority of this method is that it does not require any off line calculations. The bane of this method is: it considers only the static perspective of the security analysis, whereas there are some other factors which have to be considered for analysing the contingencies that directs to disconnections in the system. Further, the repetition of contingency ranking will be resolved through means of hybridization of proposed method with Differential Evolution. The above mentioned suggestion may be taken into consideration as future scope of the research work.The practical importance of this suggested method is to operate the system in an agile way with the defensive operation at the time of contingency, the company will be able to deliver the power to the consumer in the amount affordable way . During contingency, if the quantity of energy is not that much satisfied then it should be quantified for two parameters such as gain and losses in the electric utility.

References

1.Kalyani S ,Swarup K S . Pattern analysis and classification for security evaluation in power networks, Electrical Power and Energy Systems 2013, 44(1), pp. 547-560.

2. Wood AJ, Wollenberg BF. Power Generation, Operation and Control ,John Wiley & Sons Inc., 1996, pp. 656.

3.Stott B , Alsac O , Monticelli AJ. Security analysis and optimization, Proc. IEEE, 1987, 75(12), pp . 1623-1644.

4 Agreira C I F , Pinto J A D . The Performance Indices to Contingencies Screening, 9th International Conference on Probabilistic Methods Applied to Power Systems KTH, Stockholm, Sweden – 2006, pp. 1-8.

5. Swarup K S ,Sudhakar G . Neural network approach to contingency screening and ranking in power systems, ScienceDirect, Neurocomputing 2006, 70(1-3), pp. 105-118.

6.Albuyeh F A . Bose B. Heath, "Reactive Power considerations in Automatic Contingency Selection", IEEE Transactions on Power Apparatus and Systems,1982, 101(1), pp. 107-112.

7. Medicherla T K P , Rastogi SC . A Voltage-criterion based Contingency Selection technique,IEEE Transactions on Power Apparatus and Systems, PAS- 1982, 101(9), pp.3523-3531.

8.Devaraj D , Yegnanarayana B ,Ramar K . Radial basis function networks for fast contingency ranking, Electrical Power and Energy Systems 2002 ,24(5), pp. 387-395.

9.Norris M, Peterson P , William F , Tinney T . Donald W , BreeJ . Iterative linear AC power flow solution for fast approximate outage studies , IEEE Transactions on Power Apparatus and System,1972, 91(5),pp. 2048-2058.

10. Ozdemir A,Singh C . Voltage magnitude contingency screening by constrainedoptimization method, Springer, Electr Eng 2012 , 94(4),pp. 241–248.

11. Lee C Y , Chen N . Distribution factors of Reactive Power Flow in Transmission line and Transformer outage studies, Transactions on Power Systems, 1992, 7(1), pp. 194-200.

12.Ejebe G C , Wollenberg B F . Automatic Contingency Selection, IEEE Transactions on Power Apparatus and Systems, 1979, 98(1), pp. 97-109.

13. Simon D . Biogeography-Based Optimization, IEEE Transactions on Evolutionary Computation, 2008, 12(6), pp. 702-713.

14. Storn R , Price K . Differential Evolution – A Simple and Efficient Heuristic for Global Optimization over Continuous Spaces, Journal of Global Optimization 1997, 11(4), pp. 341–359 .

15. Bhattacharya A . Hybrid Differential Evolution with Biogeography-Based Optimization for solution of Economic Load Dispatch, IEEE Transactions on Power Systems, 2010, 25(4), pp. 1955-1964.

16.Stott B , Alsac O . Fast Decoupled Load Flow, IEEE Transactions on Power Apparatus and System, 1974,91(5), pp.859-869.

17.Santos J V C D . Inverson Faris Costa, Thiago Nogueira, New genetic algorithms for contingencies selection in the static security analysis of electric power systems, Expert Systems with Applications 2015, 42(6), pp. 2849-2856.

18.Jai J , Singh R . Biogeography-Based Optimization algorithm for load dispatch in Power System, International Journal of Emerging Technology and Advanced Engineering,2013, 3(7), pp. 1-5.

19.Mario A, Albuquerque A , Carlos A , Castro C . A Contingency ranking method for Voltage Stability in real time operation Power System, IEEE Bologna Power TechConference,2003,1 .