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Composite Power System Reliability Evaluation Based on Efficient State Search Using Binary Grasshopper Optimisation Algorithm

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***Abstract*—**Reliability is a vital aspect for the safe operation of any modern technological system. This work presents a methodology for evaluating the reliability of a composite power system with Binary Grasshopper Optimisation (BGHO) algorithm in its search mechanism to select the dominant states of the system which have large existing probability and higher load curtailment. A Grasshopper of a BGHO algorithm represents the possible system state. BGHO is used for efficient exploration of system states in the problem space by generating different potential solution to achieve optimal objective. The examined system states are used to evaluate annualized system and load point reliability indices. The proposed search methodology is applied to IEEE-RTS test system and the results are compared with state of art approaches. This proposed methodology evaluates the indices similar to the existing benchmark methods while visiting less number of system states.

***Keywords*—** Power System Reliability Evaluation; Reliability indices; Binary Grasshopper Optimisation Algorithm.

I. INTRODUCTION

Modern systems and devices operate under a number of extreme operating and environmental conditions. The resulting stress can affect the normal working life of the components and test their endurance to the limit. The consequence of failures in systems ranges from minor inconvenience to significant economic loss and loss of human life. The targets in the planning and operating of modern systems are to eliminate or reduce the failures. The objective of reliability engineering is to improve the ability of the components and the devices to sustain stresses, thereby operate them normally for longer periods of time without failure. This requires efficient mechanism for evaluating reliability indices of the existing and the planned system. Reliability evaluation of such systems when generation and transmission facilities are considered together is a complex and computationally difficult task [1].

Reliability assessment of composite power system usually comprises three main steps. They are Selection of system states, Evaluation of selected states and Computation of reliability indices and other statistics. The traditional analytical contingency enumeration and Monte Carlo simulation methods differ with regard to the processes of selecting states and evaluating reliability indices. The analytical technique selects states in the increasing order in terms of contingency levels and Monte Carlo simulation techniques select states randomly based on the concept of random numbers [2].

The computational liability is due to the difficulty of tracing the numerous number of system states. But only a small number of states in the state space can contribute the accumulation reliability indices evaluation. Soft computing optimisation algorithms can perform as a searching tool for tracing such dominant system states [3].

Genetic algorithm, Particle swarm optimization, Differential Evolution, Ant Colony optimization (ACO) and Artificial Immune systems (AIS) have been successfully applied for generating system reliability evaluation and composite system reliability evaluation by various researchers [4-9]. Recently, SeyedaliMirjalili developed a meta-heuristic optimization algorithm known as grasshopper optimization algorithm by mimicking the social behaviour of grasshoppers during their life cycle [10]. It is applied to solve complex non-linear objective optimization problems in various fields and its binary version is used for feature selection problems [11].

This methodology is based on Binary Grasshopper Optimization (BGHO) algorithm for exploring the system states that contributes load curtailment with sufficient existing probability. Section 2 formulates the objective for guiding the search process. Section 3 illustrates the over view of BGHO algorithm and its implementation for system state search of composite power system. The suitability of the proposed method is verified by applying this methodology to IEEE-RTS system which is discussed in Section 4. Finally, conclusions are presented in Section 5.

II. PROBLEM FORMULATION FOR COMPOSITE SYSTEM RELIABILITY ANALYSIS

Let ‘n’ be the total number of components, ‘ng’ represents generating units and ‘nt’ represent transmission lines. The probability of state k can be calculated as

$$\mathrm{PS_k} = \prod_{i=1}^{n} \mathrm{P_i} \qquad (2.1)$$

If Ui be the forced outage rate of component i then Pi = (1-Ui) for upstate and Pi = Ui for downstate.

In Intelligent state search approach, search is carried out to explore the dominant system states which have higher existing probability and load curtailment. For failure state, load curtailment is a non-zero value and zero for success state. Load curtailment necessary for power balance can be calculated by solving DC load flow based system state evaluation model. The state probability limit is imposed as a constraint and the objective function considered is the product of state probability and the load curtailment necessary for that state to achieve real power balance.

$$\text{Max} \qquad \mathrm{PS_k} * \mathrm{LC_k} \qquad (2.2)$$

$$\text{Subject to} \mathrm{PS_k} \geq \mathrm{PS_{thres}}$$

Where LCk is the load curtailment necessary to maintain power balance for state or chromosome k and PSthres is the threshold probability limit.

III. BINARY GRASSHOPPER OPTIMIZATION (BGHO) ALGORITHM FOR STATE SEARCH

A. Overview of BGHO

In Grasshoppers life cycle, the young nymph has transformed into adult in six weeks. They are commonly seen individually in nature but they join as one of the largest swarm group of all creatures which is found in both nymph and adulthood stages [8]. Millions of young grasshoppers jump and move like rolling cylinders. The main characteristic of the swarm in the larva phase is slow movement with small steps and during adulthood stage they form a swarm in the air and have the capability to migrate over large distances with large abrupt jumps.

Nature inspired computational algorithms reasonably divide the search procedure into two affinities: Exploration and Exploitation. In exploration, the search agents are encouraged to move sharply with large steps, while they try to move locally during exploitation. These two functions, as well as target seeking, are performed by grasshoppers naturally. The analytical model employed to mimic the swarming behaviour of grasshoppers is based on this characteristics.

Each grasshopper represents a possible solution in the problem search space. In the actual search space, however there is no target because it is not possible to know exactly where the global optimum, that is our main target. Therefore, the algorithm needs to find a target for grasshoppers in each step of the optimization. In GHO, it is assumed that the fittest grasshopper during the search is accepted as a target. The structure of BGHO algorithm is presented below

i) Initialization

Set generation counter t=0 and generate initial random population for ‘m’ grasshoppers with ‘n’ control variables by using the following relation

P0 = [x10, x20,…, xi0,…,xm0] (3.1)

The ith grasshopper with ‘n’ parameters can be given by

xi0= [xi, 10, xi, 20,…, xi, j0,…, xi, n0]
(3.2)

The parameter ‘j’ of the ith grasshopper can be randomly generated as

xi, j0 = round (rand(0,1])

ii) Fitness Evaluation

Calculate the fitness of every Grasshopper based on the objective function and set the grasshopper T as the best search agent which has best fitness value in the swarm.

iii) Position Updating

New position of each grasshopper depends on its social interaction, gravity force on it and the wind advection related to it. They are modeled as follows

Social interaction

$$\mathrm{S_i} = \sum_{j=1}^{m} \mathrm{s}\left(\mathrm{d_{ij}}\right)\hat{\mathrm{d}}_{\mathrm{ij}} \qquad (3.3)$$

Where Siis the social interaction; $\mathrm{d_{ij}}$is the distance between the ithand the jthgrasshopper, $\hat{\mathrm{d}}_{\mathrm{ij}} = \frac{\mathrm{xj-xi}}{\mathrm{d_{ij}}}$ is a unit vector from ithand the jthgrasshopper.

Gravity force:

$$\mathrm{G_i} = -\mathrm{g}\hat{\mathrm{e}}_{\mathrm{g}} \qquad (3.4)$$

Where g is the gravitational constant and $\hat{\mathrm{e}}_{\mathrm{g}}$is a unity vector towards the Centre of the Earth.

Wind advection:

$$\mathrm{A_i} = \mathrm{U}\hat{\mathrm{e}}_{\mathrm{w}} \qquad (3.5)$$

Where U is a constant drift and $\hat{\mathrm{e}}_{\mathrm{w}}$is a unity vector in the direction of wind.

Combining Equ. (3.2), (3.4) and (3.5), the step change in the position of the grasshopper in the search space is given by

$$\Delta X = C_1 \left[\sum_{\substack{j=1 \\ j \neq i}}^{m} C_2 \frac{ub-lb}{2} s(|X_j^t - X_i^t|) \frac{X_j^t - X_i^t}{d_{ij}} \right] \quad (3.6)$$

Whereub is the upper bound in the particular dimension, lb is the lower bound in the particular dimension, X_j^t and X_i^t are position of jth and ith Grasshopper respectively.

$$S(r) = f e^{\frac{-r}{l}} - e^{-r} \quad (3.7)$$

The outer adaptive coefficient C1 reduces the search area in the direction of the target grasshopper as the iteration increases.Theinneradaptivecoefficient C2hasbeenusedto reducetheeffectoftheattractionandrepulsionforcesbetweengrasshoppersproportionallytothenumberofiterations.

$$C_1 = c_{max} - l\,\frac{c_{max} - c_{min}}{L};\; C_2 = c_{max} + l\,\frac{c_{max} - c_{min}}{L} \quad (3.8)$$

The coefficient C1andC2shrinks the comfort zone proportional to the number of generations. Where cmaxis the maximum value, cminis the minimum value, l indicates the current iteration, and L is the maximum number of iterations. It may be fixed as 1 and 0.00001 for cmaxandcminrespectively. The sigmoidal transfer function for the position change vector of a grasshopper vector at tth iteration is

$$T(\Delta X_t) = \frac{1}{1 + e^{-\Delta X_t}} \quad (3.9)$$

(3.9)

Position of the grasshopper in t+1 iteration for kth dimension is given by

$$X_{t+1}^k = \begin{cases} 1 & \text{if } r < T(\Delta X_{t+1}^k) \\ 0 & \text{if } r \geq T(\Delta X_{t+1}^k) \end{cases} \quad (3.10)$$

Where r is the random number in the range of 0 to 1.

iv) Termination

The iterative procedure can be terminated when any one of the following stopping criteria is met, a satisfactory solution has been reached or a state with no further progress in solution has been reached or a predefined number of iterations have been completed. The position of the best grasshopper is converged as best possible optimal solution for the given objective.

B. *Implementation of BGHO for State Search*

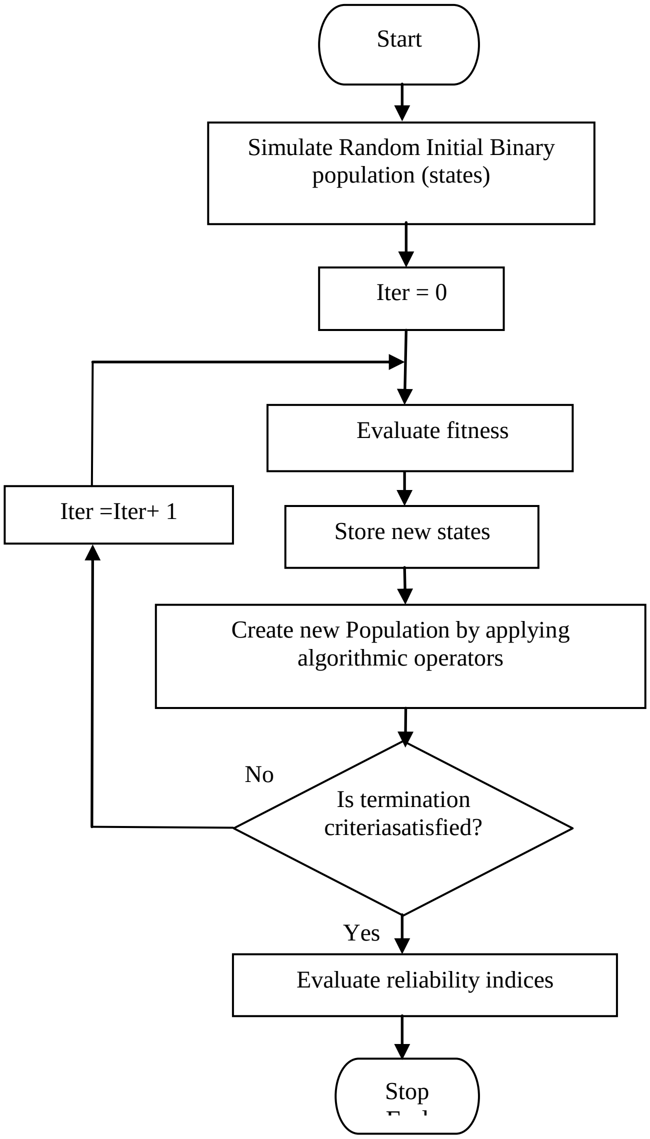

Figure1: State Search Mechanism

The algorithmic steps involved in the BGHO search mechanism for composite system reliability evaluation are summarized as follows.

1. Initialize the BGHO parameters i.e. population of grasshoppers NP, dimension of each grasshopper D, maximum number of iterations Itermax, Cmin, Cmax and set threshold state probability PSthres.

2. Initialize all the grasshoppers randomly using Equs. (3.1) & (3.2) and set iteration count Iter = 0.

3. For grasshopper ‘k’ compute the state probability PSk using Equ. (2.1). If $PS_k < PS_{thres}$ proceed to next grasshopper, otherwise go to next step.

4. Compute the equivalent decimal number and check the existence in the state array. If the state exists, then set the fitness of that chromosome to a very small value and proceed to next chromosome. Evaluate the fitness value based on Equ.

(2.2) and store the equivalent decimal number, PS and LC in the state array. Repeat steps 3 and 4 for all grasshoppers and proceed to next step.

5. Compute change in position of each grasshopper ΔX and its transfer function T(ΔX) based on Equs. (3.8) & (3.9)

6. Update the position of grasshoppers based on Equ. (3.10).

7. If any of the termination criteria are satisfied then stop the algorithm and go to step-8 for evaluating the reliability indices, otherwise update iteration count and go to step 3.

8. Annualized system and load point indices are calculated using the data stored in the system state array. The state array has both failure states and success states. Let the total number of failure states stored be ‘fs’. The system indices such as loss of load probability (LOLP), loss of load exception (LOLE), expected demand not supplied (EDNS) and expected energy not supplied (EENS) are evaluated as follows. $LOLP = \sum_{k=1}^{fs} PS_{\text{k}}$

$$LOLE = LOLP * 8736$$

$$EDNS = \sum_{k=1}^{fs} PS_{\text{k}} * LC_k$$

$$EENS = EDNS * 8736$$

IV. BGHO ALGORITHM APPLIED TO IEEE-RTS SYSTEM

IEEE–RTS system consisting of 24 buses, 38 transmission lines and 32 generators with 10 of the buses are connected to generators. The total peak load for the system is 2250 MW while the total generating capacity is 3405 MW. Only peak load levels were used for the purpose of this study [12-13].

The termination criteria adopted in this approach are either maximum number of generations algorithm completed or number of new states stored in the state array or relative change in the loss of load probability index stays below a small specified threshold value for a consecutive number of generations of algorithm.

BGHO parameters used in the simulation are population size = 80, Cmax=1, Cmin=0.00001. and maximum generation = 750. The threshold state probability is fixed as 10-12. The algorithm stopped after, either maximum number of generations reached or relative change in LOLP index after 75 consecutive generations is less than the value of 0.005.

Table 1: Load Point Indices

Bus No.	LOLP	LOLE hr/yr	EDNS MW	EENS MWhr/yr
1	0.0021	18.3456	0.08321	726.9226
2	0.0069	60.2784	0.249092	2176.068
3	0.0053	46.3008	0.287542	2511.967
4	0.0061	53.2896	0.179016	1563.884
5	0.0049	42.8064	0.200978	1755.744
6	0.0081	70.7616	0.419382	3663.721
7	0.0058	50.6688	0.239607	2093.207
8	0.0096	83.8656	0.573286	5008.226
9	0.0001	0.8736	0.019663	171.776
10	0.0001	0.8736	0.01792	156.5491
13	0.0219	191.3184	2.150148	18783.69
14	0.0001	0.8736	0.00063	5.50368
15	0.0119	103.9584	0.819314	7157.527
16	0.0150	131.04	0.526539	4599.845
18	0.0521	455.1456	6.915624	60414.89
19	0.0137	119.6832	0.698651	6103.415
20	0.0078	68.1408	0.291089	2542.954

The total number of system states in the state array is 43,291 from which 34,587 are failure states. The annualized load point indices evaluated are presented in Table 1. The system indices evaluated with annualized load pattern are presented in Table 2.

Indices evaluated based on BGHO is compared with analytical state enumeration method considering generation contingencies up to 5th level & transmission line contingencies up to 3rd level, state sampling Monte Carlo simulation (MCS), GA and Binary differential evolution approaches. In state sampling MCS the number of states sampled increases rapidly with the estimate accuracy. It is found that the proposed BGHO approach evaluates the indices similar to other benchmark methods and also converges nearer to analytical method.

Table 2: Annualized System Indices

Approach	LOLP	LOLE hr/yr	EDNS MW	EENSMW hr/yr	Number of states analyzed
BGHO	0.08103	707.8780	13.6901	119596.72	43,291
Analytical[14]	0.08142	711.2851	13.7600	120208.11	2228647850
MCS[15]	0.08580	749.5488	14.9724	130799.00	10000
BDE [9]	0.08043	702.6365	13.6758	119471.81	43726
GA[9]	0.08029	701.4134	13.4539	117533.27	51271

V. CONCLUSION AND FUTURE SCOPE

This methodology proposed a state search technique in conjunction with Binary Grasshopper Optimisation algorithm. The state searching mechanism is developed based on evaluating the adequacy of the available power generation and the power transferring capabilities of transmission lines to meet the system load and the existing probability of the explored system state. The effectiveness of the proposed BGHO method was demonstrated on IEEE RTS. The state search technique has resulted in reducing the computation burden significantly by effectively exploring dominant failure states. Also, the reliability indices evaluated by the BGHO method correspond closely with those indices obtained based on benchmark Analytical method, state sampling Monte Carlo simulation method and other state-of-the-art heuristic search methods, while requiring lower computational burden.

REFERENCES

[1] Pereira MVF, Pinto LMVG, Cunha SHF, Oliveira GC, Monte Carlo based Composite Reliability Evaluation – Modeling Aspect and Computational Results. IEEE tutorial course on Reliability assessment of composite generation and transmission systems. IEEE special publication, 1989.

[2] Pereira MVF, Balu NJ, Composite generation/transmission reliability evaluation. Proceedings of the IEEE 80:470, 1992.

[3] Chanan singh, Linghfeng Wang (2008) Role of artificial intelligence in the reliability evaluation of electric power systems. Turkish Journal of Electrical Engineering & Computer Sciences 16(3):189, 2008.

[4] Samaan N, Singh C, Adequacy assessment of power system generation Using a modified simple genetic algorithm. IEEE Transactions on Power Systems 17:974, 2002.

[5] Mohammed Benidris, Salem Elsaiah and Joydeep Mitra, Power System Reliability Evaluation using a State Space Classification Technique and Particle Swarm Optimisation Search Method, IET Generation, Transmission and Distribution, Vol 9, No 14, pp 1865–1873, Nov 2015.

[6] Green, R. C., Wang, L., Alam, M., Singh, C.: 'An Examination of Ar- tificial Immune System Optimization in Intelligent State Space Pruning for LOLP Estimation'. Proc. North American Power Symposium, pp. 1-7, 2011.

[7] Green, R. C., Wang, L., Wang, Z., Alam, M., Singh, C.: 'Power System Reliability Assessment Using Intelligent State Space Pruning Techniques: A Comparative Study'. Proc. IEEE International Conference on Power System Technology, pp. 1–8, 2010.

[8] Miranda V, de Magalhaes Carvalho L, da Rosa MA, da Silva AML, Singh C, Improving Power System Reliability Calculation Efficiency With EPSO Variants. IEEE Transactions on Power Systems 24:1772 , 2009.

[9] R.Ashok Bakkiyaraj and N.Kumarappan, Differential Evolution Based Intelligent System State Search Method for Composite Power System Reliability Evaluation, Journal of the Institution of Engineers (India): Series B, Springer, Vol. 96, pp.237–244, 2015.

[10] Shahrzad Saremi, Seyedali Mirjalili, Andrew Lewis, ''Grasshopper Optimisation Algorithm: Theory and application,'' Advances in Engineering Software, pp. 30–47, 2017.

[11] Majdi Mafarja et.al, Binary grasshopper optimisation algorithm approaches for feature selection problems, Expert Systems With Applications, Vol. 117, pp. 267–286, 2019.

[12] Billinton R, Kumar S, Chowdhury N, Chu K, Debnath K, Goel L, et al, A reliability test system for educational purposes-basic data. IEEE Transactions on Power Systems 14: 1238, 1989.

[13] IEEE Committee Report, IEEE Reliability Test System. IEEE transactions on Power apparatus and systems 98:2047, 1979.

[14] Billinton R, Wenyuan L, Hybrid approach for reliability evaluation of composite generation and transmission systems using Monte-Carlo simulation and enumeration technique. IEE proceedings-C on Generation, Transmission and Distribution 138: 233, 1991.

[15] Jonnavithula A, Composite System reliability evaluation using sequential Monte Carlo simulation. Ph.D. Thesis. University of Saskatchewan. Canada,1997.