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Simulation Modelling on Risk Based Optimal Power Flow Using Bio Inspired Algorithm

Dr.T.Govindaraj[1], S.Dinesh[2]

[1]Professor and head of the department, EEE, Muthayammal Engineering College, Rasipuram, Tamilnadu, India[1]

[2]M.E.PSE Scholar, Department of EEE, Muthayammal Engineering College, Rasipuram, Tamilnadu, India[2]

Abstract: Optimization of power system operation is vital for ensuring economics and security. This works considers optimization of fuel cost for achieving economics with security as a constraint. The real power outputs from generators are the control variables in optimal power flow (OPF). Conventional OPF minimizes only the fuel cost. Adequate security with regard to line flow violation is not guaranteed. This works takes into account the line flow as a constraint. Security is improved by adjusting the line power flows. The OPF-SC is a nonlinear programming optimization problem with complex discontinuous solution space. Cuckoo search algorithm is a recently developed algorithm known for its simplicity yet good searching capability. The control parameters are the real power generation, generator bus voltage, transformer tap position and SVC settings. The proposed methodology is to be tested on the standard IEEE-30 bus system.

Index terms: cuckoo search, risk based optimal power flow,IEEE-30 Bus,Fuel cost,SVC,OPF-SC.

1. INTRODUCTION

Power system operation is essentially a decision making process that meets the power demand in an economic way while maintaining system security. so in power industry they often adopts a criterion called N-1 security criterion which the system as a whole sustain failure of an single element such as generator, transformer(or)transmission line thus ensures the security of power system after the occurrence of any single contingency. These problems faced by the power industry pays a simple way to develop an optimization problem called security constrained optimal power flow(SCOPF) which is derived from the old technique called optimal power flow (OPF).The above mentioned optimal power flow(OPF)which is an power flow technique used to optimize the entire system . The optimal power flow which operates by having some constraints for example cost minimization, security as a constrained. This optimal power flow is a constrained optimal power flow. In the security constrained optimal power flow(SCOPF)which can only adopts two way called the deterministic way –either the system is secure (or) insecure[1]. At the same time it cannot quantify that the risk in the power system network. Being taken the risk into account with the security of power system a newly developed operation called risk based security constrained optimal power flow (RB-SCOPF) has been established for the power system reliable operation. The objective of this work is to minimize the cost and maximize the security of a power system. This proposed system is simulated with IEEE 30 bus system. The rest of the paper is organized as follows section II describes the formulation of SCOPF, RBSCOPF.Section III describes the proposed cuckoo search algorithm. Section IV describes simulation results. Section V describes the conclusion[1]-[20].

2.PROBLEM FORMULATION

2.1 Security Constrained Optimal Power flow

The formulation of optimal power flow with an security as a constraints are called security constrained optimal power flow. In addition to this, they mainly deals with the contingency conditions of the entire power system before and after the disturbance called pre-contingency and post-contingency states. These contingency states considering the “N-1” security [1] criterion called Security Constrained Optimal Power Flow (SCOPF).

2.2 Risk Based Optimal Power Flow

The Risk Based Optimal Power Flow (RBOPF) is one type of optimal power flow which is mainly deals with the optimal power flow by taking the risk as a constraints. The power system which is a large components network operating together. If the cost of the system is just considered, the optimal power flow which only minimizes the fuel cost of the total power system (or) by any of the objective like power loss minimization,var planning etc.,they just do only that part of the system, but in this if we see the overall security of the system is not ensured.If the total power system wants to work properly to supply the consumers they have to be under a great security. Then only they can supply for the consumers. To ensure the whole system security here we consider the risk of the system. By considering the risk vales the security of the system is ensured by the Risk Based Optimal Power Flow (RBOPF).

2.3 Objective function of the proposed system

A.Objective Function

The goal of the proposed work is to optimize the control parameters to minimize the cost and maximize the security.

$$f = \min\left(w_1 F_i(P_{G\,i}) + w_2 Risk(E_j)\right) \quad (1)$$

Where,

$$F_i(P_{G\,i}) = a_{i\,k} + b_{i\,k}P_{G\,i} + c_{i\,k}P_G^2 \quad (2)$$

Where, , a_i, b_i, c_i, e_i and f_i are the cost coefficients of generating unit and P_{Gi} is the real power generation of i^{th} unit. U (i,k) is equal ‘1’ if k^{th} fuel is used in i^{th} generator otherwise it is equal to ‘0’.

Subject to the following constraints:

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Overload contingency

The severity function for overload is defined for each line or transformer, as a percentage of rating.

B.Discrete Severity Function

Severity is set to '0' when the power flow is below 100% of nominal value and set to '1' for and above 100% of the nominal value.

C. *Discrete Severity function for overload*

The severity problem is defined as

$$Sev(V_i) = \begin{cases} 0, & PR < 100\% \\ 1, & PR \geq 100\% \end{cases} \quad (3)$$

D.Probability

It is the likeliness that a contingency can create a violation. In RBSA, the probability of a contingency that can cause security violation is termed as event likelihood. The simplest way of obtaining probability for a contingency is based on the system operator's experiences. Any event has a probability of occurrence, which can be in the range 0 to 1. A zero probability means that the event will not occur; a probability of 1 means that it will occur. A more reliable way is using modern probabilistic and statistic techniques to derive the contingency probability distribution through collection and analysis of historic data. This probability data is available as a standard data. A widely used expression for contingency probability based on Poisson distribution is given below,

$$Pr(E_j) = 1 - e^{-\lambda_j} \quad (4)$$

Where E_j is Contingency j and λ_j is the failure rate per unit time.Failure rate is the frequency with which an element fails. It is often denoted by the Greek letter λ (lambda). The failure rate of a system usually depends on time, with the rate varying over the life cycle of the system.

E.Risk index

Risk index is defined as the degree of risk level, the power system attains at an operating condition, when exposed to contingencies. Risk index is expressed as the product of event likelihood and severity of a contingency.

$$Risk(E_j) = Pr(E_j) * Sev(E_j) \quad (5)$$

For instance, the low voltage risk at bus 'i' can be calculated as

$$Risk(V_i, E_j) = Pr(E_j) * Sev(V_i, E_j) \quad (6)$$

The risk of a system during a contingency is equal to the sum of individual contingency risk, as expressed below,

$$Risk(E_j) = \sum_{j=1}^{N} Risk(E_j) = \sum_{j=1}^{N} Pr(E_j) * Sev(E_j) \quad (7)$$

Equality Constraints

$$P_{gi} - P_{di} - \sum_{j=1}^{N} |V_i||V_j||Y_{ji}| \cos(\delta_i - \delta_j - \theta_{ij}) = 0 \quad (8)$$

$$Q_{gi} - Q_{di} - \sum_{j=1}^{N} |V_i||V_j||Y_{ji}| \sin(\delta_i - \delta_j - \theta_{ij}) = 0 \quad (9)$$

$$\sum P_{gi} - P_D - P_L = 0 \quad (10)$$

Where P_D is the demand power and P_L is the total transmission network losses.

Inequality Constraints

Branch power flow limit:

$$|S_{Di}^{min}| \leq |S_i| \leq |S_{Di}^{max}| \quad i = 1, \dots nd \quad (11)$$

Generator MVAR outputs:

$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{min} \quad i = 1, \dots ng \quad (12)$$

Real power generation output:

$$P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max} \quad i = 1, \dots ng \quad (13)$$

Transformers tap setting:

$$t_k^{min} \leq t_k \leq t_k^{max} \quad (14)$$

3. BIO-INSPIRED ALGORITHMS

The definition of bio inspired algorithms is simple and they are defined as they are the category of algorithms that imitate the way nature performs. They are quite popular because of their unique characteristics called simple and by the reducing the rigorous mathematical approaches. The algorithm used here is the cuckoo search algorithm which is an recently developed bio-inspired algorithm follows an behavior of the cuckoo bird.

A.Cuckoo Search

For simplicity in describing our new Cuckoo Search, we now use the following three idealized rules[15]:

1) Each cuckoo lays one egg at a time, and dumps its egg in randomly chosen nest
2) The best nests with high quality of eggs will carry over to the next generations
3) The number of available host nests is fixed, and the egg laid by a cuckoo is discovered by the host bird with a probability $p_a \in [0, 1]$. In this case, the host bird can either throw the egg away or abandon the nest, and build a completely new nest.

For simplicity, this last assumption can be approximated by the fraction p_a of the NP nests are replaced by new nests (with new random solutions).For a maximization problem, the quality or fitness of a solution can simply be proportional to the value of the objective function. Other forms of fitness can be defined in a similar way to the fitness function in genetic algorithms. For simplicity, we can use the following simple representations that each egg in a nest represents a solution, and a cuckoo egg represent a new solution, the aim is to use the new and potentially better solutions (cuckoos) to replace a not-so-good solution in the nests. Of course, this algorithm can be extended to the more complicated case where each nest has multiple eggs representing a set of solutions. For this present work, we will use the simplest approach where each nest has only a single egg.

When generating new solutions $\boldsymbol{x}^{(t+1)}$ for, say, a cuckoo *i*, a L´evy flight is performed

$$x_i^{t+1} = x_i^{t+1} + \alpha \oplus L' \quad (15)$$

where α > 0 is the step size which should be related to the scales of the problem of interests. In most cases, we can use α = 1. The above equation is essentially the stochastic equation for random walk. In general, a random walk is a Markov chain whose next status/location only depends on the current location (the first term in the above equation) and the transition probability (the second term). The product ⊕ means entry wise multiplications. This entry wise product is similar to those used in PSO, but here the random walk via L´evy flight is more efficient in exploring the search space as its step length is much longer in the long run. The L´evy flight essentially provides a random walk while the random step length is drawn from a L´evy distribution

$$L\acute{e}vy \sim u = t^{-\lambda}, \quad (1 < \lambda \leq 3) \qquad (16)$$

which has an infinite variance with an infinite mean. Here the steps essentially form a random walk process with a power law step-length distribution with a heavy tail. Some of the new solutions should be generated by L´evy walk around the best solution obtained so far, this will speed up the local search. However, a substantial fraction of the new solutions should be generated by far field randomization and whose locations should be far enough from the current best solution, this will make sure the system will not be trapped in a local optimum.

B.L´evy Flights

L'evy flight is the mechanism which is followed by some of the natural creatures to go on searching their food by a separate flight mechanism. This mechanism which actually a flight taken by the creature that it first go straight and suddenly it takes 90° turn and this straight drive and a sudden turn is called L flight. They obey the principal of power law. This is a random walk which comes under the section of probability and this was first found by the paul levy a French mathematician he found that leavy flight is a random walk having a step length which follows a probability distribution which is heavy tailed.this levy flight is having many applications in various fields of earth quake analysis, food searching mechanism of animals and behavior of human beings etc.,.

C.Algorithm

The algorithm of cuckoo search is given as follows,
Step 1 : Initialize the population(host nest ,n).
Step 2 : Get a cuckoo randomly by levy flight.
Step 3 : Evaluate its fitness F_i .
Step 4 : Choose a nest among 'n' nests(j) randomly(F_j).
Step5 : Check whether the F_i is greater than Fj if yes go to next step, if not go to step 7.
Step6 : Assume j as the best solution.
Step7 : Replace j by the next solution (i.e)check for the next nest among' n'.
Step8 : Destroy a fraction of worst nest and built new ones at new location via levy flights.
Step9 : keep the best solution (best nest).
Step10: check for the maxiteration ,if yes find the current best(best nest)and if not go to step1.

C.Flow Chart

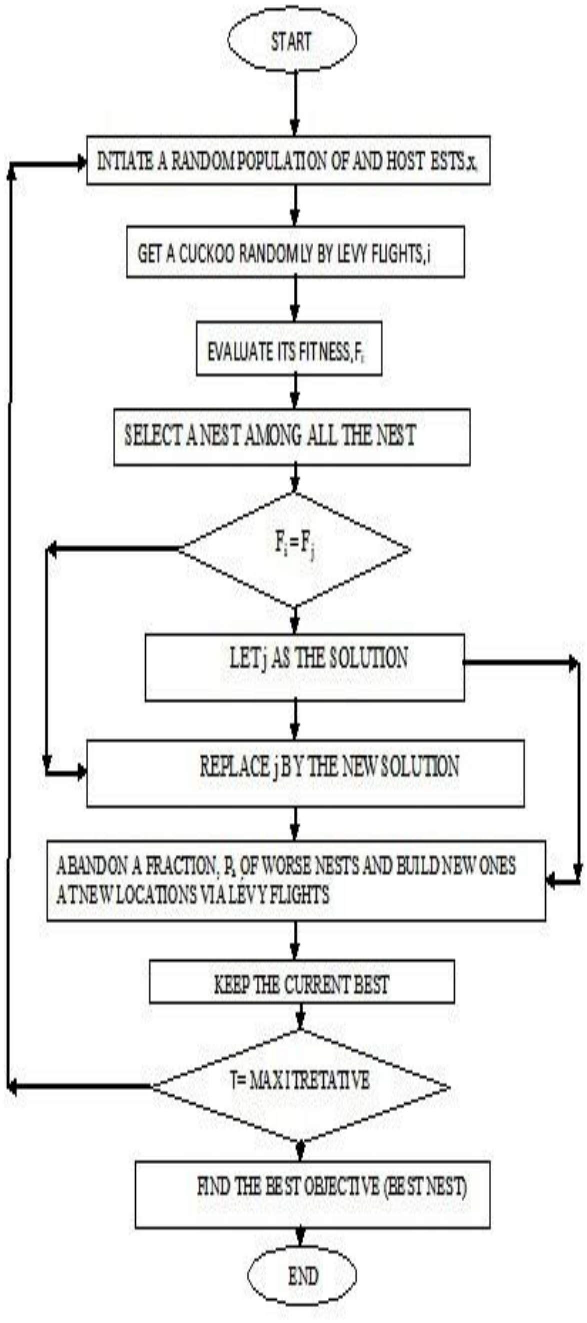

Fig.1 Flow Chart of cuckoo search algorithm

4. SIMULATION RESULT

In this section the numerical results on the IEEE 30 bus system is proposed by using the cuckoo search algorithm. The results are obtained by using MATLAB R2010a and 2.40 GHz Intel Core i3 CPU and 4 Gb RAM PC.

A.Risk Based Optimal Power Flow

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```
OBJ =

  814.5520


RISK =

    2.4629


COST =

  826.9835


SIZE =

  Columns 1 through 16

   50.4594   22.0205   16.4091   16.4521   10.8997    1.0823    1.0312    0.9894
1.0281    1.0064    1.0286    1.0121    1.0417    1.0071    1.1102    8.2628

  Column 17

    6.5035


LOC =

     2     5     8    11    13     1     2     5     8    11    13    11    12    15
36    10    24
```

Fig.2 Matlab output of RBOPF

In the result the OBJ which describes the best object of the system which is the best cuckoo, the best cuckoo gives the best solution of the system which is the cost and corresponding risk of the system. The size specifies the cuckoo in total population and this location(LOC)gives the nest location of that particular cuckoo corresponding to the size. The cost shows the optimal cost value of the system and the risk shows that the risk value for the optimized cost.

B.Convergence curve

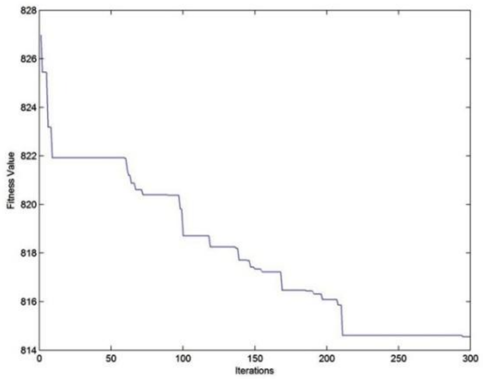

Fig.3 Fitness and iterations curve

5. CONCLUSION

In this work, the recently developed bio-inspired algorithm called cuckoo search algorithm is used to solve the risk based optimal power flow problem in the large power systems network. In this work the optimal power flow is formulated with the security (risk) as a constraint. In this the minimization of fuel cost is achieved with the corresponding risk value and it tells that even though the cost is minimized there is some risk for the power system. This formulation of the problem was successfully performed to find the best cost, best risk, and best location of the control parameters of the test system. The simulation result shows the robustness of the cuckoo search algorithm in solving the risk based optimal power flow problem.

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BIOGRAPHY

Dr.Govindaraj Thangavel born in Tiruppur , India , in 1964. He received the B.E. degree from Coimbatore Institute of Technology, M.E. degree from PSG College of Technology and Ph.D. from Jadavpur University, Kolkatta, India in 1987, 1993 and 2010 respectively. His Biography is included in Who's Who in Science and Engineering 2011-2012 (11th Edition). Scientific Award of Excellence 2011 from American Biographical Institute (ABI). Outstanding Scientist of The 21st century by International Biographical centre of Cambridge, England 2011.

Since July 2009 he has been Professor and Head of the Department of Electrical and Electronics Engineering, Muthayammal Engineering College affiliated to Anna University, Chennai, India. His Current research interests includes Permanent magnet machines, Axial flux Linear oscillating Motor, Advanced Embedded power electronics controllers,finite element analysis of special electrical machines,Power system Engineering and Intelligent controllers.He is a Fellow of Institution of Engineers India(FIE) and Chartered Engineer (India).Senior Member of International Association of Computer Science and Information. Technology (IACSIT). Member of International Association of Engineers(IAENG), Life Member of Indian Society for Technical Education(MISTE). Ph.D. Recognized Research Supervisor for Anna University and Satyabama University Chennai. Editorial Board Member for journals like International Journal of Computer and Electrical Engineering,International Journal of Engineering and Technology,International Journal of Engineering and Advanced Technology (IJEAT).International Journal Peer Reviewer for Taylor &Francis International Journal "Electrical Power Components & System"United Kingdom,Journal of Electrical and Electronics Engineering Research,Journal of Engineering and Technology Research (JETR),International Journal of the Physical Sciences,Association for the Advancement of Modelling and Simulation Techniques in Enterprises,International Journal of Engineering & Computer Science (IJECS),Scientific Research and Essays,Journal of Engineering and Computer Innovation,E3 Journal of Energy Oil and Gas Research,World Academy of Science, Engineering and Technology,Journal of Electrical and Control Engineering (JECE),Applied Computational Electromagnetics Society etc.. He has published 132 research papers in International/National Conferences and Journals. Organized 40 National / International Conferences/Seminars/Workshops. Received Best paper award for ICEESPEEE 09 conference paper. Coordinator for AICTE Sponsored SDP on special Drives,2011.Coordinator for AICTE Sponsored National Seminar on Computational Intelligence Techniques in Green Energy, 2011.Chief Coordinator and Investigator for AICTE sponsored MODROBS - Modernization of Electrical Machines Laboratory. Coordinator for AICTE Sponsored International Seminar on "Power Quality Issues in Renewable Energy Sources and Hybrid Generating System", July 2013.

S.Dinesh born in Mettur, India,1991.He received the B.E degree from SKR Engineering College,Chennai,2012. Now he is pursuing M.E PSE degree in Muthayammal Engineering College,Rasipuram,India.His area of intrest in power system operation,restructure power system.