Unconstraint Optimal Power Flow using Improved Cuckoo Search Algorithm

S Solaimani*, P Arul*
Department of Electrical and Electronics Engineering, Jayaram College of Engineering & Technology, Trichy, India

Article Info
Article history:
Received 02 April 2017
Received in revised form
20 May 2017
Accepted 28 May 2017
Available online 15 June 2017

Keywords: Optimal Power Flow, Optimization techniques, cuckoo search, Fuel Cost, Power system.

Abstract
This paper presents an efficient and reliable a swarm-Intelligence based algorithm and bio-Inspired algorithm approach to unconstraint obtain optimal power flow (OPF) problem solution. This approach employs a nature inspired meta-heuristics optimization algorithm such as improved cuckoo search algorithm to determine the optimal setting of control variable. The performance of the improved cuckoo search algorithm (ICS) is examined and tested on IEEE 30 bus test system with objective function is minimization of fuel cost. The solution is done using MATLAB software.

1. Introduction

An optimal power flow (OPF) has become one of the most important problems and it is the fundamental tool that enables electric utilities to specify economic operating and secure states in power system. The main objective of the OPF problem is to optimize a chosen objective function such as fuel cost, voltage profile improvement, voltage stability enhancement, through optimal adjustment of power system control variable while at the same time satisfying system operation condition with power flow equation and inequality constraints [1-4]. The control variable involves the tap ratio transformer, the generator real power, the generator bus voltage and reactive power of source. In the general the OPF problem is a large scale, highly constraints, nonlinear and non-convex optimization problem [6-7], it has taken decades to develop efficient algorithm for its solution.

The recently developed swarm-Intelligence based algorithm and bio-inspired algorithm such as cuckoo search (CS) developed by yang and deb (2009) [16]. As most real-world problem is nonlinear and multimodality may imply that it may not be possible to find the true global optimality with 100% certainty for a problem. The ICS is potentially far more efficient than particle swarm optimization (PSO) and genetic algorithm (GA). To imitate natural phenomena, most Meta heuristic algorithm combines rule and randomness. These phenomena include the biological evolutionary processes, such as genetic algorithm, evolutionary algorithm, differential algorithm, animal behavior, such as particle swarm optimization and cuckoo search algorithm.

The new improved cuckoo search algorithm based on behavior of cuckoo bird in breading and Levy bird based random population. A nature inspired meta-heuristics optimization algorithm such as improved cuckoo search algorithm to determine the optimal setting control variable. The main objective is the minimization of fuel cost function, which is derived from setting control variable. The main objective is the minimization of fuel cost function, which is derived from incremental cost curve, is the objective function and also called as the total generation cost. This proposed system is simulated with IEEE 30 bus system. The rest of the paper is organized as follow section II describes the mathematical formation of optimal power flow. Section III describes the bio-inspired algorithm with includes cuckoo breeding manner and lévy flights and improved cuckoo search. Section IV describes the improved cuckoo search algorithm. Section V describes the results and discussions. Section VI describes conclusion.

***Corresponding Author,**
E-mail address: solai.mani53@gmail.com; eee_hod@jayaramcet.edu.in

2. Mathematical formulation of optimal power flow

The general form of optimal power flow problem can be mathematically represented as,

Minimize F (x,u) (1)

Subject to:

$$g(x,u)=0 \quad (2)$$

$$h_{min} < h(x,u) < h_{max} \quad (3)$$

Where,

F(x,u) is the objective function
g(x,u) represent equality constraints.
h (x,u) represent inequality constraints.

The conventional formulation of the optimal power flow (OPF) problem determines the optimal setting of control variables such as the real power generators, generator terminal voltage, transformer tap setting and phase-shifter angles. The objective function F(x,u) as given as,

$$\text{Min } N = \sum_{j=1}^{N} Fj\,(P_j) \quad (4)$$

Equality constraints

Hear g is the equality constraints represent typical power flow equations:

$$P_k^G - P_k^L - = \sum_{i=1}^{N} V_k V_i [G_{ki}\cos(\theta_k - \theta_i) + B_{ki}\sin(\theta_k - \theta_i)] \quad (5)$$

$$Q_k^G - Q_k^L - = \sum_{i=1}^{N} V_k V_i [G_{ki}\cos(\theta_k - \theta_i) - B_{ki}\sin(\theta_k - \theta_i)] \quad (6)$$

k=1, 2… N

Where,

N is the number of buses.
P_k^G is the active power generated.
Q_k^G is the reactive power generated.
P_k^L is the load active power.
Q_k^L is the load reactive power.

G_{ki} and are B_{ki} the transfer conductance and susceptance between bus k and bus i respectively.

Inequality constraints

Here h is the inequality constraints represented as,

Voltage constraints:

$$V_j^{min} \le V_j \le V_j^{max} \qquad j\epsilon N_b \qquad (7)$$

Generator constraints: real power output and reactive power output.

$$P_{gj}^{min} \le P_{gj} \le P_{gj}^{max} \qquad j\epsilon N_g \qquad (8)$$

$$Q_{gj}^{min} \le Q_{gj} \le Q_{gj}^{max} \qquad j\epsilon N_g \qquad (9)$$

Transformer taps setting constraints:

$$U_j^{min} \le U_j \le U_j^{max} \qquad j\epsilon N_t \qquad (10)$$

The power flow equations are used as equality constraints and the inequality constraints are the limit on active and reactive power generation, power shifting transformer setting, bus bar voltage magnitudes and apparent power flow in branches [1-7].

2.1 Bio-inspired algorithms

The definition of bio inspired in 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 characteristic called simple and by the reducing the rigorous mathematical approaches. The algorithm used here is improved cuckoo search algorithm.

3. Improved Cuckoo Search Algorithm

3.1 Cuckoo breeding manner

Cuckoo is fascinating birds, not only because of the beautiful sounds they can make, but also because of their aggressive reproduction strategy. Some species such as the *ani and guira* cuckoos lay their eggs in communal nests, though they may remove others' eggs to increase the hatching probability of their own eggs. A number of species engage the brood parasitism by laying their eggs in the nest of other host birds. There are three basic types of brood parasitism: intra- specific brood parasitism, co-operative breeding, and nest take-over. Some host birds can engage direct conflict with the intruding cuckoos [16]. If a host bird discovers the eggs are not their own, they will either throw these alien eggs away or simply abandon its nest and build a new nest elsewhere. Some cuckoo species such as the New World brood-parasitic *Tapera* have evolved in such a way that female parasitic cuckoos are often very specialized in the mimicry in color a pattern of the eggs of a few chosen host species. This reduces the probability of their reproductively.

3.2 Lévy Flights

A Levy Flight can be thought of as a random walk where the step size has a Levy tailed probability distribution. The name Levy Flight came after the French mathematician Paul Pierre levy .The term Levy Flight was coined by Benoit Mandelbrot who used specific definition of the distribution of the step sizes. Eventually Levy Flight term has been using to refer discrete grid rather than continuous space. It is a Markov Process. Exponential property of Levy Flight gives it a scale invariant property and they are used to model data for exhibiting/ showing clusters. In nature many animals and insects follow the properties of Levy Flight. Recent studies of Reynolds and Frye demonstrate that fruit flies or drosophila melanogaster covers the skies by using numerous series of straight flight paths/ routes followed by a sudden right angle turn which is a Levy-flight-style intermittent scale free search pattern [7]. Hunter-gatherer forage pattern exhibit the typical feathers of Levy Flight, observed by Ju/'bonsai on human behavior. Studies also show that light rays follow Levy Flights in optical material. Ultimately, it is being used in optimization search and significant results are emerging.

3.4 Improved Cuckoo search

Fig.1: Pseudo code of Improved Cuckoo search via Lévy flights.

```
begin
Objective   function is f(x), x=(x1,…..,xd)^T
Generate an initial population of
        n host nests xi(i=1,2,….,n)
While (t<MaxGeneration) or (stop the criterion)
        Get a cuckoo randomly by a Lévy flights
            evaluate its quality/fitness Fi
        Choose the nest among n (say,  j) a  randomly
        if   (Fi > Fj),
             replace j by a  new solution;
        end
        A fraction (pa) of the worse nests
             Are abandoned and a new ones are built;
        keep a best solution
              (or nests with quality solutions);
        Rank a solution and find a current best
end while
        post process  the  results and the visualization
end
```

In order to model the improved cuckoo search algorithm, the following three idealized rules are developed:

- Each cuckoo lays just one egg at a time, and dumps it in a randomly chosen nest.
- The best nest with high quality of eggs (solutions) will carry over to the next generation.
- The number of available host nests is constant, and each cuckoo egg can be discovered by the host bird with the probability of $p_a \epsilon [0, 1]$.

As a further approximation, this last assumption can be approximated by a fraction p_a of the n host nests which 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 manner to the fitness function in genetic algorithms [17].

Based on these three rules, the basic steps of the Improved Cuckoo Search (ICS) can be summarized as the pseudo code shown in figure. 1.

When generating new solution $x^{(1+t)}$ for, a cuckoo i, a lévf flight is performer

$$x_i^{(1+t)} = x_i^{(t)} + \alpha\, s \otimes H(P_a - \varepsilon) \otimes (x_j^t - x_k^t) \qquad (11)$$

Where,

x_j^t and x_k^t are two different solution selected randomly by random permutation .

H(u) is a Heaviside function, ε is a random number drawn from a uniform distribution.

s is the step size.

On the other hand, the global random walk is carried out by using Lévy flights

$$x_i^{(1+t)} = x_i^{(t)} + \alpha L(s,\lambda) \quad (12)$$

Where

$$L(s,\lambda) = \frac{\lambda\gamma\sin(\pi\lambda/2)}{\pi}\frac{1}{s^{1+\lambda}}, \quad (s \gg s_0 > 0) \quad (13)$$

Here $\alpha > 0$ is the set – size –scaling factor, which should be related to the scales of the problem of interests. In most case, we can use $\alpha = O(L/10)$, where L is the characteristic scale of the problem of interest which in some case $\alpha = O(L/100)$ can be more effective and avoid flying too far. Equation (13) is essentially to stochastic equation for a random walk [18]. In general, a random walk is a Markov chain whose next status/location only depends on the current location (the first term in Eq. (13)) and the transition probability (the second term)[16-19].

3.5 IMPROVED Cuckoo Search Algorithm for OPF

Step 1: Read the system data which consists of objective function in fuel cost coefficients, minimum and maximum power limit of all generating units, bus bar voltage magnitude.
Step 2: Initialize the parameters and constants of cuckoo algorithm. They are n, p_a, and beta.
Step 3: Generate n number of nests randomly between λ_{min} and λmax.
Step 4: Set the maximum number of iteration.
Step 5: Calculate the fitness values corresponding to n number of cuckoos.
Step 6: Obtain the best fitness value nest by comparing all the fitness values and also obtain the best nests corresponding to the best fitness value new nest.
Step 7: Find the new nest by using step size between the λ_{min} and λ_{max} limit.
Step 8: Find the fitness value, if Fi > Fj value then sends the nest values to newnest. Next update bestnest by comparing fitness value.
Step 9: New solution by Random walk
In this if random value > P_a then find the stepsize 1 between any two nests. Then find newnest 1 must be within the limits. Again update the bestnest by comparing fitness value. If this condition violates then go to step 5 and repeat this procedure.
Step 10: Finally bestnest given the optimal solution of an optimal power flow problem and the results are printed.

4. Results and Discussions

In this s study a numerical result on the IEEE 30 bus system consists of 6 thermal units, 24 load bus and 41 transmission lines [20] is proposed by using the improved cuckoo search algorithm. The results are obtained by using MATLAB R2009b and 2040GHz Intel core i3 CPU and 4 GP RAM PC.

4. Results and Discussions

In this s study a numerical result on the IEEE 30 bus system consists of 6 thermal units, 24 load bus and 41 transmission lines [20] is proposed by using the improved cuckoo search algorithm. The results are obtained by using MATLAB R2009b and 2040GHz Intel core i3 CPU and 4 GP RAM PC.
The improved cuckoo search algorithm is 500 iteration. In these results is fitness value and iteration for improved cuckoo search algorithm show in Figure.3 the convergence curve is minimizes the cost function.

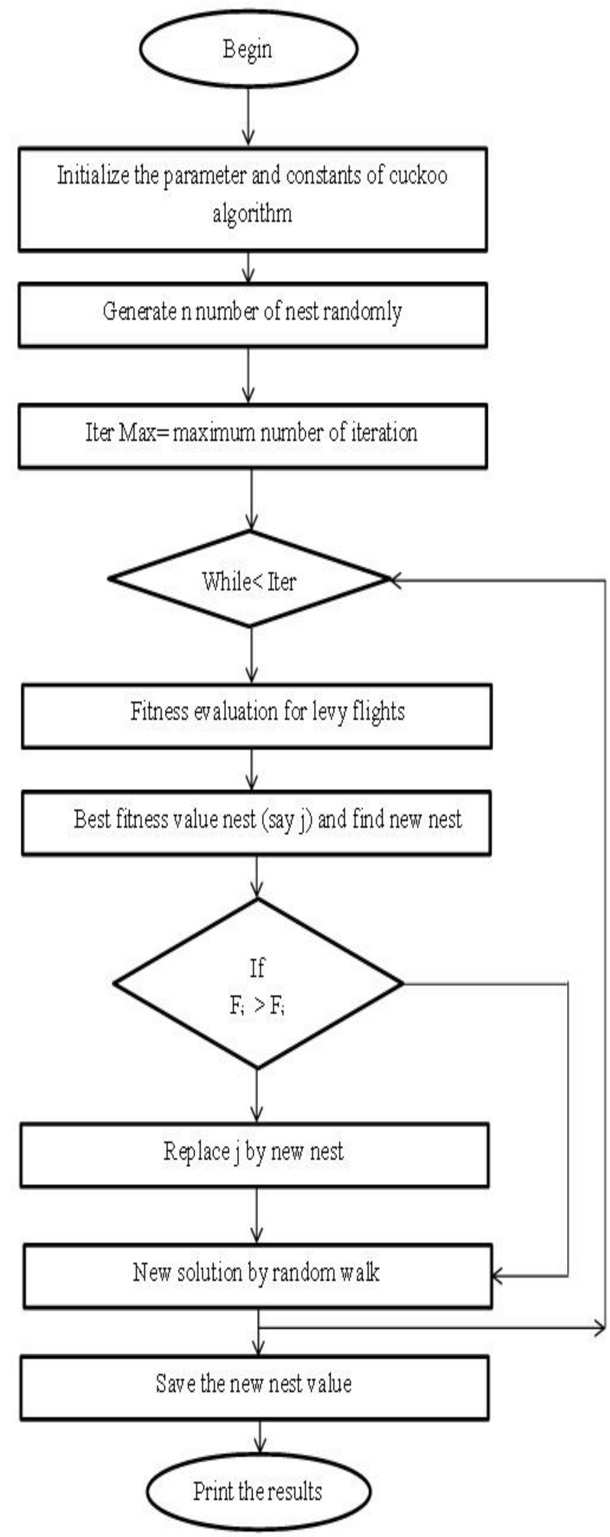

Fig. 2: Flow chat of ICS Algorithm.

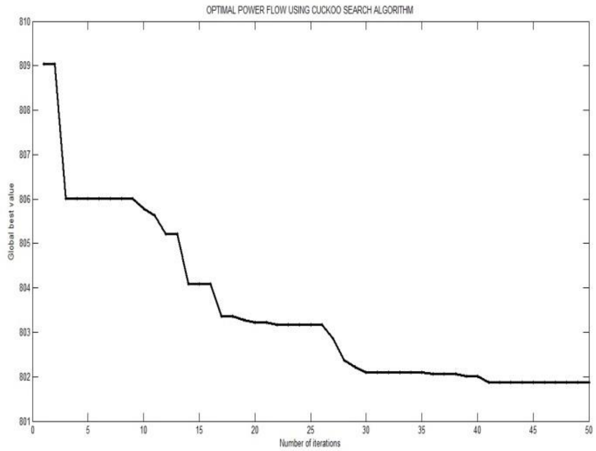

Fig. 3: Iteration vs. Fitness value

Table 1: Result ICS Compared with GA and PSO,CS Methods for the IEEE 30 bus Electrical network

	GA	PSO	CS	ICS
Fuel cost [$/hr.]	803.056	802.013	801.849	801.849
Total loss[MW]	9.579	9.379	9.339	9.339
Convergence time [s]	680.2	14.63	40.406	14.63

From table 1 comparing results Genetic algorithm (GA), and Particles Swarm Optimization (PSO), cuckoo search (CS) with Improved cuckoo search algorithm.ICS given better convergence of other algorithm with minimum loss. Even though PSO algorithm given the faster convergence and ICS 100% success rate. The best cost function is Improved cuckoo search algorithm initial cost (at 1st iteration) is 810.220 $/hr. and it falls to (at 500 iteration) is 801.849 $/hr.

5.Conclusions

In this paper, Improved Cuckoo Search Algorithm for Unconstraint Optimal Power Flow problem of power system is the minimization of fuel cost is considered as objective function. This approach was successfully and influentially performed to find the optimal setting of the test system. The simulation results proved the robustness and superiority of ICS approach to solve the OPF problem. The effectiveness of this algorithm is demonstrated on IEEE 30 bus system using MATLAB platform.

References

[1] HW Dommel, WFTinney. Optimal power flow solution, IEEE Transaction on power system, PAS-8, 1968, 1866-1876.

[2] RC Burchett, HH Happ, KA Wirgau. Large-scal optimal power flow, IEEE trans. Power Apparat, Syst., PAS-101, 1982, 3722-3732.

[3] A Santos, GRMda Costa. Optimal-power-flow solution by Newton's method appiled to an augmented Lagrangian function. IEEE proc-gener. Transm, Distrib, 142(1), 1995.

[4] MA Abiodo. Optimal power flow using partical swarm optimization, Electr power Engergy syst,.24, 2002, 563-71.

[5] P Yumbla JM Ramirez, C Coello. Optimal power flow subject to security constraints solved with a particlee swarm optimizer, IEEE Trans. Power Syst., 23(1), 2008, 33-40.

[6] Anastasios G Bakirtzis, Pandel N Biskas, Christoforos E Zoumas, Vasilios Petridis. Optimal power flow by Enhanced Genetic Algorithm. IEEE transactions on power systems, 17(2), 2002.

[7] A Abou El Ela, MA Abido, SR Spea. Optimal power flow using differential evolution algorithm, 2009.

[8] DP Cristian, R Teslovan, C Barbulescus, S Kilyeni, A Simo. PSO Based OPF Algorithm, IEEE EuroCon 2013. 1-4 July 2013. Zagrb, Croatia.

[9] J Yuryevich, KP Wong. Evolutionary Programming Based Optimal Power Flow Algorithm, IEEE Transactions on power systems, 14(4), 1999.

[10] M.R. AlRashidi, ME EI-Hawary. Hybrid Particles Swarm Optimization Approach for Solving thr Discrete OPF Problem Considering the Value Loding Effects, IEEE Transactions on Power Systems, 22(4), 2007.

[11] AVN Babu, S Sivanagaraju. A solution to the optimal power flow problem: A new approach based on two steps initialization, Proc. of IEEE India International Conference (INDICONO) on Engineering Sustainable Solutions, BITS, Hyderabad, India, Dec.2011.

[12] S Das, A Abraham, A Konark. Particles swarmoptimization and differential evolution algorithmss: technicall analysis, applications and hybridization perpectives, Appl Soft Comput J 7 (3), 2008,1019-1026.

[13] Y Li, JDM Calley. Risk-based Optimal Power Flow and System Operation State, IEEE 978-1-4244-4241-6/09, 2009.

[14] CA Roa-Sepul veda, BJP-Lazo. A solution to the optimal power flow using simulated annealing, IEEE Porto Power Teach Conference, 10-13th September, Porto, Portugal.

[15] AS Sankar, KS.Anjaneyulu. Maintaining Voltage Stability by Optimal Locating and Sizing by Combined Evolutionary Algorithm, International Journal of Computer Applications (0975-8887) 84(12) 2013.

[16] XS Yang, SDeb. Cuckoo search via Levy flights, proc.of World Conress on Nature & Biologically Inspiredmcomputing,NaBIC,IEEEPublications,USA, 2009, 210-214.

[17] XS Yang, SDeb. Engineering Optimisation by cuckoo search, Int. J Mathematical Modelling and Numerical Optimisation, 1(4), 2010, 330-343.

[18] Yang XS. Nature-Inspired Metaheurisitic Algorithms. Luniver press; 2008

[19] DN Schegner, Ongsakul. Cuckoo search algorithm for non-convex economic dispatch, IET Gener. Transm. Distrib., 7 (6), 2013, 645-654.

IEEE 30-bus system data avabile at http:// www.ee. Washington.edu/research/psta.