Indonesian Journal of Electrical Engineering and Informatics (IJEEI)
Vol. 3, No. 4, December 2015, pp. 191~198
DOI: 10.11591/ijeei.v3i4.173

Decline of Real Power Loss and Preservation of Voltage Stability by using Chirping Algorithm

K. Lenin[1], B. Ravindhranath Reddy[2], M. Surya Kalavathi[3]
[1] Research Scholar, JNTU, Hyderabad 500 085 India
[2] Deputy Executive Engineer, JNTU, Hyderabad 500 085 India
[3] Professor of Electrical and Electronics Engineering, JNTU, Hyderabad 500 085, India
email: gklenin@gmail.com

Abstract

In this paper, a newChirping Algorithm (CA) is developed based on the chirping behaviour of crickets for solving the reactive power optimization problem. It is based on the chirping behaviour of crickets (insect) found almost everywhere around the world. CA algorithm is utilized to enhance the search with good exploration and exploitation, because almost every algorithm has difficulty in reaching the optimal solution. The proposed Chirping Algorithm (CA) has been tested in standard IEEE 30, 57,118 bus test systems and simulation results show clearly the better performance of the proposed algorithm in reducing the real power loss and control variables are well within the limits.

Keywords: *optimal reactive power, transmission loss, chirping algorithm*

1. Introduction

The main objective of optimal reactive power dispatch (ORPD) problem is to minimize both the real power loss and bus voltage deviation. Various numerical methods like the gradient method [1]-[2], Newton method [3] and linear programming [4]-[7] have been adopted to solve the optimal reactive power dispatch problem. Both the gradient and Newton methods have the complexity in managing inequality constraints. The problem of voltage stability and collapse play a vital role in power system planning and operation [8]. Evolutionary algorithms such as genetic algorithm have been already proposed to solve the reactive power flow problem [9]-[11]. In [12],[13], Hybrid differential evolution algorithm and Biogeography Based algorithm is projected to solve the reactive power dispatch problem. In [14],[15], an improved fuzzy based method and evolutionary programming is used to solve the optimal reactive power dispatch problem. In [16],[17], the optimal reactive power flow problem is solved by integrating a genetic algorithm with a nonlinear interior point method and pattern algorithm is used to solve ac-dc optimal reactive power flow model with the generator capability limits. In [18],[19] a two-step approach and a programming based approach is used to solve the optimal reactive power dispatch problem. In [20] a probabilistic algorithm is utilized for optimal reactive power provision in hybrid electricity markets with uncertain loads. We propose new CA algorithm to enhance the search with good exploration and exploitation, because almost every algorithm suffer in some mode in reaching the optimal solution. Cricket is an insect which emit a peculiar sound that is commonly known as chirping. Though the male crickets usually chirp, some female crickets do as well [21]-[23].Generally cricket chirps for two main things, first one when they want to mate then they emit a calling chirp and it is fairly loud and it will attracts female crickets. And second one, they chirp as violent behaviour which is called as aggressive chirp. This violent chirp is a very loud trill and is formed to fight with other male crickets. The proposed CA algorithm has been evaluated in standard IEEE 30, 57,118 bus test systems. The simulation results show that our proposed methodology outperforms all the entitled reported algorithms in minimization of real power loss.

2. Objective Function

2.1. Active power loss

The objective of the reactive power dispatch is to minimize the active power loss in the transmission network, which can be described as follows:

Received June 6, 2015; Revised October 5, 2015; Accepted October 18, 2015

$$F = PL = \sum_{k\in Nbr} g_k \left(V_i^2 + V_j^2 - 2V_iV_j cos\theta_{ij}\right) \quad (1)$$

or

$$F = PL = \sum_{i\in Ng} P_{gi} - P_d = P_{gslack} + \sum_{i\neq slack}^{Ng} P_{gi} - P_d \quad (2)$$

Where g_k is the conductance of branch between nodes i and j, Nbr is the total number of transmission lines in power systems. P_d is the total active power demand, P_{gi} is the generator active power of unit i, and P_{gsalck} is the generator active power of slack bus.

2.2. Voltage profile improvement

For minimizing the voltage deviation in PQ buses, the objective function becomes:

$$F = PL + \omega_v \times VD \quad (3)$$

Where ω_v: is a weighting factor of voltage deviation.
VD is the voltage deviation given by:

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \quad (4)$$

2.3. Equality Constraint

The equality constraint of the ORPD problem is represented by the power balance equation, where the total power generation must cover the total power demand and the power losses:

$$P_G = P_D + P_L \quad (5)$$

This equation is solved by running Newton Raphson load flow method, by calculating the active power of slack bus to determine active power loss.

2.4. Inequality Constraints

The inequality constraints reflect the limits on components in the power system as well as the limits created to ensure system security. Upper and lower bounds on the active power of slack bus, and reactive power of generators:

$$P_{gslack}^{min} \le P_{gslack} \le P_{gslack}^{max} \quad (6)$$

$$Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max}, i \in N_g \quad (7)$$

Upper and lower bounds on the bus voltage magnitudes:

$$V_i^{min} \le V_i \le V_i^{max}, i \in N \quad (8)$$

Upper and lower bounds on the transformers tap ratios:

$$T_i^{min} \le T_i \le T_i^{max}, i \in N_T \quad (9)$$

Upper and lower bounds on the compensators reactive powers:

$$Q_c^{min} \le Q_c \le Q_C^{max}, i \in N_C \quad (10)$$

Where N is the total number of buses, N_T is the total number of Transformers; $N_c$is the total number of shunt reactive compensators.

3. Proposed Chirping Algorithm

Based on the chirping characteristics of crickets and their movement in space for mating and aggression the Chirping Algorithm (CA) is formulated to solve the reactive power problem. Each cricket is presumed to be a solution in the exploration space and is categorized by its position in the exploration space. Out of the total cricket population, few of them are arbitrarilynominated as female populations. Crickets are presumed to be in two conditions. At first when the male cricket chirps for mating, the female crickets are seduced and other male crickets move away. The male and female crickets will mate and produce offspring. They move to a new-fangled place, which means they are taken to improvedpositions in the exploration space. The fascination is based on the loudness of the chirping sound .From the chirping rate the frequency and velocity of the sound is calculated. Secondly, when the cricket chirps for antagonism other male crickets are enticed and female crickets will move away. All crickets may not be chirping for antagonism. The algorithm assumes that the probability of a cricket, chirping for antagonism is p which is between 0 and 1. When a cricket chirps for antagonism, it is assumed that they arbitrarily walk to another male cricket and fight. The persuasive cricket takes the place of the solution and eliminates the loser cricket.

3.1. Calculation of chirping rate

Amos Emerson Dolbear, an American physicist and naturalist, calculated the relationship between air temperature and the rate at which crickets chirp.

The temperature (T_f) in degrees Fahrenheit from the number of chirps per minute (N_c) is calculated as,

$$T_f = 50 + \frac{N_c - 40}{4} \tag{11}$$

And its reformulated to give the temperature in degrees Celsius (T_c), is given by,

$$T_c = 10 + \frac{N_c - 40}{7} \tag{12}$$

The chirping rate can be calculated in a certain temperature T_c or T_f is given by ,

$$N_c = (T_c - 10) * 7 + 40 \tag{13}$$

Or

$$N_c = \left(T_f - 50\right) * 4 + 40 \tag{14}$$

And the frequency F and velocity V of the cricket's chirping is calculated based on the chirping rate N_c,

$$F_c = N_c * \gamma \tag{15}$$

$$V = F * \lambda \tag{16}$$

Where,γ is anarbitrary value and $\lambda \in [0,1]$is the wavelength.

The step size of each cricket is calculated as:

$$distance = \frac{V}{F} \tag{17}$$

$$Step = \beta * distance * (position - Better\ position\ ) \tag{18}$$

Where β =0.01 is a constant value and position is the current position and Better position is the best position ever encountered by the cricket.

Then the cricket will move to the new position by using the following formula:

$$New\ position = position + step\ size\ * \gamma \tag{19}$$

The equations (11)-(19) are used when the crickets chirp for mating and they change their step size according to the chirping rate, frequency, velocity and distance at a certain temperature. For easiness, it is presumed that when the crickets chirp for antagonism they move to new position using arbitrary walk.

Procedure for - mating_chirp ( )

```
    Begin for every cricket,
1. Compute the Chirping rate $N_c$of each cricket based on the temperature using equation (13) or (14)
2. Compute the new frequency F and velocity V of each cricket using equation (15) and (16);
3. Compute the step size using equation (17),(18)
4. Transfer each cricket to the new position using equation (19)
5. Return crickets in new position
End
```

Procedure for - mating ( )

```
1. For every Male crickets $m_A$ in their new position, arbitrarily choose a female cricket $f_E$
2. Arbitrarily choose a cut point in both $m_A$ and $f_E$ .
3. Interchangethe genetic materials of both $m_A$ and $f_E$ with reference to their cut points to create two new offspring. This is Similar to crossover in Genetic algorithm.
4. Compute the fitness of the offspring.
5. Return the best of the two offspring and the parents as the new cricket position.
End
```

Procedure for - aggr_chirp ( )

```
1. If rand>P then arbitrarily walk to the new position
2. Compute the fitness of the cricket in the new position.
3. Pick the best cricket
4. Return the best cricket position)
End
```

CA algorithm for solving optimal reactive power problem

```
1. Set the cricket's position
2. Arbitrarily choose k crickets as female crickets
3. Compute the fitness of each cricket
4. Pick the best cricket $f_{best\_cricket}$with their position
5. Fix$g_{best\_ cricket}$ as the existing$f_{best\_cricket}$ andin the initial generation $g_{best\_ cricket}$-$f_{best\_cricket}$
6. While (stoppingcriteria is not met)
Then
    a. Chirp for mating - Procedure mating_chirp ( )
    b. Allow male crickets to mate with female crickets - Procedure mating ( )
    c. Chirp for antagonism with probability P - Procedure aggr_chirp ( )
    d. Calculate the fitness
    e. Pick$f_{best\_cricket}$, from the new-fangled positions.
    f. If $f_{best\_cricket}>g_{best\_ cricket}$, then modernize$g_{best\_cricket}$with the existing$f_{best\_cricket}$.
7. End while
8. Return the global best cricket at termination.
End
```

4. Results and Discussion

At first CA algorithm has been verified in IEEE 30-bus, 41 branch system. It has 6 generator-bus voltage magnitudes, 4 transformer-tap settings, and 2 bus shunt reactive compensators. Bus 1 is slack bus and 2, 5, 8, 11 and 13 are taken as PV generator buses and the rest are PQ load buses. Control variables limits are listed in Table 1.

Table 1. Preliminary Variable Limits (PU)

Variables	Min. Value	Max. Value	Type
Generator Bus	0.92	1.12	Continuous
Load Bus	0.94	1.04	Continuous
Transformer-Tap	0.94	1.04	Discrete
Shunt Reactive Compensator	-0.11	0.30	Discrete

The power limits generators buses are represented in Table 2. Generators buses (PV) 2,5,8,11,13 and slack bus is 1.

Table 2. Generators Power Limits

Bus	Pg	Pgmin	Pgmax	Qgmin
1	98.00	51	202	-21
2	81.00	22	81	-21
5	53.00	16	53	-16
8	21.00	11	34	-16
11	21.00	11	29	-11
13	21.00	13	41	-16

Table 3. Values of Control Variables after Optimization

Control Variables	CA
V1	1.0647
V2	1.0462
V5	1.0278
V8	1.0279
V11	1.0782
V13	1.0589
T4,12	0.00
T6,9	0.01
T6,10	0.90
T28,27	0.91
Q10	0.12
Q24	0.12
Real power loss	4.2987
Voltage deviation	0.9082

Table 3 shows the proposed approach succeeds in keeping the control variables within limits. Table 4 summarizes the results of the optimal solution obtained by various methods.

Table 4. Comparison Results

Methods	Real power loss (MW)
SGA (24)	4.98
PSO (25)	4.9262
LP (26)	5.988
EP (26)	4.963
CGA (26)	4.980
AGA (26)	4.926
CLPSO (26)	4.7208
HSA (27)	4.7624
BB-BC (28)	4.690
CA	4.2987

Secondly the proposed hybrid CA algorithm is tested in standard IEEE-57 bus power system. The reactive power compensation buses are 18, 25 and 53. Bus 2, 3, 6, 8, 9 and 12 are PV buses and bus 1 is selected as slack-bus. The system variable limits are given in Table 5.

The preliminary conditions for the IEEE-57 bus power system are given as follows:

P_{load}= 12.422p.u. Q_{load} = 3.339p.u.

The total initial generations and power losses are obtained as follows:

$\sum P_G$ = 12.7729p.u. $\sum Q_G$ = 3.4559p.u.

P_{loss}= 0.27450p.u. Q_{loss} = -1.2249p.u.

Table 6 shows the various system control variables i.e. generator bus voltages, shunt capacitances and transformer tap settings obtained after CA based optimization which are within the acceptable limits. In Table 7, shows the comparison of optimum results obtained from proposed CA with other optimization techniques. These results indicate the robustness of proposed CA approach for providing better optimal solution in case of IEEE-57 bus system.

Table 5. Variable limits

Reactive Power Generation Limits

Bus no	1	2	3	6	8	9	12
Qgmin	-1.4	-.015	-.02	-0.04	-1.3	-0.03	-0.4
Qgmax	1	0.3	0.4	0.21	1	0.04	1.50

Voltage And Tap Setting Limits

vgmin	vgmax	vpqmin	vpqmax	tkmin	tkmax
0.5	1.0	0.91	1.01	0.5	1.0

Shunt Capacitor Limits

Bus no	18	25	53
Qcmin	0	0	0
Qcmax	10	5.2	6.1

Table 6. Control variables obtained after optimization

Control Variables	CA
V1	1.1
V2	1.069
V3	1.057
V6	1.032
V8	1.034
V9	1.028
V12	1.032
Qc18	0.0798
Qc25	0.248
Qc53	0.0589
T4-18	1.010
T21-20	1.078
T24-25	0.978
T24-26	0.949
T7-29	1.083
T34-32	0.957
T11-41	1.010
T15-45	1.059
T14-46	0.917
T10-51	1.030
T13-49	1.059
T11-43	0.917
T40-56	0.903
T39-57	0.957
T9-55	0.967

Table 7. Comparison results

S.No.	Optimization Algorithm	Finest Solution	Poorest Solution	Normal Solution
1	NLP [29]	0.25902	0.30854	0.27858
2	CGA [29]	0.25244	0.27507	0.26293
3	AGA [29]	0.24564	0.26671	0.25127
4	PSO-w [29]	0.24270	0.26152	0.24725
5	PSO-cf [29]	0.24280	0.26032	0.24698
6	CLPSO [29]	0.24515	0.24780	0.24673
7	SPSO-07 [29]	0.24430	0.25457	0.24752
8	L-DE [29]	0.27812	0.41909	0.33177
9	L-SACP-DE [29]	0.27915	0.36978	0.31032
10	L-SaDE [29]	0.24267	0.24391	0.24311
11	SOA [29]	0.24265	0.24280	0.24270
12	LM [30]	0.2484	0.2922	0.2641
13	MBEP1 [30]	0.2474	0.2848	0.2643
14	MBEP2 [30]	0.2482	0.283	0.2592
15	BES100 [30]	0.2438	0.263	0.2541
16	BES200 [30]	0.3417	0.2486	0.2443
17	Proposed CA	0.22298	0.23102	0.23115

Then CA has been tested in standard IEEE 118-bus test system [24] .The system has 54 generator buses, 64 load buses, 186 branches and 9 of them are with the tap setting transformers. The limits of voltage on generator buses are 0.95,-1.1 per-unit., and on load buses are 0.95,-1.05 per-unit. The limit of transformer rate is 0.9,-1.1, with the changes step of 0.025. The limitations of reactive power source are listed in Table 8, with the change in step of 0.01.

Table 8. Limitation of reactive power sources

BUS	5	34	37	44	45	46	48
QCMAX	0	14	0	10	10	10	15
QCMIN	-40	0	-25	0	0	0	0
BUS	74	79	82	83	105	107	110
QCMAX	12	20	20	10	20	6	6
QCMIN	0	0	0	0	0	0	0

In this case, the number of population is increased to 120 to explore the larger solution space. The total number of generation times is set to 200. The statistical comparison results of 50 trial runs have been list in Table 9 and the results clearly show the better performance of proposed algorithm.

Table 9. Comparison results

Active power loss (p.u)	BBO [32]	ILSBBO/ strategy1 [32]	ILSBBO/ strategy1 [32]	Proposed CA
min	128.77	126.98	124.78	120.06
max	132.64	137.34	132.39	129.05
Average	130.21	130.37	129.22	122.89

5. Conclusion

Chirping Algorithm has been successfully applied for Optimal Reactive Power dispatch problem.Chirping Algorithm based optimal reactive power problem has been tested in standard IEEE30, 57,118 bus systems. Performance comparisons with standard population-based algorithms have given inspiring results. Real power loss has been significantlyabridged and control variables are well within the limits.Chirping Algorithmarisesefficaciously to find good solutions when compared to that of other algorithms. The simulation results presented in preceding section prove the capability ofChirping Algorithm method to reach at near global optimal solution.

References

[1] O. Alsac, B. Scott. Optimal load flow with steady state security. *IEEE Transaction*. 1973; PAS: 745-751.

[2] Lee KY, Paru YM, Oritz JL. A united approach to optimal real and reactive power dispatch. *IEEE Transactions on power Apparatus and systems*. 1985; PAS-104: 1147-1153.

[3] A. Monticelli, MVF. Pereira, S. Granville. Security constrained optimal power flow with post contingency corrective rescheduling. *IEEE Transactions on Power Systems*. 1987; PWRS-2(1): 175-182.

[4] Deeb N, Shahidehpur SM. Linear reactive power optimization in a large power network using the decomposition approach. *IEEE Transactions on power system*. 1990; 5(2): 428-435.

[5] E. Hobson. Network consrained reactive power control using linear programming. *IEEE Transactions on power systems*. 1980; PAS -99(4): 868-877.

[6] KY. Lee, YM. Park, JL. Oritz. Fuel –cost optimization for both real and reactive power dispatches. *IEE Proc.* 131C(3): 85-93.

[7] MK. Mangoli, KY. Lee. Optimal real and reactive power control using linear programming. *Electr. Power Syst. Res*. 1993; 26: 1-10.

[8] CA. Canizares, ACZ. de Souza, VH. Quintana. *Comparison of performance indices for detection of proximity to voltage collapse.* 1996; 11(3): 1441-1450.

[9] SR. Paranjothi, K. Anburaja. Optimal power flow using refined genetic algorithm. *Electr. Power Compon. Syst*. 2002; 30: 1055-1063.

[10] D. Devaraj, B. Yeganarayana. *Genetic algorithm based optimal power flow for security enhancement*. IEE proc-Generation.Transmission and. Distribution. 6 November 2005: 152.

[11] A. Berizzi, C. Bovo, M. Merlo, M. Delfanti. A ga approach to compare orpf objective functions including secondary voltage regulation. *Electric Power Systems Research*. 2012; 84(1): 187 – 194.

[12] CF. Yang, GG. Lai, CH. Lee, CT. Su, GW. Chang. Optimal setting of reactive compensation devices with an improved voltage stability index for voltage stability enhancement. *International Journal of Electrical Power and Energy Systems*. 2012; 37(1): 50 – 57.

[13] P. Roy, S. Ghoshal, S. Thakur. Optimal var control for improvements in voltage profiles and for real power loss minimization using biogeography based optimization. *International Journal of Electrical Power and Energy Systems.* 2012; 43(1): 830 – 838.

[14] B. Venkatesh, G. Sadasivam, M. Khan. A new optimal reactive power scheduling method for loss minimization and voltage stability margin maximization using successive multi-objective fuzzy lp technique. *IEEE Transactions on Power Systems*. 2000; 15(2): 844–851.

[15] W. Yan, S. Lu, D. Yu. A novel optimal reactive power dispatch method based on an improved hybrid evolutionary programming technique. *IEEE Transactions on Power Systems.* 2004; 19(2): 913–918.

[16] W. Yan, F. Liu, C. Chung, K. Wong. A hybrid genetic algorithminterior point method for optimal reactive power flow. *IEEE Transactions on Power Systems*. 2006; 21(3): 1163–1169.

[17] J. Yu, W. Yan, W. Li, C. Chung, K. Wong. An unfixed piecewiseoptimal reactive power-flow model and its algorithm for ac-dc systems. *IEEE Transactions on Power Systems.* 2008; 23(1): 170 –176.

[18] F. Capitanescu. Assessing reactive power reserves with respect to operating constraints and voltage stability. *IEEE Transactions on Power Systems.* 2011; 26(4): 2224–2234.

[19] Z. Hu, X. Wang, G. Taylor. Stochastic optimal reactive power dispatch: Formulation and solution method. *International Journal of Electrical Power and Energy Systems.* 2010; 32(6): 615 – 621.

[20] A. Kargarian, M. Raoofat, M. Mohammadi. Probabilistic reactive power procurement in hybrid electricity markets with uncertain loads. *Electric Power Systems Research.* 2012; 82(1): 68–80.

[21] Lorenz, K, N. Tinbergen. *Behavior of the House Cricket*. Achetadomesticus. 2010.

[22] William D. Brown, Adam T. Smith, BM., JG. *Aggressive contests in house crickets: size, motivation and the information content of aggressive songs.* Animal Behaviour. Elsevier. 2006; 72: 225-233.

[23] Jonti Deuri, S. Siva Sathya. A Novel Cricket Chirping Algorithm for Engineering Optimization Problem. *Advances in Natural and Applied Sciences.* 2015; 9(6): 397-402.

[24] IEEE. *The IEEE 30-bus test system and the IEEE 118-test system*. 1993. http://www.ee.washington.edu/trsearch/pstca/.