IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 09, Issue 1 (January. 2019), ||V (I) || PP 20-26

Optimal Power Flow Solution Using Crow Search Algorithm

[1]Sreekakulam Naresh, [2]Prof. M. Damodar Reddy and [3]Y V Krishna Reddy
[1] Sri Venkateswara University, Dept. Of EEE, Tirupati, India
[2, 3] Sri Venkateswara University, Dept. Of EEE, Tirupati, India
Corresponding Author: Sreekakulam Naresh

Abstract: - This paper describes Crow Search Algorithm (CSA), inspired by the intelligent behaviour of crows to solve Optimal Power Flow (OPF) problem. CSA is a population-based method; works on behaviour of crows how to retrieve their reserve food in secrete places when the food is needed. OPF is the most familiar problem in power system optimization. The OPF problem formulation includes various constraints like generator, active power; reactive power limits and also valve point loading. The proposed method developed on the IEEE 14-bus, 30-bus and 26-bus power systems for optimize the cost of generation, emission and active power loss in single objective optimization space. The optimal results are compared to those informed in the literature. The results prove that the CSA has faster convergence and lesser cost as compared with other OPF solution methods.

Keywords: - Crow Search Algorithm, Optimal Power Flow, Emission, Active power loss, Valve-point loading.

Date of Submission: 18-12-2018 Date of acceptance: 03-01-2019

I. INTRODUCTION

The Optimal Power Flow (OPF) problem was initially introduced in 1960's (Carpentier 1962). With the help of OPF to find the optimal settings of power system network that optimizes the system objective functions such as total generation cost, system power loss, emission of generating units while satisfying its power flow equations, and operating limits of equipment. Many conventional methods used for solving OPF problem but these methods have limitation for local optima and facing difficulty regarding inequality constraint. To overcome these difficulties some heuristics approaches has been proposed. Evolutionary Programming (EP) [3], Genetic Algorithm (GA) [4, 5], Artificial Bee Colony (ABC) [6], and Particle Swarm Optimization (PSO) [7, 8] and some hybrid methods are MSG-HS [16], SFLA-SA [17] used to obtain solution of OPF problem.

The coding and operators of those algorithms have been modified to apply in various engineering problems [11]. Modified PSO (MPSO) [12] has been obtained by changing the set-on boundary strategies and velocity reflection, and in case of Modified DE (MDE) [13] random uniform distribution used. By including DE and PSO operators obtaining Moth Swarm Algorithm (MSA) [14] these are find the solutions for OPF problem. The final objective of this paper is to optimize the objective functions are cost of generation, transmission losses and emission by approaching the Newton Raphson based Crow Search Algorithm (CSA) [18] is applied to IEEE 14,-bus, 30-bus, and 26-bus test systems. The proposed method optimal solutions are compared with recently methods results which are mention in literature. As a result, CSA Provides better results than those in the literature.

II. OPTIMAL POWER FLOW

In this paper, the objective functions of OPF problem is minimization of generation cost, minimization of losses and minimization of emission to the generator units meeting inequality and equality constraints. The general form of OPF problem as follows:

$$\text{Minimize:} f(x,u) \tag{1}$$

$$\text{Subject to:} g(x,u) = 0 \tag{2}$$

$$h(x,u) \le 0 \tag{3}$$

Where f(x,u):objective function, g(x,u): equality constraint, h(x,u): inequality constraint.

2.1 State Variables

In order to obtain the state of the power system, set of state variables are represented in Eqn. (4).

$$x^T = [V_{L1} \dots V_{LNG}, P_{G1}, Q_{G1} \dots Q_{GNG}, S_{L1} \dots S_{LNG}] \tag{4}$$

V_L : Load bus voltage, P_{G1} : slack bus active power, Q_G : generator active powers, S_L : transmission line loading

2.2 Control Variables

In order to control the power flow, the set of parameters are represented as decision vector represented in Eqn. (5).

$$u^T = [V_{G1} ... V_{GNG}, P_{G2} ... P_{GNG}, T_1 ... T_{NT}] \tag{5}$$

V_G : generator voltages, P_G : generator real power outputs except slack bus T : transformers tap settings

2.3. Constraints

To minimize the objective function the OPF problem need to satisfy both equality and inequality constraints. The equality constraint treated as power balance constraints. The inequality constraints considered as operating limits of power system components.

2.3.1. Equality constraints

The equality constraints for the OPF problem are, balances of the active and reactive power represented in Eqn. (6) and Eqn. (7).

$$P_{Gi} - P_{Di} - V_i \sum_{j=1}^{Nb} V_j [G_{ij} cos(\delta_{ij}) + B_{ij} sin(\delta_{ij})] = 0 \tag{6}$$

$$Q_{Gi} - Q_{Di} - V_i \sum_{j=1}^{Nb} V_j [G_{ij} cos(\delta_{ij}) + B_{ij} sin(\delta_{ij})] = 0 \tag{7}$$

2.3.2 Inequality Constraints:

The Inequality constraints for OPF problem are considered to restrict the conditions of operation for getting a better optimal condition:

***Generator limits*:**

$$V_i^{min} \le V_i \le V_i^{max} \tag{8}$$

$$P_{Gi}^{min} \le P_{Gi} \le P_{Gi}^{max} \quad \text{Where i = 1, 2... Ng.} \tag{9}$$

Voltages at loading buses:

$$V_j^{min} \le V_j \le V_j^{max} \quad \text{Where j = 1, 2… npq;} \tag{10}$$

In order to obtain the optimal solution while satisfying the above constraints performing load flow with help of Newton Raphson method and optimal power flow can obtained by CSA optimization technique.

III. CROW SEARCH ALGORITHM

Crow Search Algorithm (CSA) is a population-based technique, which works on behaviour of crows how to retrieve their stored excess food in hiding places when the food is needed.

Implementation of CSA for optimization

Step 1: Initialize of parameters

The optimization problem, decision variables and constraints are defined. Then, the parameters of CSA are maximum iterations, flock size (n), flight length (fl) and awareness probability (ap) initialized.

Step 2: Initialize position and memory of crows

$$\begin{aligned} &l = 0;\ u = 1; \%\ \text{Lower and upper bounds} \\ &x(i,j) = l - (l - u) * rand; \%\ \text{Position of the crows in the space} \end{aligned} \tag{11}$$

Step 3: Evaluate fitness (objective) function

Find the fitness value for the new position of each crow.

Step 4: Update to new position

$$xnew(i,:) = x(i,:) + fl * rand * (mem(num(i),:) - x(i,:)) \tag{12}$$

$$xnew(i,j) = l - (l-u) * rand \tag{13}$$

Step 5: Update memory

$$m^{i,iter+1} = \begin{cases} x^{i,iter+1} & f(x^{i,iter+1}) \text{ is better than } f(m^{i,iter}) \\ m^{i,iter+1} = m^{i,iter} & \text{otherwise} \end{cases} \tag{14}$$

Step 6: Check termination criterion

$$\begin{aligned} & ffit(t) = \min(fit\_mem); \% \text{ Best found value until maximum iteration} \\ & \min(fit\_mem); \end{aligned} \tag{15}$$

IV. SIMULATION RESULTS

The IEEE 14-bus [8], 26-bus and IEEE-30 [14] systems are used to test the effectiveness of the proposed method for solving OPF problem. Various case studies are examined, which are précised in Table 1. All simulation results are obtained by MATLAB programs in MATLAB.

Table 1: Various case studies investigated in this paper.

Test case	Objective function	Test system
case 1	Convex fuel cost	IEEE 14-BUS, 26-BUS, IEEE 30-BUS
case 2	Non-convex fuel cost	IEEE 14-BUS, IEEE 30-BUS
case 3	Power loss	IEEE 14-BUS, 26-BUS, IEEE 30-BUS
case 4	Piecewise quadratic fuel cost	IEEE 30-BUS
case 5	Emission	IEEE 30-BUS

4.1 CASE 1: Convex fuel cost

Minimization of cost for the convex fuel cost function to the test systems consider as case 1. In order to minimize the fuel cost consider as quadratic fuel cost function as objective function as follows:

$$F_k(P_{Gk}) = a_k P_{Gk}^2 + b_k P_{Gk} + c_k \tag{16}$$

The CSA algorithm examined on IEEE 14-BUS [8], 26-BUS [5] and IEEE 30-BUS [14] test systems has active power demand 259MW, 1263 MW and 283.4 MW respectively. The simulation results obtained by proposed method are presented in Table 2 for three test systems.

Table 2: Optimal result obtained by CSA for Case 1

IEEE 14-BUS		26-BUS		IEEE 30-BUS	
Pg1(MW)	143.23	Pg1(MW)	472.3985	Pg1(MW)	171.9912
Pg2(MW)	48.71	Pg2(MW)	163.6627	Pg2(MW)	47.9521
Pg3(MW)	31.73	Pg3(MW)	246.9230	Pg5(MW)	21.1610
Pg6(MW)	21.93	Pg4(MW)	125.8830	Pg8(MW)	27.0344
Pg8(MW)	19.57	Pg5(MW)	163.9105	Pg11(MW)	11.3203
		Pg26(MW)	103.2064	Pg13(MW)	12.0000
Gen.Cost($/hr)	**814.5879**	Gen.Cost($/hr)	**15175.3175**	Gen.Cost($/hr)	**800.3995**
Losses(MW)	6.1945	Losses(MW)	12.9845	Ploss(MW)	9.0560
				Qloss(MVAR)	32.9622
				Emission(Ton/h)	0.2426

For IEEE-14 bus test system proposed method provide optimal cost 814.5879 ($/h) and transmission losses are 6.1945 MW. Similarly for 26-bus test system CSA provide optimal cost 15175.3175 ($/h) less as compare with GA [5], GA-FUZZY [5] and GSA [5] methods optimal costs as 15434.67 ($/h), 15431.69 ($/h) and 15467.45 ($/h) respectively. The optimal cost for IEEE-30 system is 800.3995 ($/h) for load demand of 283.4 MW. The proposed method provide less cost as compared with FPA [14], MPSO [14] and MSA [14] methods. The comparative results for test systems are presented in Table 3.

Table 3: Comparative results for Case 1 test systems

26-BUS		IEEE 30-BUS	
Method	Fuel Cost ($/h)	Method	Fuel Cost ($/h)
GA [5]	15434.67	FPA [14]	802.7983
GA-FUZZY [5]	15431.69	MPSO [14]	800.5164
GSA [5]	15467.45	MSA [14]	800.5099
CSA	**15175.3175**	CSA	**800.3995**

4.2 CASE 2: Non-convex fuel cost

In order to make the OPF problem as complex including the valve-point effect in generator fuel cost function. The fuel cost functions with inclusion of valve-point effect as follows:

$$F = F_C(P_G) = \sum_{k=1}^{N_G}(a_k P_{Gk}^2 + b_k P_{Gk} + c_k) + \left| e_{ck} \times \sin(f_{ck} \times (P_{Gk}^{min} - P_{Gk})) \right| \quad (\$/h) \tag{17}$$

For the above problem the proposed method examined on IEEE-14 bus [8] and IEEE-30 bus [14] test system has load of demand 259 MW and 283.4 MW. The simulation results of fitness function, active powers of generating units and power losses of the test systems are presented in Table 4.

Table 4: Optimal result obtained by CSA for Case 2

IEEE 14-BUS		IEEE 30-BUS	
Pg1(MW)	144.40	Pg1(MW)	134.9079
Pg2(MW)	48.18	Pg2(MW)	79.9999
Pg3(MW)	31.46	Pg5(MW)	25.1494
Pg6(MW)	21.76	Pg8(MW)	10.0000
Pg8(MW)	19.44	Pg11(MW)	21.6337
		Pg13(MW)	19.3919
Gen.Cost($/hr)	**814.59928**	Gen.Cost($/hr)	**922.1680**
Losses(MW)	6.2530	Ploss(MW)	7.6830
		Qloss(MVAR)	38.2009
		Emission(Ton/h)	0.1910

From the Table 4 observe that, due to the valve-point effect operating cost increases for both the test systems. The simulation results of the proposed method are comparing with recently published methods and presented in Table 5. It can be conclude that CSA method provide optimal as compare with other methods.

Table 5: Comparative results for Case 2 test systems

IEEE 14-BUS		IEEE 30-BUS	
Method	Fuel Cost ($/h)	Method	Fuel Cost ($/h)
GA [8]	926.55	FPA [14]	931.7458
PSO [8]	833.57	MPSO [14]	952.3039
		MSA [14]	930.7441
CSA	**814.59928**	CSA	**922.1680**

4.3 CASE 3: Minimization of Power loss

The objective function for the case 3 is minimization of power loss for non-convex function represented in Eqn. (21).

$$f = \sum_{i=1}^{nl}\sum_{j\neq i}^{nl} G_{ij}V_i^2 + V_j^2 - 2V_iV_j\cos(\delta_i - \delta_j) \quad (MW) \tag{18}$$

The proposed method examined on IEEE 14-BUS [8], 26-BUS [5] and IEEE 30-BUS [14] test systems power loss minimization as objective function. The simulation results obtained by proposed method are presented in Table 6, it can be conclude that the operating cost increases when power loss minimization considered as objective function.

Table 6: Optimal result obtained by CSA for Case 3

IEEE 14-BUS		26-BUS		IEEE 30-BUS	
Pg1(MW)	72.654	Pg1(MW)	313.951	Pg1(MW)	54.1445
Pg2(MW)	77.574	Pg2(MW)	197.607	Pg2(MW)	77.7851
Pg3(MW)	48.786	Pg3(MW)	297.559	Pg5(MW)	49.9918
Pg6(MW)	33.975	Pg4(MW)	149.578	Pg8(MW)	34.9999
Pg8(MW)	29.361	Pg5(MW)	198.075	Pg11(MW)	29.9920
		Pg26(MW)	119.221	Pg13(MW)	39.9999
Gen.Cost($/hr)	**1143.4055**	Gen.Cost($/hr)	**15266.2208**	Gen.Cost($/hr)	965.8423
Losses(MW)	**3.2699**	Losses(MW)	12.4636	Ploss(MW)	**3.0135**
				Qloss(MVAR)	52.7278
				Emission(Ton/h)	0.1108

4.4 CASE 4: Piecewise quadratic fuel cost

The objective function for the case 4 is minimization of piecewise fuel cost for convex function as follows:

$$F = F_C(P_{Gk}) = \begin{cases} a_{k1}P_{Gk}^2 + b_{k1}P_{Gk} + c_{k1} & P_{Gk}^{min} \le P_{Gk} \le P_{Gk1} \\ a_{k2}P_{Gk}^2 + b_{k2}P_{Gk} + c_{k2} & P_{Gk1} \le P_{Gk} \le P_{Gk2} \\ . & \\ ..a_{kn}P_{Gk}^2 + b_{kn}P_{Gk} + c_{kn} & P_{Gk(n-1)} \le P_{Gk} \le P_{Gk}^{max} \end{cases} \quad (19)$$

The objective function examined on IEEE 30-bus [14] test system, simulation results presented in Table 7 and comparison results are presented in Table 8. From the results conclude that CSA method provide better results as compare with remaining methods.

Table 7: Optimal results provided by CSA method for Case 4 and Case 5

IEEE 30-Bus		
	Case 4	Case 5
Pg1(MW)	139.9999	55.8821
Pg2(MW)	54.9999	77.0059
Pg5(MW)	23.6403	49.9800
Pg8(MW)	34.9999	34.7040
Pg11(MW)	17.5955	29.9722
Pg13(MW)	19.2555	39.3950
Gen.Cost($/hr)	**644.7789**	960.3062
Emission(Ton/h)	0.1839	**0.1760**
Ploss(MW)	7.0914	3.5395
Qloss(MW)	40.4620	52.6550

4.5 CASE 5: Minimization of Emission

The objective function for the case 5 is minimization of emission for non-convex function represented in Eqn. (20).

$$F = E(P_G) = \sum_{k=1}^{N_G} (\alpha_k P_{Gk}^2 + \beta_k P_{Gk} + \gamma_k) + \xi_{ck} \times \exp(P_{Gk}\lambda_k) \quad (ton/h) \quad (20)$$

The objective function examined on IEEE 30-bus [14] test system, simulation results presented in Table 7 and comparison results are presented in Table 8. From the results conclude that CSA method provide better results as compare with remaining methods.

Table 8: Comparative results for IEEE-30 bus test system

30 BUS	Objective function	FPA [14]	MPSO [14]	MSA [14]	CSA
Case 4	Gen.Cost($/hr)	651.3768	646.7263	646.8364	**644.7789**
	Emission(Ton/h)	0.2808	0.2834	0.2835	0.1839
	Plosses(MW)	7.2355	6.8008	6.8001	7.0914
	Qloss(MW)	36.7308	28.9301	29.6667	40.4620
Case 5	Gen.Cost($/hr)	948.949	879.9464	944.5003	960.3062
	Emission(Ton/h)	0.2052	0.2324	0.2048	**0.1760**
	Plosses(MW)	4.492	7.0467	3.2358	3.5395
	Qloss(MW)	23.6465	35.2525	22.6688	52.6550

V. CONCLUSION

This paper has presented a Crow Search Algorithm (CSA) and applied to solve OPF problem for different objective functions in IEEE 14- bus, 26-bus and IEEE-30 bus test power systems. The Crow Search algorithm has shown effective results in terms of convergence, consistency in different runs and lesser generation cost as compared to other techniques. These advantages are obtained by the intelligent behaviour of crows during food hunting process. In order to demonstrate the potential of this method, tested on IEEE 30 bus system for non-convex cost function, piecewise cost function also. The obtained optimal results are compared with EP based OPF with greater satisfaction.

REFERENCES

[1]. Harprit kaur and Y.S Brar, "Optimal Power Flow Using Power World Simulator" 2010 IEEE Electrical Power & Energy Conference

[2]. Xiaojiao Tong and Mugang Lin, "Semismooth Newton-Type Algorithms for Solving Optimal Power Flow Problems" 2005 IEEE/PES Transmission and Distribution Conference & Exhibition: Asia and Pacific Dalian, China

[3]. L L Lai and J T M a, "Power Flow Control In Facts Using Evolutionary Programming", 0-7803-2759-4/95/$4.00 *0*1995 IEEE

[4]. R.Narmatha Banu and D.Devaraj, "Optimal Power Flow for Steady state security enhancement using Genetic Algorithm with FACTS devices", 2008 IEEE Region 10 Colloquium and the Third ICIIS, Kharagpur, INDIA December 8-10

[5]. Ashish Saini, Devendra K. Chaturvedi, "Optimal Power Flow Solution: a GA-Fuzzy System Approach", International Journal of Emerging Electric Power Systems, Volume 5, Issue 2, 2006.

[6]. Fahad S. Abu-Mouti and Mohamed E. El-Hawary, "Overview of Artificial Bee Colony (ABC) Algorithm and Its Applications", 978-1-4673-0750-5/12/$31.00 ©2012 IEEE

[7]. Hamzeh Hajian-Hoseinabadi, Seyed Hamid Hosseini and Mehdi Hajian, "Optimal Power Flow Solution by a Modified Particle Swarm Optimization Algorithm".

[8]. Belgin Emre TURKAY and Rengin Idil CABADAG, "Optimal Power Flow Solution Using Particle Swarm
Optimization Algorithm", EuroCon 2013 • 1-4 July 2013 • Zagreb, Croatia

[9]. Rengin Idil CABADAG, Belgin Emre TURKAY, "Heuristic Methods To Solve Optimal Power Flow Problem", *R. I. CABADAG and B. E. TURKAY / IU-JEEE Vol. 13(2), (2013), 1653-1659*

[10]. Leonard L.Grigsby "Power system stability and control", 3 rd edition, CRC press, Taylor and francis group.

[11]. Ilhem Bouss, Julien Lepagnot and Patrick Siarry, *"*A survey on optimization metaheuristics*",* Information Sciences (2013), doi: Doi.org/10.1016/j.ins.2013.02.041

[12]. Amin Karami a,n, Manel Guerrero-Zapata "A fuzzy anomaly detection system based on hybrid PSO-Kmeans
algorithm in content-centric networks", Neurocomputing

[13]. Leandro dos Santos Coelho, Viviana Cocco Mariani "Solution of Jiles–Atherton vector hysteresis parameters estimation
by modified Differential Evolution approaches", Expert Systems with Applications 39 (2012) 2021–2025.

[14]. Al-Attar Ali Mohamed, Yahia S. Mohamed and Ahmed A.M. "Optimal power flow using moth swarm algorithm" Electric Power Systems Research 142 (2017) 190–206.

[15]. Tahir Nadeem Malik, Azzam ul Asar, "A new hybrid approach for the solution of nonconvex economic dispatch problem with valve-point effects", Electric Power Systems Research 80 (2010) 1128–1136
[16]. Celal Yasar, Serdar Özyön, "A new hybrid approach for nonconvex economic dispatch problem with valve-point effect" Energy 36 (2011) 5838e5845.
[17]. Taher Niknam, Mohammad Rasoul Narimani, "A new hybrid algorithm for optimal power flow considering prohibited zones and valve point effect", Energy Conversion and Management 58 (2012) 197–206.
[18]. Alireza Askarzadeh "A novel metaheuristic method for solving constrained engineering optimization problems: Crow search algorithm", Computers and Structures 169 (2016) 1–12.

Sreekakulam Naresh. "Optimal Power Flow Solution Using Crow Search Algorithm." IOSR Journal of Engineering (IOSRJEN), vol. 09, no. 01, 2019, pp. 20-26.