Research Article
Open Access
CrossMark

Sepiida algorithm for solving optimal reactive power problem

Abstract

This paper presents Sepiida Algorithm (SA) for solving optimal reactive power problem. The algorithm imitates the method of colour altering behaviour used by the Sepiida. The patterns and colours seen in Sepiida are produced by reflected light from different layers of cells including (chromatophores, leucophores and iridophores) heap together, and it is the amalgamation of certain cells at once that allows Sepiida to acquire such a huge array of patterns and colours. The projected algorithm considers two key progressions: reflection and visibility. Reflection process is projected to replicate the light reflection mechanism used by these three layers, while the visibility is projected to replicate the visibility of matching pattern used by the Sepiida. These two processes are used as a explore strategy to find the global optimal solution. The proposed Sepiida Algorithm (SA) has been tested on standard IEEE 118 & practical 191 bus test systems and simulation results show clearly the better performance of the proposed algorithm in reducing the real power loss.

Keywords: optimal reactive power, transmission loss, sepiida algorithm, reflection, visibility

Volume 4 Issue 4 - 2018

K Lenin
Department of EEE, Prasad V Potluri Siddhartha Institute of Technology, India

Correspondence: K Lenin, Department of EEE, Prasad V Potluri Siddhartha Institute of Technology, India,
Email gklenin@gmail.com

Received: July 24, 2018 | **Published:** August 30, 2018

Introduction

The main objective of optimal reactive power problem is to minimize 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. If linear programming is applied then the input- output function has to be uttered as a set of linear functions which mostly lead to loss of accuracy. The problem of voltage stability and collapse play a major 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] Evolutionary algorithm is a heuristic approach used for minimization problems by utilizing nonlinear and non-differentiable continuous space functions. In,[12] Hybrid differential evolution algorithm is proposed to improve the voltage stability index. In[13] Biogeography Based algorithm is projected to solve the reactive power dispatch problem. In,[14] a fuzzy based method is used to solve the optimal reactive power scheduling method. In,[15] an improved evolutionary programming is used to solve the optimal reactive power dispatch problem. In,[16] the optimal reactive power flow problem is solved by integrating a genetic algorithm with a nonlinear interior point method. In,[17] a pattern algorithm is used to solve ac-dc optimal reactive power flow model with the generator capability limits. In F Capitanescu[18] proposes a two-step approach to evaluate Reactive power reserves with respect to operating constraints and voltage stability. In[19] a programming based approach is used to solve the optimal reactive power dispatch problem. In A Kargarian et al.[20] present a probabilistic algorithm for optimal reactive power provision in hybrid electricity markets with uncertain loads. This paper proposes New Sepiida Algorithm (NCFA) is proposed for solving reactive power dispatch problem. The proposed algorithm imitates the light reflection process through the amalgamation of these layers, and the visibility of matching pattern procedure used by Sepiida to match its background.[21–29] The algorithm divides the population (cells) into four groups, each group works autonomously sharing only the best solution. Two of them used as a global search, while others used as a local search. The proposed Sepiida Algorithm (SA) has been tested on standard IEEE 118 & practical 191 bus test systems and simulation results show clearly the better performance of the proposed algorithm in reducing the real power loss.

Problem formulation

Active power loss

The objective of the reactive power dispatch problem is to minimize the active power loss and can be defined in equations as follows:

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

Where g_k: is the conductance of branch between nodes i and j, Nbr: is the total number of transmission lines in power systems.

Voltage profile improvement

To minimize the voltage deviation in PQ buses, the objective function can be written as:

$$F = PL + \omega_V \times VD \quad (2)$$

Where ω_v - is a weighting factor of voltage deviation.

VD is the voltage deviation given by:

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \quad (3)$$

Equality constraint

The equality constraint of the problem is indicated by the power balance equation as follows:

$$P_G = P_D + P_L \quad (4)$$

Where the total power generation PG has to cover the total power demand P_D and the power losses P_L.

Inequality constraints

The inequality constraint implies the limits on components in the power system in addition to the limits created to make sure system security. Upper and lower bounds on the active power of slack bus, and reactive power of generators are written as follows:

$$P_{gslack}^{min} \le P_{gslack} \le P_{gslack}^{max} \quad (5)$$

$$Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max}, i \in N_g \quad (6)$$

Upper and lower bounds on the bus voltage magnitudes:

$$V_i^{min} \le V_i \le V_i^{max}, i \in N \quad (7)$$

Upper and lower bounds on the transformers tap ratios:

$$T_i^{min} \le T_i \le T_i^{max}, i \in N_T \quad (8)$$

Upper and lower bounds on the compensators

$$Q_c^{min} \le Q_c \le Q_C^{max}, i \in N_C \quad (9)$$

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.

Sepiida skin apparatus

Sepiida is a type of cephalopods which is well known for its ability to alter its colour shown in Figure 1 either apparently disappears into its environment or to create dramatic displays. The patterns and colours seen in cephalopods are formed by different layers of cells stacked collectively including chromatophores, leucophores and iridophores, and it is the amalgamation of certain cells operations of reflecting light and matching patterns at once that allows cephalopods to acquire such a huge array of patterns and colours. These layers are explained as follows:

Figure 1 Sepiida.

Chromatophores: are groups of cells that comprise an elastic saccule that holds a pigment, as well as 15-25 muscles attached to this saccule .These cells are positioned directly under the skin of Sepiida. When the muscles contract, they elongate the saccule allowing the pigment within to wrap a larger surface area. When the muscles relax, the saccule reduces in size and hides the pigment.

Iridophores: are found in the next layer under the chromatophores. Iridophores are layered stacks of platelets that are chitinous in some species and protein based in others. They are accountable for producing the metallic looking greens, blues and gold's seen in some species, as well as the silver colour in the region of the eyes and ink sac of others. Iridophores work by reflecting light and can be used to conceal organs, as is often the case with the silver coloration in the region of the eyes and ink sacs. In addition, they aid in concealment and communication.

Leucophores: these cells are accountable for the white spots happening on some species of Sepiida, squid and octopus. Leucophores are flattened, branched cells that are thought to disperse and reflect incoming light. In this way, the colour of the leucophores will reflect the prime wavelength of light in the environment. In white light they will be white, while in blue light they will be blue. It is contemplation that this adds to the animal's capability to unify into its environment. Chromatophores cells have red, orange, yellow, black, and brown pigments. But a set of mirror-like cells (iridophores and leucophores) permits Sepiida skin to guess all the affluent and speckled colours of its environment. The look of the Sepiida thus depends on which skin elements affect the light incident on the skin. Light may be reflected by either chromatophores or by reflecting cells (iridophores or leucophores) or a amalgamation of both, and it is the physiological volatility of the chromatophores and reflecting cells that enables the Sepiida to create such a wide repertoire of optical effects. A illustration in Figure 2 of Sepiida skin detailing the three main skin structures(chromatophores, iridophores and leucophores), two illustration states (a, b) and three distinct ray traces (1, 2, 3) show the stylish means by which Sepiida can alter reflective colour.

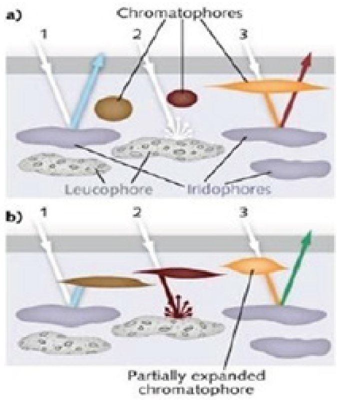

Figure 2 Diagram of Sepiida skin detailing the three main skin structures (chromatophores, iridophores and leucophores).

Sepiida algorithm

The projected Sepiida algorithm imitates the work of the three cell layers that are used by Sepiida to change its skin colours. To do this, we reordered the six cases shown in Figure 2 to be as shown below Figure 3. From Figure 3 we imagine two main processes (*reflection* and *visibility*). Reflection method represents the system used by Sepiida to reflect incoming light and it can by any case of the six cases considered in Figure 3. While visibility is representing the matching pattern precision that the Sepiida try to replicate the patterns appear in its environment. It understood that the final pattern is the global optimum solution, while visibility is the difference between the best solution and the present solution. The projected Sepiida Algorithm is designed based on these two methods (*reflection* and *visibility*) and they used as a explore strategy to find the new solutions. The formulation of finding the new solution (*newP*) using reflection and visibility is described in (10).

$$newP = reflection + visibility \quad (10)$$

The main steps of SA algorithm are concise as follow:

a. Begin the population with arbitrary solutions, compute and keep the best solution and the average value of the best solution's points.

b. Employ communication operator between chromatophores and iridophores cells in case 1 and 2, to create a new solution based on the reflection and the visibility of pattern (global search).

c. Employ iridophores cells operators in case 3 and 4 to compute new solutions based on the reflected light coming from best solution and the visibility of matching pattern (local search).

d. Employ leucophores cells operator in case 5 to create new-fangled solution by reflecting light from the area around the best solution and visibility of the pattern (local search).

e. Employ leucophores cells operator in case 6 for arbitrary solution by reflecting incoming light (global search).

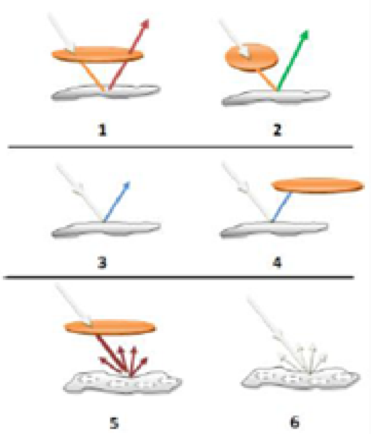

Figure 3 Reorder of the six cases.

Initialization

First the population P (*cells*) of N primary solutions $P = cells = \{points1, points2, ..., points\ N\}$, is extend over d-dimensional problem space at arbitrary positions (*points*) using (11).

$$P[i].points[j] = random * (upperlimit - lowerlimit) + lowerlimit \quad (11)$$

Where *upperLimit* and *lowerLimit* are the upper and the lower limits in the problem area and *random* is a randomnumber between (0, 1).Each individual $points_i$ in of the population represents a solo cell and it is connected with two values, fitness and a vector of d-dimension continuous values. After that the best solution will be reserved in *Best*, and the average of the *Best* points are computed and stored in AV_{Best}. Then the population is alienated into four groups of cells. Each group will work autonomously sharing only the best solution, two of them (group 1 and 4) are work as a local search, while group 2 and 3 are work as a global search.

Group 1-simulation of case 1 and 2

Reflected color (light) shown in Figure 3 case (1 and 2) is formed due the communication between chromatophores and iridophores cells, each chromatophores cell will contract or relax its muscles to extend or shrink its saccule. While iridophores cells will reflect the light that is coming from chromatophores cells. The reflected light may infiltrate the chromatophores cells or not. The elongate and shrink process in chromatophores cells and the reflected light from iridophores cells and visibility of the pattern used by Sepiida to match its background, are used to find a new-fangled solution. The formulations of these progressions are described in (11) and (12), respectively.

$$reflection_j = R * G_1[i]\,points[j] \quad (12)$$

$$visibility_j = V * (Best\ points[j] - G_1[i]points[j]) \quad (13)$$

In (11) and (12), G_1 stand for a group of chromatophors cells used to simulates case (1 and 2). i, is the i^{th} cell of group G_1. *Points*[*j*] symbolize the j^{th} point of i^{th} cell. *Best. Points* stand forthe best solution points. R, represents the reflection degree used to find the elongate range of the saccule when the muscles of the cell is in contract or relax. V, represents the visibility degree of the concluding view of the pattern. The value of R and V are computed as follows:

$$R = random(\ ) * (r_1 - r_2)\,r_2 \quad (14)$$

$$V = random(\ ) * (v_1 - v_2)\,v_2 \quad (15)$$

Where, *random*() function is a function used to create an arbitrary numbers between (0, 1). r_1, r_2 are two constant values used to find the stretch interval of the chromatophores cells. While v_1 and v_2 are two stable values used to find the interval of the visibility's degree of the final view of the pattern. Sometime the value of R or value of V is just set to 1 or else it will be computed. In this group only value of V is set to 1 and R will be computed.

Group 2-simulation of case 3 and 4

As described before the iridophores cells are light reflecting cells. From Figure 3, case (3 and 4), the iridophores cells will reflect inward light from the outside (environment), and the reflected colour is a precise colour. Iridophores cells are assisting in camouflage or used to conceal organs. It believed that the concealed organs are represented by the best solution. So the formulation of finding the visibility is left behind as it, while the formulation of finding the reflection is rewritten as follows:

$$reflection_j = R * Best\ point[j] \quad (16)$$

Group 3-simulation of case 5

Leucophores cells are work as a mirror. In this way, the cells will reflect the predominant wavelength of light in the environment. In white light they will reflect the white, in brown light they will reflect brown and etc., In this case (case5 in Figure 3) the light is coming through chromatophores cells with specific colour. The reflected light is very similar to the light that coming from the chromatophores cells. In order to cover the similarity between the incoming colour and the reflected colour, we assumed that the incoming colour is the best solution (*Best*), and the reflected colour could be any value around the *Best*. The interval that is used around the *Best* is produced by visibility. The two Equations (11) and (12) of finding the reflection and the visibility are modified as follows:

$$reflection_j = R * Best\ point[j] \quad (17)$$

$$visibility_j = V * (Best\ points[j] - AV_{Best}) \quad (18)$$

Where, AV_{Best} is the average value of the *Best* points. The value of R is set to 1, while the value of V will be computed.

Group 4- simulation of case 6

In this case, the leucophores cells will just reflect the inward light from the environment. This operator permits the Sepiida to unify itself into its environment. As a recreation, one can presume that any incoming colour from the environment will be reflected as it and can be represented by any arbitrary solution. Thus this case (case 6 in Figure 3) works as initialization utilize (10) to find the new solutions.

Sepiida Algorithm for Solving Optimal Reactive Power Problem

i. Begin population (P [N]) with random solutions. Allocate the values of r_1, r_2, v_1, v_2.

ii. Calculate fitness of the population and Keep the best solution in Best.

iii. Segregate population (cells) into four groups (G_1, G_2, G_3 and G_4).

iv. While (stopping criterion is not met)

v. Compute the average value of the best solution, and accumulate it in AV_{Best}.

vi. Case (1, 2)

For every cell in G_1 do

Create new solution using Equation (12 and 13)

If (the new solution is better than the Best)

Reinstate the Best with it.

If (the new solution is better than the current solution)

Reinstate the current solution with it.

End

vii. Case (3, 4)

For every cell in G_2 do

Create new solution use Equations (16, 13)

If (the new solution is better than the Best)

Reinstate the Best with it.

If (the new solution is better than the current solution)

Reinstate the current solution with it.

End

viii. Case (5)

For every cell in G_3 do

Create new solution use Equations (17, 18)

If (the new solution is better than the Best)

Reinstate the Best with it.

If (the new solution is better than the current solution)

Reinstate the current solution with it.

End

ix. Case (6)

For each cell in G_4 do

Create a random solution using Equation (11)

If (the new solution is better than the Best)

Replace the Best with it.

If (the new solution is better than the current solution)

Reinstate the current solution with it.

End

10. End While.

11. Return the best solution (Best)

Simulation results

At first Sepiida Algorithm (SA) has been tested in standard IEEE 118-bus test system.[30] 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 -1.05per-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 1, with the change in step of 0.01.

Table 1 Limitation of reactive power sources

BUS	5	34	37	44	45	46	48
$QC_{maximum}$	0	14	0	10	10	10	15
$QC_{minimum}$	-40	0	-25	0	0	0	0
BUS	74	79	82	83	105	107	110
$QC_{maximum}$	12	20	20	10	20	6	6
$QC_{minimum}$	0	0	0	0	0	0	0

QC- shunt capcitor

The statistical comparison results have been listed in Table 2 and the results clearly show the better performance of proposed Sepiida Algorithm (SA). Proposed algorithm reduces the real power loss considerably when compared to other reported standard algorithms in the above tabular column. Then the Sepiida Algorithm (SA) has been tested in practical 191 test system and the following results have been obtained. In Practical 191 test bus system – Number of Generators = 20, Number of lines = 200, Number of buses = 191 Number of transmission lines = 55. Table 3 shows the optimal control values of practical 191 test system obtained by SA method. And Table 4 shows the results about the value of the real power loss by obtained by Sepiida Algorithm (SA). Proposed algorithm has been reduced Real power loss considerably as shown in tabular column 4. It indicated the better efficiency of the algorithm.

Table 2 Comparison results

Active power loss (p.u)	BBO[31]	ILSBBO/ strategy1[31]	ILSBBO/ strategy1[31]	Proposed SA
Min	128.77	126.98	124.78	110.26
Max	132.64	137.34	132.39	118.14
Average	130.21	130.37	129.22	115.28

Citation: Lenin K. Sepiida algorithm for solving optimal reactive power problem. *Int Rob Auto J.* 2018;4(4):289–294. DOI: 10.15406/iratj.2018.04.00139

Table 3 Optimal Control values of Practical 191 utility (Indian) system by SA method

VG1	1.1	VG 11	0.9
VG 2	0.78	VG 12	1
VG 3	1.01	VG 13	1
VG 4	1.01	VG 14	0.9
VG 5	1.1	VG 15	1
VG 6	1.1	VG 16	1
VG 7	1.1	VG 17	0.9
VG 8	1.01	VG 18	1
VG 9	1.1	VG 19	1.1
VG 10	1.01	VG 20	1.1

T1	1	T21	0.9	T41	0.9
T2	1	T22	0.9	T42	0.9
T3	1	T23	0.9	T43	0.91
T4	1.1	T24	0.9	T44	0.91
T5	1	T25	0.9	T45	0.91
T6	1	T26	1	T46	0.9
T7	1	T27	0.9	T47	0.91
T8	1.01	T28	0.9	T48	1
T9	1	T29	1.01	T49	0.9
T10	1	T30	0.9	T50	0.9
T11	0.9	T31	0.9	T51	0.9
T12	1	T32	0.9	T52	0.9
T13	1.01	T33	1.01	T53	1
T14	1.01	T34	0.9	T54	0.9
T15	1.01	T35	0.9	T55	0.9
T19	1.02	T39	0.9		
T20	1.01	T40	0.9		

Table 4 Optimum real power loss values obtained for practical 191 utility (Indian) system by SA method.

Real power loss (MW)	SA
Min	139.024
Max	143.126
Average	141.028

Conclusion

In this paper Sepiida Algorithm (SA) has been successfully solved optimal reactive power problem. The projected algorithm considers two key progressions: reflection and visibility. Reflection process is projected to replicate the light reflection mechanism used by these three layers, while the visibility is projected to replicate the visibility of matching pattern used by the Sepiida. These two processes are used as a explore strategy to find the global optimal solution. The proposed Sepiida Algorithm (SA) has been tested on standard IEEE 118 & practical 191 bus test systems and simulation results show clearly the better performance of the proposed algorithm in reducing the real power loss.

Acknowledgements

None.

Conflict of interest

The author declares there is no conflict of interest.

References

1. Alsac O, Scott B. Optimal load flow with steady state security. *IEEE Transaction*. 1973;PAS -93(3):745–751.
2. Lee K Y, Paru Y M, Oritz J L. A united approach to optimal real and reactive power dispatch. *IEEE Transactions on power Apparatus and systems*. 1985;PAS-104:1147–1153.
3. Monticelli A, Pereira MVF, Granville S. Security constrained optimal power flow with post contingency corrective rescheduling. *IEEE Transactions on Power Systems*. 1987;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. Hobson E. Network constrained reactive power control using linear programming. IEEE Transactions on power systems. 1980;PAS-99(4):868–877.
6. Lee KY, Park YM, Oritz JL. Fuel –cost optimization for both real and reactive power dispatches. *IEE Proc*. 1984;131(3):85–93.
7. Mangoli MK, Lee KY. Optimal real and reactive power control using linear programming. *Electr Power Syst Res*. 1993;26:1–10.
8. Canizares CA, de Souza ACZ, Quintana VH. Comparison of performance indices for detection of proximity to voltage collapse. *IEEE Transactions on Power Systems*. 1996;11(3):1441–1450.
9. Anburaja K. Optimal power flow using refined genetic algorithm. *Electr Power Compon Syst*. 2002;30(10):1055–1063.
10. Devaraj D, Yeganarayana B. Genetic algorithm based optimal power flow for security enhancement. *IEE proc-Generation Transmission and Distribution*. 2005;152(6):899–905.
11. Berizzi A, Bovo C, Merlo M, M Delfanti. A ga approach tocompare orpf objective functions including secondary voltage regulation. *Electric Power Systems Research*. 2012;84(1):187–194.
12. Yang CF, Lai GG, Lee CH, et al. 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. Roy P, Ghoshal S, Thakur S. 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. Venkatesh B, Sadasivam G, Khan M. 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. Yan W, Lu S, Yu D. 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. Yan W, Liu F, Chung C, et al. A hybrid genetic algorithm interior point method for optimal reactive power flow. *IEEE Transactions on Power Systems*. 2006;21(3):1163–1169.
17. Yu J, Yan W, Li W, et al. An unfixed piecewise optimal reactive power-flow model and its algorithm for ac-dc systems. *IEEE Transactions on Power Systems*. 2008;23(1):170–176.
18. Capitanescu F. Assessing reactive power reserves with respect to operating constraints and voltage stability. *IEEE Transactions on Power Systems*. 2011;26(4):2224–2234.
19. Hu Z, Wang X, Taylor G. Stochastic optimal reactive power dispatch: Formulation and solution method. *International Journal of Electrical Power and Energy Systems*. 2010;32(6):615–621.
20. Kargarian A, Raoofat M, Mohammadi M. Probabilistic reactivepower procurement in hybrid electricity markets with uncertain loads. *Electric Power Systems Research*. 2012;82(1):68–80.
21. Mäthger LM1, Denton EJ, Marshall NJ, et al. Mechanisms and behavioural functions of structural coloration in cephalopods. *JR Soc Interface*. 2008;6Suppl2:S149–163.
22. Adel Sabry Eesa, Adnan Mohsin Abdulazeez Brifcani, et al. Sepiida Algorithm – A Novel Bio-Inspired Optimization Algorithm. *International Journal of Scientific & Engineering Research*. 2013;4(9).
23. Hanlon RT, Messenger JB. Cephalopod Behavior. Cambridge: Cambridge University Press, 1996. 1998;17(8):1392.
24. Florey E. Ultrastructure and function of cephalopod chromatophores. *Am Zool*. 1969;9(2):429–442.
25. Hanlon RT, Cooper KM, Budelmann BU, et al. Physiological color change in squid iridophores I, Behavior, morphology and pharmacology in Lolliguncula brevis. *Cell and Tissue Research*. 1990;259(1):3–4.
26. Cooper KM, Hanlon RT, Budelmann BU. Physiological color change in squid iridophores II, Ultra structural mechanisms in Lolliguncula brevis. *Cell and Tissue Research*. 1990;259(1):15–24.
27. Cloney RA, Brocco SL. Chromatophores organs, reflector cells, iridocytes and leucophores in cephalopods. *Am Zool*. 1983;23(3):581–592.
28. Froeschand D, Messenger JB. On leucophores and the chromatic unit of Octopus vulgaris. *J Zool*. 1978.
29. Eric K, Lydia MM, Roger TH, et al. Biological versus electronic adaptive coloration: how can one inform the other? *JR Soc Interface*. 2012:10(78):20120601.
30. The IEEE 30-bus test system and the IEEE 118-test system. 1993.
31. Jiangtao Cao, Fuli Wang, Ping Li. An Improved Biogeography-based Optimization Algorithm for Optimal Reactive Power Flow. *International Journal of Control and Automation*. 2014;7(3):161–176.