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REDUCTION OF REAL POWER LOSS AND VOLTAGE STABILITY ENHANCEMENT BY SALMO SALAR ALGORITHM

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Abstract

This paper presents a new Salmo Salar (SS) algorithm for Solving Optimal Reactive Power Dispatch Problem. Salmo Salar Algorithm imitates the annual natural events happening in the North America. Millions of Salmo salar move about through mountain streams for spawning. Proposed SS algorithm utilizes the behaviour of Salmo Salar to solve the optimal reactive power problem. Proposed (SS) algorithm has been tested in standard IEEE 30 bus test system and simulation results shows clearly about the good performance of the proposed algorithm in reducing the real power loss and enhancing the voltage stability.

Keywords: Modal Analysis; Optimal Reactive Power; Nature-Inspired Algorithm; Salmo Salar; Transmission Loss.

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1. Introduction

Optimal reactive power dispatch problem   is subject to number of uncertainties and at least in the best case to uncertainty parameters given in the demand and about the availability equivalent amount of shunt reactive power compensators. Optimal reactive power dispatch plays a major role for the operation of power systems, and it should be carried out in a proper manner, such that system reliability is not got affected. The main objective of the optimal reactive power dispatch is to maintain the level of voltage and reactive power flow within the specified limits under various operating conditions and network configurations. By utilizing a number of control tools such as switching of shunt reactive power sources, changing generator voltages or by adjusting transformer tap-settings the reactive power dispatch can be done. By doing optimal adjustment of these controls in different levels, the redistribution of the reactive power would minimize transmission losses. This procedure forms an optimal reactive power dispatch problem and it has a major influence on secure and economic operation of power systems. Various

mathematical techniques 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 has the difficulty in handling inequality constraints. If linear programming is applied then the input- output function has to be expressed 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]. Enhancing the voltage stability, voltage magnitudes within the limits alone will not be a reliable indicator to indicate that, how far an operating point is from the collapse point. The reactive power support and voltage problems are internally related to each other. This paper formulates by combining both the real power loss minimization and maximization of static voltage stability margin (SVSM) as the objectives. Global optimization has received extensive research attention, and a great number of methods have been applied to solve this problem. Evolutionary algorithms such as genetic algorithm have been already proposed to solve the reactive power flow problem[9,10].Evolutionary algorithm is a heuristic approach used for minimization problems by utilizing nonlinear and non-differentiable continuous space functions. In [11], by using Genetic algorithm optimal reactive power flow has been solved, and the main aspect considered is network security maximization. In [12] is proposed to improve the voltage stability index by using Hybrid differential evolution algorithm. In [13] Biogeography Based algorithm proposed to solve the reactive power dispatch problem. In [14] a fuzzy based method is used to solve the optimal reactive power scheduling method and it minimizes real power loss and maximizes Voltage Stability Margin. 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 standard algorithm is used to solve ac-dc optimal reactive power flow model with the generator capability limits .In [18] proposed a two-step approach to evaluate Reactive power reserves with respect to operating constraints and voltage stability. In [19] a programming based proposed approach used to solve the optimal reactive power dispatch problem. In [20] is presented a probabilistic algorithm for optimal reactive power provision in hybrid electricity markets with uncertain loads. This research paper proposes a new Salmo Salar (SS) algorithm for Solving Optimal Reactive Power Dispatch Problem. The investigational proof shows that these SS have a preference to cross from ponds and lakes moderately than canyons and timbered passages. Each of these ways is integrated with their own natural menaces. Commercial fishers are focussed on the ponds and ocean pathways while Grizzly bears hunt the Salmo salar that pass through mountain's canyons and timbered regions. Each of these two main hunters utilizes different techniques for hunting Salmo salar with higher virtues. SS utilize all above steps to handle an optimal reactive power dispatch problem .Proposed SS been evaluated in standard IEEE 30 bus test system & the simulation results shows that our proposed approach outperforms all reported algorithms in minimization of real power loss and voltage stability index .

2. Voltage Stability Evaluation

2.1. Modal Analysis for Voltage Stability Evaluation

Modal analysis is one among best methods for voltage stability enhancement in power systems. The steady state system power flow equations are given by.

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_{p\theta} & J_{pv} \\ J_{q\theta} & J_{QV} \end{bmatrix} \begin{bmatrix} \Delta\theta \\ \Delta V \end{bmatrix} \tag{1}$$

Where
ΔP = Incremental change in bus real power.
ΔQ = Incremental change in bus reactive Power injection
$\Delta\theta$ = incremental change in bus voltage angle.
ΔV = Incremental change in bus voltage Magnitude

$J_{p\theta}$, J_{PV} , $J_{Q\theta}$, J_{QV} jacobian matrix are the sub-matrixes of the System voltage stability is affected by both P and Q.

To reduce (1), let $\Delta P = 0$, then.
$$\Delta Q = \left[J_{QV} - J_{Q\theta}J_{P\theta}{}^{-1}J_{PV}\right]\Delta V = J_R\Delta V \tag{2}$$
$$\Delta V = J^{-1} - \Delta Q \tag{3}$$

Where
$$J_R = \left(J_{QV} - J_{Q\theta}J_{P\theta}{}^{-1}JPV\right) \tag{4}$$
J_R is called the reduced Jacobian matrix of the system.

2.2. Modes of Voltage Instability

Voltage Stability characteristics of the system have been identified by computing the Eigen values and Eigen vectors.
Let
$$J_R = \xi\wedge\eta \tag{5}$$

Where,
ξ = right eigenvector matrix of JR
η = left eigenvector matrix of JR
$\wedge$ = diagonal eigenvalue matrix of JR and
$$J_R{}^{-1} = \xi\wedge^{-1}\eta \tag{6}$$

From (5) and (8), we have
$$\Delta V = \xi\wedge^{-1}\eta\Delta Q \tag{7}$$
          or
$$\Delta V = \sum_I \frac{\xi_i\eta_i}{\lambda_i}\Delta Q \tag{8}$$

Where ξ_i is the ith column right eigenvector and η the ith row left eigenvector of JR.
λ_i is the ith Eigen value of JR.

The ith modal reactive power variation is,
$$\Delta Q_{mi} = K_i\xi_i \tag{9}$$
  where,
$$K_i = \sum_j \xi_{ij}{}^2 - 1 \tag{10}$$

Where
ξji is the jth element of ξi

The corresponding ith modal voltage variation is
$$\Delta V_{mi} = [1/\lambda_i]\Delta Q_{mi} \tag{11}$$
If $| \lambda i | = 0$ then the ith modal voltage will collapse .

In (10), let $\Delta Q = ek$ where ek has all its elements zero except the kth one being 1. Then,
$$\Delta V = \sum_i \frac{\eta_{1k} \xi_1}{\lambda_1} \tag{12}$$
η_{1k} k th element of η_1
V –Q sensitivity at bus k
$$\frac{\partial V_K}{\partial Q_K} = \sum_i \frac{\eta_{1k} \xi_1}{\lambda_1} = \sum_i \frac{P_{ki}}{\lambda_1} \tag{13}$$

3. Problem Formulation

The objectives of the reactive power dispatch problem is to minimize the system real power loss and maximize the static voltage stability margins (SVSM).

3.1. Minimization of Real Power Loss

Minimization of the real power loss (Ploss) in transmission lines is mathematically stated as follows.
$$P_{loss=} \sum_{\substack{k=1\\k=(i,j)}}^n g_{k(V_i^2+V_j^2-2V_i V_j \cos \theta_{ij})} \tag{14}$$

Where n is the number of transmission lines, gk is the conductance of branch k, Vi and Vj are voltage magnitude at bus i and bus j, and θij is the voltage angle difference between bus i and bus j.

3.2. Minimization of Voltage Deviation

Minimization of the voltage deviation magnitudes (VD) at load buses is mathematically stated as follows.
$$\text{Minimize VD} = \sum_{k=1}^{nl}|V_k - 1.0| \tag{15}$$
Where nl is the number of load busses and Vk is the voltage magnitude at bus k.

3.3. System Constraints

Objective functions are subjected to these constraints shown below.
Load flow equality constraints:
$$P_{Gi} - P_{Di} - V_{i\sum_{j=1}^{nb} V_j} \begin{bmatrix} G_{ij} & \cos \theta_{ij} \\ +B_{ij} & \sin \theta_{ij} \end{bmatrix} = 0, i = 1,2 \dots, nb \tag{16}$$

$$Q_{Gi} - Q_{Di} - V_{i\sum_{j=1}^{nb} V_j} \begin{bmatrix} G_{ij} & \sin \theta_{ij} \\ +B_{ij} & \cos \theta_{ij} \end{bmatrix} = 0, i = 1,2 \dots, nb \tag{17}$$

where, nb is the number of buses, PG and QG are the real and reactive power of the generator, PD and QD are the real and reactive load of the generator, and Gij and Bij are the mutual conductance and susceptance between bus i and bus j.

Generator bus voltage (VGi) inequality constraint:
$$V_{Gi}^{min} \leq V_{Gi} \leq V_{Gi}^{max}, i \in ng \tag{18}$$

Load bus voltage (VLi) inequality constraint:
$$V_{Li}^{min} \leq V_{Li} \leq V_{Li}^{max}, i \in nl \tag{19}$$

Switchable reactive power compensations (QCi) inequality constraint:
$$Q_{Ci}^{min} \leq Q_{Ci} \leq Q_{Ci}^{max}, i \in nc \tag{20}$$

Reactive power generation (QGi) inequality constraint:
$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max}, i \in ng \tag{21}$$

Transformers tap setting (Ti) inequality constraint:
$$T_i^{min} \leq T_i \leq T_i^{max}, i \in nt \tag{22}$$

Transmission line flow (SLi) inequality constraint:
$$S_{Li}^{min} \leq S_{Li}^{max}, i \in nl \tag{23}$$

Where, nc, ng and nt are numbers of the switchable reactive power sources, generators and transformers.

4. Salmo Salar (SS) Algorithm

Salmo salar phenomena are one of the annual natural events happening in the North America. And millions of Salmo salar move about through mountain streams for spawning. Since these creatures provide one among the food sources for living organisms, their way upstream is filled with serious danger. Among them, hungry Grizzly bears, human fishers and also waterfalls are most critical dangers that they have to face. The hungry Grizzly bears gather together in timbered valleys where they hunt for whatever food source they can find. However, they can barely find food and also they are in threat by hungry wolves. Salmo salar are the most significant food source for these hungry bears. Bears converse with each other to find a way with higher amount of plump Salmo salar. In fact, they follow the swarm intelligence system for hunting Salmo salar with superior merits. Humans are one of the other key hunters of Salmo salar. These fishers often assemble in Alaska where there is a fitting condition for hunting ample of Salmo salar. Humans often imitate some miscellaneous heuristic methodologies to find a region that possesses Salmo salar with higher class and number. They employ scout ships for investigate the whole way region. The rest of the fishers are incorporated in areas with higher Salmo salar concentration. At the commencement of the Salmo salar relocation, they divide into subgroups using their intuition and some stochastic interprets. Each of these groups follows dissimilar pathways to their target. Some of them choose timbered passages which are full of different unsafe hunters such as Grizzly bears and sharks, while others move towards oceans, lakes and ponds. This concept has

been utilized to create a novel intellectual optimization algorithm. The investigational proof shows that these creatures have a preference to cross from ponds and lakes moderately than canyons and timbered passages [21-24]. Each of these ways is integrated with their own natural menaces. Commercial fishers are focussed on the ponds and ocean pathways while Grizzly bears hunt the Salmo salar that pass through mountain's canyons and timbered regions [24]. Each of these two main hunters utilizes different techniques for hunting Salmo salar with higher virtues. Salmo salar (SS) utilize all above steps to handle an optimal reactive power dispatch problem.

4.1. Initialization

The solutions are initialized stochastically with a leg on each side of to the passage supremacy (between lower bound and upper bounds). Equation (24) represents a procedure which is used to initialize random solutions with respect to the solution space.

$$Initial\ solution = lb + rand * (ub - lb) \tag{24}$$

Where lb and ub are the lower and upper bounds, respectively and rand is a random number with a leg on each side of to 0 and 1 with a standardized allocation.

4.2. Pathways for Movement

Before movement, Salmo salar decide their pathway based on their intuition. This suggests a stochastic shuffling control parameter for thrusting the Salmo salar groups (initial solutions) in both pathways (evolutionary operators). Equation (25) formulates a numerical form of this procedure.

$$solution\ sharing : \begin{cases} N_{P_1} = [\mu * P_s] \\ N_{P_2} = P_s - N_{P_1} \end{cases} \tag{25}$$

Where N_{P_1} is the number of Salmo salar groups passing through ocean and ponds, N_{P_2} is the number of Salmo salar group passing through forested regions and mountain canyons, P_s is the number of all Salmo salar groups which participate in the migration and μ is a sharing factor that represents the Salmo salar instinct.

Crossing ocean, Lakes and Ponds

This investigation has been mathematically modelled as

$$\begin{cases} X_N = X_F + \delta(t, (ub - X_F)) \\ X_N = X_F + \delta(t, (X_F - lb)) \end{cases} \tag{26}$$

Where t represents the current iteration number, X_N represents a new detected region (new solution) and X_F shows the former region of the scout ship (former solution). $\delta(x, y)$ is Calculated using equation (27).

$$\delta(x, y) = y * rand * \left(1 - \frac{x}{T}\right)^b \tag{27}$$

Where T is the number of the maximum iteration, b is a random number larger than 1 and rand is a random number spanning to 0 and 1 with a uniform allocation.

The main hunters find regions with an acceptable Salmo salar concentration (solution fitness). After that, they inform the recruited agent to utilize nearby regions to find more intense areas (solution with higher fitness). This utilization has been accurately modelled in equation (28).

$$X_R = \beta * (X_{M1} - X_{M2}) + X_{M1} \tag{28}$$

Where β is a random number spanning to 0 and 1 with uniform distribution, XR represents the new detected solution by the recruited agent, XM1 is the solution obtained by the first main hunter and XM2 is the solution obtained by the second one.

4.3. Salmo salar Crossing Mountain Canyons and Forested Regions

The second operator simulates the Grizzly bears hunting line of attack. They always notify each other if they find a suitable region. If they find an area with higher Salmo salar intensity, they inform other bears. Bears hunting line of attack is scientifically expressed in equation (29),

$$X_B = cos(\varphi) * (B_R - L_R) + B_R \tag{29}$$

Where XB represents a new detected region, BR is the best reported region by the hunting team, LR is the current region for which the bears have decided to perform a local exploitation and φ is an arbitrary angle with a leg on each side of to 0 and 360 degrees. cos (φ) directs the bears to their destination.

4.4. Regrouping for Spawning

At the end of the relocation, the survived Salmo salar gather together in their target for spawning. In Salmo salar this natural event is simulated through a collection trunk. After Salmo salars pass through their pathways (operator's performance), the Salmo salar subgroups (solutions) are collected in a unique trunk. In other words, the solutions are extracted from both operators and make a unique population. At this state, the algorithm has reached the end of the first iteration.

Salmo salar algorithm for solving optimal reactive power problem.

Step 1. Set the control parameters (population size, solution space, number of variables, iterations)
Step2. Adjust the Salmo salar subgroups haphazardly
Step3. Picking the pathways depend on migration μ.
Step4.calculate the fitness of hunted Salmo salar (hunted by Grizzly bears, human fishers, scout ships)
Step5. Fold together Salmo salar for spawn
Step6. If yes take out the global solution or go to step 3.

5. Simulation Results

The efficiency of the proposed Salmo Salar (SS) algorithm is demonstrated by testing it on standard IEEE-30 bus system. The IEEE-30 bus system has 6 generator buses, 24 load buses and 41 transmission lines of which four branches are (6-9), (6-10) , (4-12) and (28-27) - are with the tap setting transformers. The lower voltage magnitude limits at all buses are 0.95 p.u. and the upper limits are 1.1 for all the PV buses and 1.05 p.u. for all the PQ buses and the reference bus. The simulation results have been presented in Tables 1, 2, 3 &4. And in the Table 5 shows the proposed algorithm powerfully reduces the real power losses when compared to other given algorithms. The optimal values of the control variables along with the minimum loss obtained are given in Table 1. Corresponding to this control variable setting, it was found that there are no limit violations in any of the state variables.

Table 1: Results of SS – ORPD optimal control variables

Control variables	Variable setting
V1	1.032
V2	1.038
V5	1.039
V8	1.031
V11	1.001
V13	1.01
T11	1.00
T12	1.00
T15	1.01
T36	1.01
Qc10	2
Qc12	2
Qc15	3
Qc17	0
Qc20	2
Qc23	3
Qc24	3
Qc29	2
Real power loss	4.2965
SVSM	0.2478

Optimal Reactive Power Dispatch problem together with voltage stability constraint problem was handled in this case as a multi-objective optimization problem where both power loss and maximum voltage stability margin of the system were optimized simultaneously. Table 2 indicates the optimal values of these control variables. Also it is found that there are no limit violations of the state variables. It indicates the voltage stability index has increased from 0.2478 to 0.2484, an advance in the system voltage stability. To determine the voltage security of the system, contingency analysis was conducted using the control variable setting obtained in case 1 and case 2. The Eigen values equivalents to the four critical contingencies are given in Table 3. From this result it is observed that the Eigen value has been improved considerably for all contingencies in the second case.

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Table 2: Results of SS -Voltage Stability Control Reactive Power Dispatch Optimal Control Variables

Control Variables	Variable Setting
V1	1.041
V2	1.040
V5	1.040
V8	1.031
V11	1.002
V13	1.032
T11	0.090
T12	0.090
T15	0.090
T36	0.090
Qc10	3
Qc12	3
Qc15	2
Qc17	3
Qc20	0
Qc23	2
Qc24	2
Qc29	3
Real power loss	4.9870
SVSM	0.2484

Table 3: Voltage Stability under Contingency State

Sl.No	Contingency	ORPD Setting	VSCRPD Setting
1	28-27	0.1409	0.1424
2	4-12	0.1649	0.1652
3	1-3	0.1769	0.1779
4	2-4	0.2029	0.2041

Table 4: Limit Violation Checking Of State Variables

State variables	Limits		ORPD	VSCRPD
	Lower	Upper		
Q1	-20	152	1.3422	-1.3269
Q2	-20	61	8.9900	9.8232
Q5	-15	49.92	25.920	26.001
Q8	-10	63.52	38.8200	40.802
Q11	-15	42	2.9300	5.002
Q13	-15	48	8.1025	6.033
V3	0.95	1.05	1.0372	1.0392
V4	0.95	1.05	1.0307	1.0328
V6	0.95	1.05	1.0282	1.0298
V7	0.95	1.05	1.0101	1.0152
V9	0.95	1.05	1.0462	1.0412
V10	0.95	1.05	1.0482	1.0498

V12	0.95	1.05	1.0400	1.0466
V14	0.95	1.05	1.0474	1.0443
V15	0.95	1.05	1.0457	1.0413
V16	0.95	1.05	1.0426	1.0405
V17	0.95	1.05	1.0382	1.0396
V18	0.95	1.05	1.0392	1.0400
V19	0.95	1.05	1.0381	1.0394
V20	0.95	1.05	1.0112	1.0194
V21	0.95	1.05	1.0435	1.0243
V22	0.95	1.05	1.0448	1.0396
V23	0.95	1.05	1.0472	1.0372
V24	0.95	1.05	1.0484	1.0372
V25	0.95	1.05	1.0142	1.0192
V26	0.95	1.05	1.0494	1.0422
V27	0.95	1.05	1.0472	1.0452
V28	0.95	1.05	1.0243	1.0283
V29	0.95	1.05	1.0439	1.0419
V30	0.95	1.05	1.0418	1.0397

Table 5: Comparison of Real Power Loss

Method	Minimum loss (MW)
Evolutionary programming [25]	5.0159
Genetic algorithm [26]	4.665
Real coded GA with Lindex as SVSM [27]	4.568
Real coded genetic algorithm [28]	4.5015
Proposed SS method	4.2965

6. Conclusion

In this paper, proposed Salmo Salar (SS) algorithm has been successfully implemented to solve optimal reactive power dispatch (ORPD) problem. The main advantages of SS when applied to the ORPD problem is optimization of different type of objective function, i.e real coded of both continuous and discrete control variables, and without difficulty in handling nonlinear constraints. Proposed SS algorithm has been tested in the IEEE 30-bus system. Simulation Results clearly show the good performance of the proposed SS algorithm in reducing the real power loss and enhancing the voltage profiles within the limits.

References

[1]   O.Alsac,and B. Scott, "Optimal load flow with steady state security",IEEE Transaction. PAS - 1973, pp. 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] A.Monticelli , M .V.F Pereira ,and S. Granville , "Security constrained optimal power flow with post contingency corrective rescheduling" , IEEE Transactions on Power Systems :PWRS-2, No. 1, pp.175-182.,1987.

[4] Deeb N ,Shahidehpur S.M ,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 PAS -99 (4) ,pp 868=877, 1980

[6] K.Y Lee ,Y.M Park , and J.L Oritz, "Fuel –cost optimization for both real and reactive power dispatches" , IEE Proc; 131C,(3), pp.85-93.

[7] M.K. Mangoli, and K.Y. Lee, "Optimal real and reactive power control using linear programming" , Electr.Power Syst.Res, Vol.26, pp.1-10,1993.

[8] C.A. Canizares , A.C.Z.de Souza and V.H. Quintana , " Comparison of performance indices for detection of proximity to voltage collapse ,'' vol. 11. no.3 , pp.1441-1450, Aug 1996 .

[9] Berizzi.C.Bovo,M.Merlo,andM.Delfanti,(2012), "A GA approach to compare ORPF objective functions including secondary voltage regulation," Electric Power Systems Research, vol. 84, no. 1, pp. 187 – 194.

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

[11] A.Berizzi, C. Bovo, M. Merlo, and M. Delfanti, "A ga approach to compare orpf objective functions including secondary voltage regulation," Electric Power Systems Research, vol. 84, no. 1, pp. 187 – 194, 2012.

[12] C.-F. Yang, G. G. Lai, C.-H. Lee, C.-T. Su, and G. W. 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, vol. 37, no. 1, pp. 50 – 57, 2012.

[13] P. Roy, S. Ghoshal, and 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, vol. 43, no. 1, pp. 830 – 838, 2012.

[14] B. Venkatesh, G. Sadasivam, and 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, vol. 15, no. 2, pp. 844 – 851, may 2000.

[15] W. Yan, S. Lu, and D. Yu, "A novel optimal reactive power dispatch method based on an improved hybrid evolutionary programming technique," IEEE Transactions on Power Systems, vol. 19, no. 2, pp. 913 – 918, may 2004.

[16] W. Yan, F. Liu, C. Chung, and K. Wong, "A hybrid genetic algorithminterior point method for optimal reactive power flow," IEEE Transactions on Power Systems, vol. 21, no. 3, pp. 1163 – 1169, aug. 2006.

[17] J. Yu, W. Yan, W. Li, C. Chung, and K. Wong, "An unfixed piecewiseoptimal reactive power-flow model and its algorithm for ac-dc systems," IEEE Transactions on Power Systems, vol. 23, no. 1, pp. 170 –176, feb. 2008.

[18] F. Capitanescu, "Assessing reactive power reserves with respect to operating constraints and voltage stability," IEEE Transactions on Power Systems, vol. 26, no. 4, pp. 2224–2234, nov. 2011.

[19] Z. Hu, X. Wang, and G. Taylor, "Stochastic optimal reactive power dispatch: Formulation and solution method," International Journal of Electrical Power and Energy Systems, vol. 32, no. 6, pp. 615 – 621, 2010.

[20] A.Kargarian, M. Raoofat, and M. Mohammadi, "Probabilistic reactive power procurement in hybrid electricity markets with uncertain loads," Electric Power Systems Research, vol. 82, no. 1, pp. 68 – 80, 2012.

[21] Mozaffari, A. Fathi, S. Behzadipour, The Great Salmon Run: A novel bio-inspired algorithm for artificial system design and optimization, International Journal of Bio-Inspired Computation 4 (2012) 286-301.

[22] Fathi, A. Mozaffari, Modeling a shape memory alloy actuator using an evolvable recursive black-box and hybrid heuristic algorithms inspired based on the annual migration of salmons in nature, Applied Soft Computing 14 (2014) 229-251.

[23] L.F. Sundstom, E. Petersson, J.I. Johnsson, Heart rate responses to predation risk in Salmo trutta are affected by the rearing environment, International Journal of Fish Biology 67(2005) 1280–1286.

[24] E.B. Taylor, A review of local adaptation in Salmonidae, with particular reference to Atlantic andPacific salmon, International Journal of Aquaculture 98(1991) 185–207.

[25] Wu Q H, Ma J T. "Power system optimal reactive power dispatch using evolutionary programming", IEEE Transactions on power systems 1995; 10(3): 1243-1248 .

[26] S.Durairaj, D.Devaraj, P.S.Kannan ,"Genetic algorithm applications to optimal reactive power dispatch with voltage stability enhancement", IE(I) Journal-EL Vol 87,September 2006.

[27] D.Devaraj , "Improved genetic algorithm for multi – objective reactive power dispatch problem", European Transactions on electrical power 2007 ; 17: 569-581.

[28] P. Aruna Jeyanthy and Dr. D. Devaraj "Optimal Reactive Power Dispatch for Voltage Stability Enhancement Using Real Coded Genetic Algorithm", International Journal of Computer and Electrical Engineering, Vol. 2, No. 4, August, 2010 1793-8163.

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