International Journal of Energy and Power Engineering
2014; 3(2): 77-82
Published online April 30, 2014 (http://www.sciencepublishinggroup.com/j/ijepe)
doi: 10.11648/j.ijepe.20140302.16

Grand salmon run algorithm for solving optimal reactive power dispatch problem

K. Lenin, B. Ravindranath Reddy, M. Surya Kalavathi

Jawaharlal Nehru Technological University Kukatpally, Hyderabad, India

Email address:
gklenin@gmail.com (K. Lenin)

To cite this article:
K. Lenin, B. Ravindranath Reddy, M. Surya Kalavathi. Grand Salmon Run Algorithm for Solving Optimal Reactive Power Dispatch Problem. *International Journal of Energy and Power Engineering.* Vol. 3, No. 2, 2014, pp. 77-82. doi: 10.11648/j.ijepe.20140302.16

Abstract: The chief aspect of solving Optimal Reactive Power Dispatch Problem (ORPD) is to minimize the real power loss and also to keep the voltage profile within the limits. In this paper, a new metaheuristic optimizing algorithm that is the simulation of "Grand Salmon Run" (GSR) is developed. The salmon run phenomena is one of the grand annual natural actions occurrence in the North America, where millions of salmons travel through mountain streams for spawn. The proposed GSR has been validated, by applying it on standard IEEE 30 bus test system. The results have been compared to other heuristics methods and the simulation results reveals about the good performance of the proposed algorithm.

Keywords: Nature-Inspired Algorithm, Salmon Run Metaheuristic, Optimal Reactive Power, Transmission Loss

1. Introduction

Reactive power optimization plays a vital job in optimal operation of power systems. Many papers by various authors has been projected to solve the optimal reactive power dispatch (ORPD) problems such as, gradient based optimization algorithm [1,2], quadratic programming, non linear programming [3] and interior point method [4-7]. In recent years standard genetic algorithm (SGA) [8] and the adaptive genetic algorithm (AGA) [9], Partial swarm optimization PSO [10-11] have been applied for solving ORPD problems. The inability of the power system to meet the demand for reactive power to preserve regular voltage profile in stressed situations acts very significant role in causing voltage collapse. In the past many innovative algorithms such as Evolutionary Algorithm [12-13], Genetic algorithm [14-15], Evolutionary strategies [16-18], Differential Evolution [19-20], Genetic programming [21] and Evolutionary programming [22] are used to solve many rigid problems in optimization. In this research paper Grand Salmon Run [23-24] is used to solve the ORPD Problem. This algorithm (GSR) is applied to obtain the optimal control variables so as to improve the voltage stability level of the system. The performance of the proposed method has been tested on IEEE 30 bus system and the results are compared with the standard GA and PSO method.

2. Problem Formulation

The Optimal Power Flow problem has been considered as general minimization problem with constraints, and can be mathematically written as :

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

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

and

$$h(x,u) \le 0 \quad (3)$$

Where f(x, u) is the objective function. g(x. u) and h(x, u) are respectively the set of equality and inequality constraints. x is the vector of state variables, and u is the vector of control variables.

The state variables are the load buses (PQ buses) voltages, angles, the generator reactive powers and the slack active generator power:

$$x = \left(P_{g1}, \theta_2, .., \theta_N, V_{L1}, ., V_{LNL}, Q_{g1}, .., Q_{gng}\right)^T \quad (4)$$

The control variables are the generator bus voltages, the shunt capacitors and the transformers tap-settings:

$$u = \left(V_g, T, Q_c\right)^T \quad (5)$$

or

$$u = \left(V_{g1}, \ldots, V_{gng}, T_1, \ldots, T_{Nt}, Q_{c1}, \ldots, Q_{cNc}\right)^T \quad (6)$$

Where Ng, Nt and Nc are the number of generators, number of tap transformers and the number of shunt compensators respectively.

3. Objective Function

3.1. Active Power Loss

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

$$F = PL = \sum_{k \in Nbr} g_k \left(V_i^2 + V_j^2 - 2V_iV_j cos\theta_{ij}\right) \quad (7)$$

or

$$F = PL = \sum_{i \in Ng} P_{gi} - P_d = P_{gslack} + \sum_{i \neq slack}^{Ng} P_{gi} - P_d \quad (8)$$

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.

3.2. Voltage Profile Improvement

For minimization of the voltage deviation in PQ buses, the objective function formulated as:

$$F = PL + \omega_v \times VD \quad (9)$$

Where ω_v: is a weighting factor of voltage deviation.

VD is the voltage deviation given by:

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \quad (10)$$

3.3. Equality Constraint

The equality constraint g(x, u) of the ORPD problem is represented by the power balance equation, where the total power generation must envelop the total power demand and the power losses:

$$P_G = P_D + P_L \quad (11)$$

3.4. Inequality Constraints

The inequality constraints h(x, u) imitate the limits on components in the power system as well as the limits created to guarantee system security. Upper and lower bounds on the active power of slack bus, and reactive power of generators:

$$P_{gslack}^{min} \leq P_{gslack} \leq P_{gslack}^{max} \quad (12)$$

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max}, i \in N_g \quad (13)$$

Upper and lower bounds on the bus voltage magnitudes:

$$V_i^{min} \leq V_i \leq V_i^{max}, i \in N \quad (14)$$

Upper and lower bounds on the transformers tap ratios:

$$T_i^{min} \leq T_i \leq T_i^{max}, i \in N_T \quad (15)$$

Upper and lower bounds on the compensators reactive powers:

$$Q_c^{min} \leq Q_c \leq Q_C^{max}, i \in N_C \quad (16)$$

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.

4. Grand Salmon Run

Grand salmon run phenomena is one of the annual natural events happening in the North America. And millions of salmons 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. Salmons are the most significant food source for these hungry bears. Bears converse with each other to find a way with higher amount of plump salmons. In fact, they follow the swarm intelligence system for hunting salmons with superior merits. Humans are one of the other key hunters of salmons. These fishers often assemble in Alaska where there is a fitting condition for hunting ample of salmons. Humans often imitate some miscellaneous heuristic methodologies to find a region that possesses salmons 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 salmon's concentration. At the commencement of the salmon's 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 salmon sharks while others move towards oceans, lakes and ponds. This concept has been utilized to create a novel intellectual optimization algorithm. Fig 1,2,3,4 shows about the salmon run, get hunted by bear, flow through timbers and get hunted by fisher men.

Fig 1. *Grand Salmon Run.*

Fig 2. *Salmon get hunted by bear.*

Fig 3. *Salmon passing woods.*

Fig 4. *Salmon get hunted by fishermen.*

The investigational proof shows that these creatures have a preference to cross from ponds and lakes moderately than canyons and timbered passages [25]. 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 salmons that pass through mountain's canyons and timbered regions [26]. Each of these two main hunters utilizes different techniques for hunting salmons with higher virtues. GSR 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 (17) represents a procedure which is used to initialize random solutions with respect to the solution space.

$$Initial\ solution = lb + rand * (ub - lb) \quad (17)$$

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, salmons decide their pathway based on their intuition. This suggests a stochastic shuffling control parameter for thrusting the salmon groups (initial solutions) in both pathways (evolutionary operators). Equation (18) formulates a numerical form of this procedure.

$$solution\ sharing : \begin{cases} N_{P_1} = [\mu * P_s] \\ N_{P_2} = P_s - N_{P_1} \end{cases} \quad (18)$$

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

A. Crossing Lakes and Ponds

Fig 5. *Salmon crossing the water flow.*

This investigation has been shown in Fig 5 and has been mathematically modelled as

$$\begin{cases} X_N = X_F + \delta\big(t, (ub - X_F)\big) \\ X_N = X_F + \delta\big(t, (X_F - lb)\big) \end{cases} \quad (19)$$

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 (20).

$$\delta(x, y) = y * rand * \left(1 - \frac{x}{T}\right)^b \quad (20)$$

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 salmon 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 (21).

$$X_R = \beta * (X_{M1} - X_{M2}) + X_{M1} \quad (21)$$

Where β is a random number spanning to 0 and 1 with uniform distribution, X_R represents the new detected solution by the recruited agent, X_{M1} is the solution obtained by the first main hunter and X_{M2} is the solution obtained by the second one.

4.3. 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 salmon intensity, they inform other bears. Bears hunting line of attack is scientifically expressed in equation (22),

$$X_B = cos(\varphi) * (B_R - L_R) + B_R \quad (22)$$

Where X_B represents a new detected region, B_R is the best reported region by the hunting team, L_R 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 salmons gather together in their target for spawning. In GSR, this natural event is simulated through a collection trunk. After salmons pass through their pathways (operator's performance), the salmon 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.

GSR algorithm for solving optimal reactive power problem.

- Step 1. Setting the control parameters (population size, solution space, number of variables, iterations)
- Step2. Initialize the salmon subgroups randomly
- Step3. Choosing the pathways depend on migrationμ.
- Step4.compute the fitness of hunted salmon (hunted by Grizzly bears, human fishers, scout ships)
- Step5. Gather together salmon for spawn
- Step6. If yes take out the global solution or go to step 3.

5. Simulation Results

GSR algorithm has been tested on the IEEE 30-bus, 41 branch system. It has a total of 13 control variables as follows: 6 generator-bus voltage magnitudes, 4 transformer-tap settings, and 2 bus shunt reactive compensators. Bus 1 is the slack bus, 2, 5, 8, 11 and 13 are taken as PV generator buses and the rest are PQ load buses. The variables limits are listed in table 1.

Table 1. *Initial Variables Limits (PU).*

Control variables	Min. value	Max. value	Type
Generator: Vg	0.90	1.10	Continuous
Load Bus: VL	0.93	1.03	Continuous
T	0.92	1.03	Discrete
Qc	-0.11	0.32	Discrete

The transformer taps and the reactive power source installation are discrete with the changes step of 0.01. The power limits generators buses are represented in Table2. Generators buses are: PV buses 2,5,8,11,13 and slack bus is 1.the others are PQ-buses.

Table 2. *Generators Power Limits in MW and MVAR.*

Bus n°	Pg	Pgmin	Pgmax	Qgmin
1	97.00	50	200	-20
2	80.00	22	80	-20
5	52.00	16	52	-14
8	20.00	11	32	-14
11	20.00	11	28	-10
13	20.00	13	40	-14

Table 3. *Values of Control Variables after Optimization and Active Power Loss.*

Control Variables (p.u)	GSR
V1	1.0231
V2	1.0240
V5	1.0204
V8	1.0261
V11	1.0721
V13	1.0431
T4,12	0.00
T6,9	0.02
T6,10	0.90
T28,27	0.90
Q10	0.10
Q24	0.10
PLOSS	4.8901
VD	0.8992

The proposed approach succeeds in maintenance the dependent variables within their limits. Table 4 summarize the results of the optimal solution obtained by PSO, SGA and GSR methods. It reveals the decrease of real power loss after optimization.

Table 4. *Comparison Results.*

SGA[9]	PSO[10]	GSR
4.98 Mw	4.9262Mw	4.8901Mw

6. Conclusion

In this paper, the proposed GSR has been successfully implemented to solve ORPD problem. The main advantage of the algorithm is solving the objective function with real coded of both continuous, discrete control variables, and easily handling nonlinear constraints. The proposed algorithm has been tested on the IEEE 30-bus system .And the results were compared with the other heuristic methods such as SGA and PSO algorithm reported in the literature.

References

[1] H.W. Dommel, W.F. Tinney. Optimal power flow solutions. IEEE, Trans. On power Apparatus and Systems, VOL. PAS-87, octobre 1968,pp.1866-1876.

[2] Lee K, Park Y, Ortiz J. A. United approach to optimal real and reactive power dispatch. IEEE Trans Power Appar. Syst. 1985; 104(5):1147-53.

[3] Y. Y. Hong, D.I. Sun, S. Y. Lin and C. J. Lin. Multi-year multi-case optimal AVR planning. IEEE Trans. Power Syst., vol.5 , no.4, pp.1294-1301,Nov.1990.

[4] J. A. Momoh, S. X. GUO, E .C. Ogbuobiri, and R. Adapa. The quadratic interior point method solving power system optimization problems. IEEE Trans. Power Syst. vol. 9, no. 3, pp. 1327-1336,Aug.1994.

[5] S. Granville. Optimal Reactive Dispatch Through Interior Point Methods. IEEE Trans. Power Syst. vol. 9, no. 1, pp. 136-146, Feb. 1994.

[6] J.A. Momoh, J. Z. Zhu. Improved interior point method for OPF problems. IEEE Trans. On power systems; Vol. 14, No. 3, pp. 1114-1120, August 1999.

[7] Y.C. Wu, A. S. Debs, and R.E. Marsten. A Direct nonlinear predictor-corrector primal-dual interior point algorithm for optimal power flows. IEEE Transactions on power systems Vol. 9, no. 2, pp 876-883, may 1994.

[8] L.L .Lai, J.T. Ma, R. Yokoma, M. Zhao. Improved genetic algorithms for optimal power flow under both normal and contingent operation states. Electrical Power & Energy System, Vol. 19, No. 5, p. 287-292, 1997.

[9] Q.H. Wu, Y.J.Cao, and J.Y. Wen. Optimal reactive power dispatch using an adaptive genetic algorithm. Int. J. Elect. Power Energy Syst. Vol 20. Pp. 563-569; Aug 1998.

[10] B. Zhao, C. X. Guo, and Y.J. CAO. Multiagent-based particle swarm optimization approach for optimal reactive power dispatch. IEEE Trans. Power Syst. Vol. 20, no. 2, pp. 1070-1078, May 2005.

[11] J. G. Vlachogiannis, K.Y. Lee. A Comparative study on particle swarm optimization for optimal steady-state performance of power systems. IEEE trans. on Power Syst., vol. 21, no. 4, pp. 1718-1728, Nov. 2006.

[12] A.E. Eiben and J.E. Smith. Introduction to Evolutionary Computing. Springer-Verlag, Berlin, 2003.

[13] Charles Darwin. The origin of species. John Murray, London, UK, 1859.

[14] D. Goldberg. Genetic Algorithms in Search, Optimization, and Machine Learning. Addison-Wesley, MA, 1996.

[15] John H. Holland. Adaptation in Natural and Artificial Systems: An Introductory Analysis with Applications to Biology, Control and Artificial Intelligence. MIT Press, Cambridge, MA, USA, 1992.

[16] Thomas B¨ack. Evolutionary algorithms in theory and practice - evolution strategies, evolutionary programming, genetic algorithms. Oxford University Press, 1996.

[17] Fister, M. Mernik, and B. Filipiˇc. Graph 3-coloring with a hybrid self-adaptive evolutionary algorithm. Computational optimization and applications, pages 1–32, 2012.

[18] F. Neri and V. Tirronen. Recent advances in differential evolution: a survey and experimental analysis. Artificial Intelligence Review, 33(1–2):61–106, 2010.

[19] J. Brest, S. Greiner, B. Boskovic, M. Mernik, and V. Zumer. Selfadapting control parameters in differential evolution: A comparative study on numerical benchmark problems. Evolutionary Computation, IEEE Transactions on, 10(6):646–657, 2006.

[20] S. Das and P.N. Suganthan. Differential evolution: A survey of the state-of-the-art. Evolutionary Computation, IEEE Transactions on, 15(1):4–31, 2011.

[21] John R. Koza. Genetic programming 2 - automatic discovery of reusable programs. Complex adaptive systems. MIT Press, 1994.

[22] L. J. Fogel, A. J. Owens, and M. J. Walsh. Artificial Intelligence through Simulated Evolution. John Wiley, New York, USA, 1966.

[23] B´enichou, O., Loverdo, C., Moreau, M., and Voituriez, R., Twodimensional intermittent search processes: An alternative to L´evy flight strategies, Phys. Rev., E74, 020102(R), (2006).

[24] 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.

[25] 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.

[26] 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.

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

Biography

K. Lenin has received his B.E., Degree, electrical and electronics engineering in 1999 from university of madras, Chennai, India and M.E., Degree in power systems in 2000 from Annamalai University, TamilNadu, India. Presently pursuing Ph.D., degree at JNTU, Hyderabad, India.

Bhumanapally. RavindhranathReddy, Born on 3rd September,1969. Got his B. Tech in Electrical & Electronics Engineering from the J.N.T.U. College of Engg., Anantapur in the year 1991. Completed his M. Tech in Energy Systems in IPGSR of J.N.T. University Hyderabad in the year 1997. Obtained his doctoral degree from JNTUA, Anantapur University in the field of Electrical Power Systems. Published 12 Research Papers and presently guiding 6 Ph.D. Scholars. He was specialized in Power Systems, High Voltage Engineering and Control Systems. His research interests include Simulation studies on Transients of different power system equipment.

M. Surya Kalavathi has received her B. Tech. Electrical and Electronics Engineering from SVU, Andhra Pradesh, India and M. Tech, power system operation and control from SVU, Andhra Pradesh, India. she received her Phd. Degree from JNTU, hyderabad and Post doc. From CMU – USA. Currently she is Professor and Head of the electrical and electronics engineering department in JNTU, Hyderabad, India and she has Published 16 Research Papers and presently guiding 5 Ph.D. Scholars. She has specialised in Power Systems, High Voltage Engineering and Control Systems. Her research interests include Simulation studies on Transients of different power system equipment. She has 18 years of experience. She has invited for various lectures in institutes.