PSO approach for Reactive Power Optimisation

Sharad Chandra Rajpoot[1] Prashant Singh Rajpoot[2] Sanjay Kumar Singhai[3] Anil Kumar Shukla[4]
[1,2]Assistant Professor [3]Professor [4]Associate Professor
[1,2,3,4]Department of Electrical Engineering
[1]G.E.C. Jagdalpur, Bastar, Chhattisgarh, India [2]L.C.I.T., Bilaspur, Chhattisgarh India [3,4]G.E.C. Bilaspur, Chhattisgarh, India

Abstract— the reactive power compensation approached with primary objective of reactive power generation and the secondary aim to mitigate the active power losses with the voltage and reactive power constrains. Voltage optimization is a term given to the systematic controlled reduction in the voltages received by an energy consumer to reduce energy use, power demand and reactive power demand. While some voltage 'optimization' devices have a fixed voltage adjustment, others electronically regulate the voltage automatically. Voltage optimization is an electrical energy saving technique which is mainly installed in series with the mains electricity supply to provide a reduced supply voltage for the site's equipment. Typically, voltage optimization can improve power quality by balancing phase voltages and filtering harmonics and transients from the supply, although not always. Voltage optimizers are essentially transformers used to deliver power at a reduced voltage from the raw mains supply.

Key words: Voltage Optimization, Voltage and Reactive Power Constrains, Active Power, Reactive Power, Reactive Power Compensation

I. INTRODUCTION

In computer science, particle swarm optimization (PSO) is a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. It solves a problem by having a population of candidate solutions, here dubbed particles, and moving these particles around in the search-space according to simple mathematical formulae over the particle's position and velocity.[2] Each particle's movement is influenced by its local best known position, but is also guided toward the best known positions in the search-space, which are updated as better positions are found by other particles. This is expected to move the swarm toward the best solutions.[1]

PSO is a metaheuristic as it makes few or no assumptions about the problem being optimized and can search very large spaces of candidate solutions. However, metaheuristics such as PSO do not guarantee an optimal solution is ever found. Also, PSO does not use the gradient of the problem being optimized, which means PSO does not require that the optimization problem be differentiable as is required by classic optimization methods such as gradient descent and quasi-newton methods.[4]

II. REACTIVE POWER OPTIMISATION USING PSO

A. Overview

The purpose of Reactive Power Dispatch is mainly to improve the voltage profile in the system and to minimize the real power transmission loss while satisfying the unit and system constraints. [6]This goal is achieved by proper adjustment of reactive power control variables like Generator bus voltage magnitudes (V_{gi}), transformer tap settings (t_i), reactive power generation of the capacitor bank (Q_{ci}).

To solve the RPD problem, a number of conventional optimization techniques have been proposed. These include the Gradient method, Non-linear Programming (NLP), Quadratic Programming (QP), Linear programming (LP) and Interior point method. Though these techniques have been successfully applied for solving the reactive power dispatch problem, still some difficulties are associated with them. One of the difficulties is the multimodal characteristic of the problems to be handled. Also, due to the non-differential, non-linearity and non-convex nature of the RPD problem, majority of the techniques converge to a local optimum. Recently, Evolutionary Computation techniques like Genetic Algorithm (GA) [11], Evolutionary Programming (EP) [12] and Evolutionary Strategy [13] have been applied to solve the optimal dispatch problem. In this chapter Particle swarm optimization has been proposed to solve Reactive Power Dispatch problem.

B. Problem Formulation

The objective of RPD is to identify the reactive power control variables, which minimizes the Real power loss (P_{loss}) of the system. This is mathematically stated as follows:

Minimize F= [f1]

$$\boxed{f_1 = P_{loss} = \sum_{\substack{k\in N_l \\ k=(i,j)}} g_k (V_i^2 + V_j^2 - 2V_iV_j Cos\theta_{ij})} \quad (1)$$

The reactive power optimization problem is subjected to the following constraints.

1) Equality Constraints

These constraints represent load flow equation such as

$$\boxed{P_i - V_i \sum_{j=1}^{N_B} V_j (G_{ij} Cos\theta_{ij} + B_{ij} Sin\theta_{ij}) = 0, i \in N_B - 1} \quad (2)$$

$$\boxed{Q_i - V_i \sum_{j=1}^{N_B} V_j (G_{ij} Sin\theta_{ij} - B_{ij} Cos\theta_{ij}) = 0, i \in N_{PQ}} \quad (3)$$

2) Inequality Constraints

These constraints represent the system operating constraints. Generator bus voltages (V_{gi}), reactive power generated by the capacitor (Q_{ci}), transformer tap setting (t_k), are control variables and they are self-restricted. Load bus voltages (V_{load}) reactive power generation of generator (Q_{gi}) and line flow limit (S_l) are state variables, whose limits are satisfied by adding a penalty terms in the objective function. These constraints are formulated as

a) Voltage limits

$$V_i^{min} \le V_i \le V_i^{max} ; i \in N_B \quad (4)$$

b) Generator reactive power capability limit

$$Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max} ; i \in N_g \quad (5)$$

c) Capacitor reactive power generation limit

$$Q_{ci}^{min} \le Q_{ci} \le Q_{ci}^{max} ; i \in N_c \quad (6)$$

d) Transformer tap setting limit

$$t_k^{min} \le t_k \le t_k^{max}\ ; i \in N_T \qquad (7)$$

e) Transmission line flow limit

$$S_l \le S_l^{max}\ ; l \in N_l \qquad (8)$$

C. Evaluation Function

Each particle consists of voltages, taps and shunts encoded in it. The size of each particle is equal to sum of no of voltages excluding slack bus voltage, taps, and shunts. The fitness function employed is

$$\text{Fit(ii)}=\frac{100}{100+\text{loss}} \qquad (9)$$

III. ALGORITHM

1) Read the system data.
2) Form Ybus matrix. Form B1 sub matrix. Decompose B1 by Cholesky decomposition.
3) Randomly initialize population and velocities of particles.
4) Set Pbest=0 and iteration count=1.
5) Set particle count=1
6) Decode the particle. Decoded particle gives the values of voltage magnitudes, tap values and shunts.
7) Form the Y_{bus} and B2 sub matrix from Y_{bus} computed in step8.Decompose B2 by Cholesky decomposition
8) Run FDC load flow. From converged voltages compute total system transmission Loss, stability index from Eq (5.1), emission cost, fuel cost.
9) Calculate the evaluation value of each individual in the population using Eq.(5.9). Compare each individual's evaluation value with its P_{best} . If the evaluation value of each individual is better than the previous P_{best}, the current value is set to be P_{best}.
10) Increment individual count by 1. If count < population size go to step (6).
11) The best evaluation value among the P_{bests} is denoted as g_{best}.
12) Modify the member velocity V of each individual according to

$$v_i^{k+1} = k*(w* v_i^k + c_1*rand_1*(pbest_i - x_i) + c_2*rand_2*(gbest_i - x_i))$$

$$x_i^{k+1}= x_i + v_i^{k+1}$$

13) Modify the member position of each individual Pi according to $Pi^{(k+1)}=Pi^{(k)}+Vi^{(k+1)}$ $Pi^{(k+1)}$ must satisfy the constraints.
14) Increment iteration count by 1.If the number of iterations reaches the maximum, then go to Step 15, Otherwise, go to Step 5
15) The individual that generates the latest g_{best}, is the required control vector for the loss optimization sub problem. Print the results.

IV. CASE STUDIES

In order to demonstrate the effectiveness and robustness of the proposed technique, minimization of real power is demonstrated on IEEE 30 and IEEE 57 bus systems.

A. IEEE 30 Bus System

The IEEE 30-bus system data is given at appendix A. 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 lower and upper limits of the transformer tapping are 0.9 and 1.1 p.u. respectively.

The PSO parameters used in this case study are: No of particles 60, learning factors c_1=2.05, c_2=2.05, weight factor w=1.2, constriction factor K=0.7925. Maximum number of iterations = 100. The settings of PSO control parameters are maximum generation=100.

Graphs of emission release, fuel cost, and total system losses are shown in Fig.

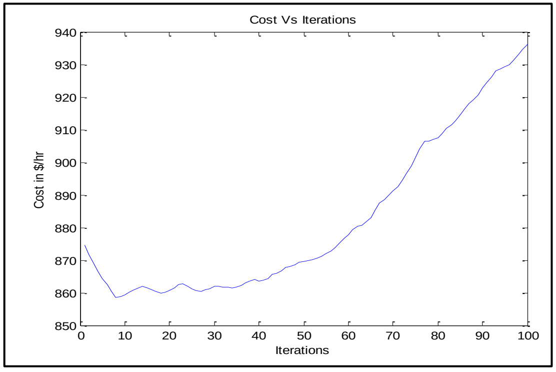

Fig. 1: Total Cost

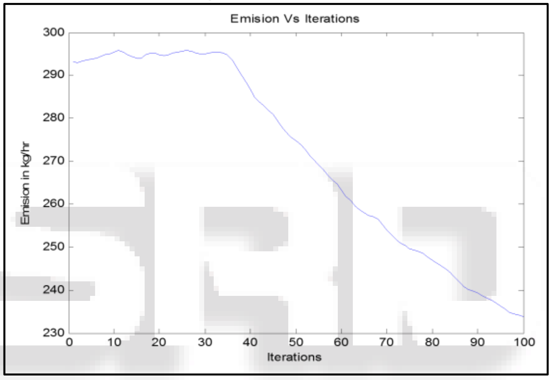

Fig. 2: Total Emission

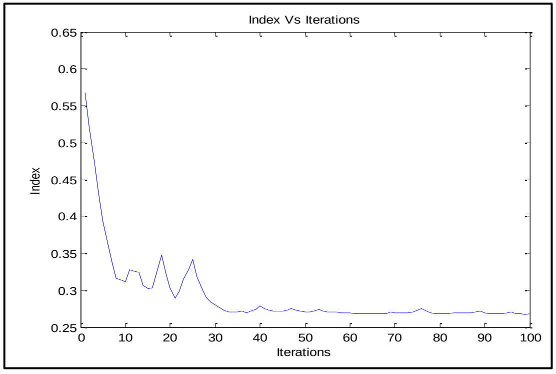

Fig. 3: Total Losses

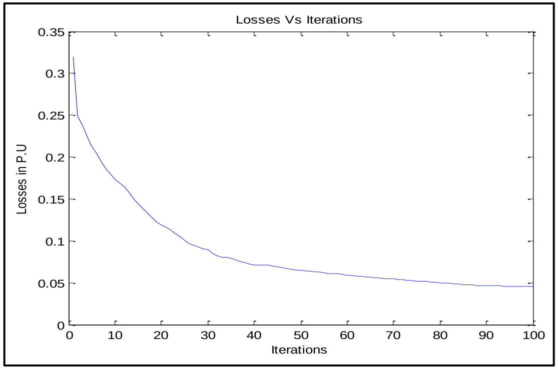

Fig. 4: Total Losses

Table Minimum of all the 25 results,

Table Positions of tap changing transformers

S. No	From-To buses	Tap value
1	6-9	0.90000
2	6-10	0.97500
3	4-12	0.92500
4	28-27	0.90000

Table 1: Positions of tap changing transformers

S. No	From-To buses	Shunt suceptance
1	10	1.035562
2	24	1.0

Table 2: Shunt suceptance values

S. No	Voltage	Pgen	Qgen	Lindex
1	1.000000	0.856877	-0.339003	0.000000
2	1.006214	0.641306	0.114202	0.000000
3	0.994342	0.50000	0.184145	0.000000
4	0.997359	0.296320	0.601253	0.000000
5	1.010968	0.192793	-0.023115	0.000000
6	1.000000	0.400014	0.783465	0.000000
7	1.003291	0.000001	0.000001	0.001361
8	0.998947	-0.000000	0.000000	0.004567
9	0.992144	-0.000024	0.000019	0.085890
10	0.932749	0.000065	0.000014	0.163421
11	0.992144	0.000000	0.000000	0.085890
12	0.924340	-0.000937	-0.000252	0.149197
13	0.912675	-0.000001	-0.000005	0.173556
14	0.909051	-0.000016	-0.000005	0.177775
15	0.905863	0.000012	0.000008	0.182053
16	0.910840	0.000950	0.000280	0.182093
17	0.920205	-0.000011	0.000006	0.177019
18	0.901680	-0.000006	-0.000003	0.201254
19	0.902609	0.000002	0.000002	0.204130
20	0.909245	0.000007	0.000002	0.195440
21	0.910708	0.000009	0.000010	0.187501
22	0.908774	-0.000065	-0.000018	0.188764
23	0.895190	-0.000002	-0.000000	0.198642
24	0.890572	-0.000005	-0.000002	0.207108
25	0.884088	-0.000000	0.000000	0.205901
26	0.863616	-0.000000	0.000000	0.234741
27	0.889953	-0.000002	-0.000000	0.193494
28	0.996185	-0.000003	0.000002	0.010264
29	0.866732	-0.000000	0.000000	0.237824
30	0.853318	0.000001	0.000001	0.267288

Table 3: Final bus voltages, power generations and Lindex values

B. IEEE 57 Bus System

The IEEE 57 bus system data is presented at appendix B. The PSO parameters used in this case study are: No of particles 60, learning factors c_1=2.05, c_2=2.05, weight factor w=1.2, constriction factor K=0.7925. Maximum number of iterations = 100. Minimum of all 25 independent runs is given in table 5.6.

Fuel Cost ($/hr)	Emission (kg/hr)	Loss (MW)	Stability Index
754.82509	149.425212	22.679544	2.191044

Table 4: Minimum of all 25 independent runs

Total System generation = 1239.179544MW

S. No	From-To buses	Tap value
1	4-18	0.925000
2	4-18	0.900000
3	20-21	1.050000
4	24-25	1.050000
5	24-25	1.000000
6	24-26	0.900000
7	7-29	0.987500
8	32-34	0.900000
9	11-41	0.900000
10	15-45	0.925000
11	14-46	0.937500
12	10-51	0.925000
13	13-49	0.900000
14	11-43	0.925000
15	40-56	1.100000
16	39-57	0.962500
17	9-55	1.1

Table 5: Positions of tap changing transformers

S. No	From-To buses	Shunt suceptance
1	18	1.038298
2	25	1.054264
3	53	1.030127

Table 6: Shunt suceptance values

Graph of total transmission loss as function of iterations is shown in Fig 5.

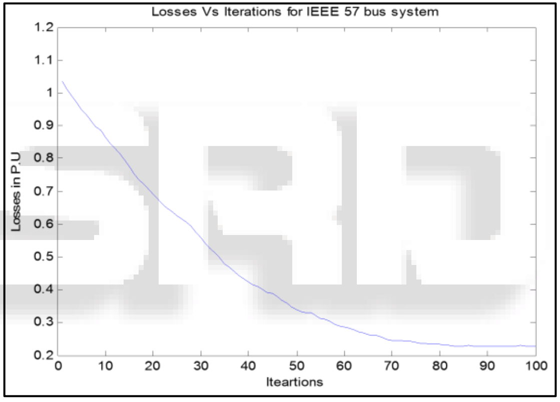

Fig. 5: Total Losses

Reactive Power Optimization for Voltage Stability Limit Improvement Incorporating TCSC Device through DE/PSO under Contingency Condition.

V. CONCLUSION

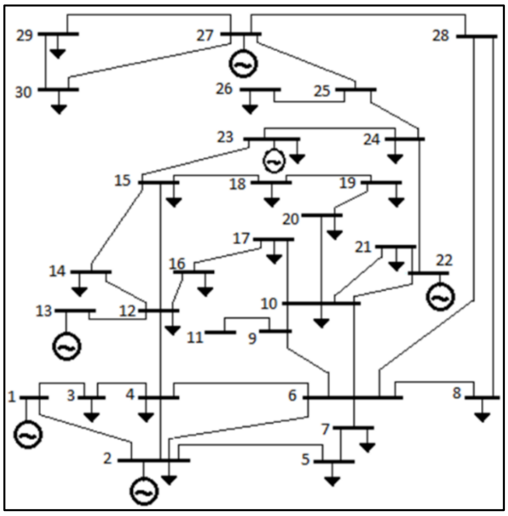

Fig. 6: One line dig of 30 bus system

Reactive power is that power which is used by the machine for their own used. It consumed for the production of the flux magnetic field or the torque in the machine. It not converted in use full output just like an active power.

In this way its compensation is very important. It is also help full for the power factor improvement and economical power dispatch in power system. So here we adopted the PSO Particle Swarm Optimization Based Optimal Reactive Power Dispatch approach by which it can be limited within the prescribe limit.

REFERENCE

[1] C. W. Taylor, Power System Voltage Stability. New York: McGraw-Hill, 1994P.

[2] Kessel and H. Glavitsch, "Estimating the Voltage Stability of Power System," IEEE Transactions on Power Delivery, Vol. PWRD-1, No. 3, pp. 346- 354, July 1986.

[3] H. Wan, J. D. Mc Calley and V. Vittal, “Risk Based Voltage Security Assessment”, IEEE Transaction on Power Systems, Vol. 15, No. 4, Nov. 2000, pp. 1247 – 1254.

[4] Feng Dong, et al, “Improving Voltage Stability by Reactive Power Reserve Management” IEEE Transactions on Power Systems, Vol. 20, N0.1, pp.338-345, February 2005.

[5] T. Menezes, L. C. da Silva, and V. F. da Costa, “Dynamic VAR Sources Scheduling for Improving Voltage Stability Margin,” IEEE Transaction on Power Systems, Vol. 18, No. 2, pp. 969–971, May 2003.

[6] S. Granville, “Optimal Reactive Dispatch through Interior Point Methods,” IEEE Transactions on Power Systems, Vol. 9, No. 1, pp. 136–146, Feb. 1994.

[7] E. Vaahedi, Y. Mansour, C. Fuchs, S. Granville, M. D. L. Latore, and H. Hamadanizadeh, “Dynamic Security Constrained Optimal Power Flow/var Planning,” IEEE Transactions on Power Systems, Vol. 16, No. 1, pp. 38–43, Feb. 2001.

[8] K. Price, R. Storn, “Differential evolution – A Simple and Efficient Adaptive Scheme for Global Optimization over Continuous Spaces, Technical Report, International Computer Science Institute”, Berkley, 1995.

[9] J. Kennedy, R. Eberhart, "Particle swarm optimization”, Proceedings of the IEEE International Conference on Neural Networks, pp. 1942- 1948 1995.

[10] P. Subbaraj and P. N. Rajnarayanan , "Hybrid Particle Swarm Optimization Based Optimal Reactive Power Dispatch", International Journal of Computer Applications, Vol. 1, No. 5, pp.65-70, February 2010.

[11] K. Mahadevan and P. S. kannan, "Comprehensive Learning Particle Swarm Optimization for Reactive Power Dispatch”, Electric Power Systems Research, Vol. 10, No. 2, pp. 641-652, March 2010.

[12] P. Aruna Jeyanthy and 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, pp. 734-740, August 2010.

[13] M. Z. M. Idrus, I. Musirin and Z. Zainuddin, “Biological Computing Technique for Optimal Reactive Power Dispatch”, Colloqium on Signal Processing and its Application CSPA 2006, 11 – 13 March 2006 Pahang, Malaysia, pp. 112 - 118.

[14] H. Yoshida, K.Kawata, Y.Fukuyama, S.Takayama and Y.Nakanishi, "A Particle Swarm Optimization for Reactive Power and Voltage Control Considering Voltage Security Assessment," IEEE Transactions on Power Systems, Vol.15, pp. 1232-1239, 2000.

[15] N G. Hingorani, L. Gyugyi, Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems, IEEE Press, New- York, 2000.

[16] N Yorino, E.E. El-Araby, H.sasaki and Sh Harada, “A New Formulation for FACTS Allocation for Security Against Voltage Collapse,” IEEE Transactions on Power Systems, Vol. 18, No.1, pp3- 10, February 2003.

[17] Lu Yunqiang and Abur Ali,: “Improving System Static Security via Optimal Placement of Thyristor Controlled Series Capacitor (TCSC)”, IEEE, PES, WM, Columbus, Ohio, USA., Jan. 2001.