International Journal of Research in Science & Technology
Volume 2 | Issue 4 | April 2015 | ISSN: 2349-0845

A Particle Swarm Optimization for Optimal Reactive Power Dispatch

Suresh Kumar[1], **Sunil Kumar Goyal**[2]

[1] Department of Electrical Engineering, Apex Inst. of Engg. & Technology, Jaipur, Rajasthan, India
[2] Department of Electrical Engineering, Manipal University, Jaipur, Rajasthan, India

Article Info

Article history:

Received on 11th April 2015
Accepted on 17th April 2015.
Published on 20th April 2015

Keyword:

Particle Swarm Optimization, Reactive Power Optimization, Power Loss Minimization.

ABSTRACT

This paper presents particle swarm optimization (PSO) based approach for solving optimal reactive power dispatch for minimizing power losses. The control variables are bus voltage magnitudes (continuous type), transformer tap settings (discrete type) and reactive power generation of capacitor banks (discrete type). The algorithm solution of PSO is tested on a standard IEEE 30 Bus system. The intention is to minimize power losses by optimizing the reactive power dispatch with optimal setting of control variables without violating inequality constraints and satisfying equality constraint. The detailed results for different cases have been listed

Corresponding Author:

Suresh Kumar
Apex Inst. of Engg. & Technology,
Department of Electrical Engineering,
Jaipur, Rajasthan, India
Email Id: eerskb@gmail.com

I. INTRODUCTION

Power system is a very bulk, complex and interconnected set-up having generation, transmission, distribution and loads. The power system operates in a constantly changing environment as generator outputs, loads and key operating parameters keep changing continually. The focus has been on implementation of equipments that can keep the power system reliable. In modern time, power networks operate under highly stressful situations as power demand is continuously increasing so the analysis of power system is don't while considering thses factors. The major concerns for power systems are: minimization of cost, minimization of losses, cost and stability (both voltage stability & power sytem stability) [1].

Optimization in power system governs with the overall economics of the full system. The power system optimization consists of best sizing and placement of reactive power resources (reactors, capacitors, and SVCs). The control settings like active power of generators, electrical device faucets, and regular voltages of generators are optimized not just for the base case system configuration however conjointly for many completely different system configurations.

Load flow or Power flow solution is essential for continuous evaluation of power system, planning the control and best operation of power system. The quest of any power system is to run the system optimally. The purpose of an Optimal Power Flow (OPF) algorithm is to search out steady stateoperation point that minimize generation cost, loss etc. or maximizes financial aid, loadability etc. while maintaining satisfactory system performance in terms of limits onreal and reactive powers of generators, line flow bounds, output of numerous compensatingdevices etc. The proper selection and coordination of apparatus for governing reactive power and voltage stability are amongst the main tasks of power system engineers. Conventionally, classical optimization methods were used to efficiently solve OPF. In recent years, Artificial Intelligence (AI) methods have been emerged that can solve extremely advanced OPF issues.

Reactive power optimization is having significant importance for both in day-to-day operations of power systems and for future planning. It utilizes all the reactive power sources judiciously, while forecasting suitable location and size of VAR compensation in a system. The financial side of reactive power planning and scheduling have a remarkable effect on the profitable and reliable operation of a power system as the fuel costs and capital investments are increasing day by day [2]. The electric power systems all over the world are moving in the direction of decontrolled or deregulated electricity markets. Additional services like frequency control, system control and system restart are required to control frequency, security, stability and voltage profile of the system and to safeguard the generation and transmission. Reactive power and voltage control is a mandatory service to sustain voltage profile through injecting or absorbing reactive power in electricity market.

The first comprehensive survey related to optimal power dispatch was given by H.H. Happ which reviewed the development of optimal dispatch (or economic dispatch) and he summarized the different methodologies to OPF along with their limitations and with both single area and multiple area cases. Afterward an IEEE working group presented bibliography survey of major economic-security function which was mainly related to operating economicsof the system. In the bibliography survey, the economic dispatch was conferred under "Real Time Operation" function with different categories [3]. Subsequently, Carpentier conferred a survey and classified the optimal power flow algorithms established on their solution methodology which included the power flow equations, generator real and reactive power constraints, bus voltage magnitude constraints, and bus voltage angle difference constraints for buses connected by transmission elements. If voltage and angle are taken as variables in place of P and Q, the restriction of fixing the reference voltage can be lifted.Later, Chowdhary prepared a survey report on economic load methods which pointed out the importance and related area to economic load dispatch, optimal power flow, economic dispatch related to AGC etc. [4]. E. Lobato et al. anticipated LP centered OPF for optimization (minimization) of transmission losses and generator reactive margins of the Spanish power system. N. Grudinin suggested a reactive power optimization model that was based on successive quadratic programming (SQP) methods. A wide spread variety of conventional optimization methods have been applied in deciphering the RPO problems considering a single objective function such as Newton-based techniques [5,6], quadratic programming[7], linear programming[8-9], non-linear programming [9],Sequential unconstrained minimization technique[10], interior point methods [11] and parametric method [12].

For a power system, the difficulty of reactive power planning may be categorized to be an optimization problem for which numerous methods have been proposed to solve. For solution of all optimization problems, no known single optimization method is available. A lot of optimization methodologies have been recognized in recent years for deciphering different kinds of optimization problems. The conventional optimization methodologies are: Linear programming (LP), non-linear programming and gradient based techniques for solving reactive power optimization problems [13-16]. As linearized models use approximations, consequently optimal results are not signified by LP for objective function being utilized in reactive power optimization problem. Adding to that, conventional or Traditional solution strategies have tendency to converge to a local optimal solution instead of the global one.

Expert System methodologies have also been recommended for reactive power based calculations, which are based mostly on 'if-then' dependent rules. The evolutionary computational methodologies i.e. Evolutionary programming (EP), Genetic algorithm (GA) and Evolutionary strategy have moreover been estimated to solve the optimizations troubles involving to the reactive power dispatch [17-19]. For deciphering complex engineering difficulties, the modern (non-traditional) optimization approaches are very influential and accepted approaches. These approaches are genetic algorithm, neural networks, fuzzy optimization, ant colony optimization and particle swarm optimization algorithm.

Particle Swarm Optimizer is a population-based stochastic method for global minimization of objective functions [20]. Objective functions are a way of quantifying everyday real world problems that describe properties that need to be minimized to obtain some particular outcome. Often objective functions can have many parameters that will influence the property that is being optimized. Objective functions will have a number of characteristics that help determine the how well it will be optimized. One of its main attractions is its ability to find optimal solutions without the need to compute derivatives. It is, in summary, multi-point derivative-free optimizer.

II. Reactive Power Optimization

Reactive power is essential for reliable operation of the bulk power system as it supports power flow. The reactive power is an indispensable element of the AC transmission grid. The demand of reactive power changes at a greater rate than the active power for the same change in voltage. Throughout the normal regular operation, power systems can go through both over-voltage and under-voltage violations which can be overcome by voltage or reactive power control. By monitoring the production, adsorption and flow of reactive power on all the stages in the system, voltage or reactive power control can retain the voltage profile inside permissible limit and decrease the transmission losses. Generators connected for transmission are usually essential for supporting reactive power flow.

Reactive power optimization (RPO) is one of the difficult optimization problems in operation and control of power system. RPO problem is a special tool to obtain the optimal state of the control variables by minimizing the certain objectives while satisfying the equality and inequality constraints. The most commonly used objective is loss minimization. The control or independent variables of power system are real power generation excluding lack bus, voltage magnitudes at generator buses, transformer tap settings and reactive power injection due to capacitor/inductor banks. The dependent or state variables are load bus voltage magnitudes and angles, slack bus power generation, reactive power generation at generator buses and transmission line loadings.

A comparatively modern, new and powerful technique Particle Swarm Optimization (PSO) has been practically revealed to execute well on numerous optimization problems [20-21]. The population based stochastic optimization technique i.e. PSO algorithm is applied while satisfying equality constraints and not violating inequality constraints. The endeavour of minimising reactive power losses is achieved by correct adjustment of reactive power variables like reactive power generation of capacitor banks (Q_{ci}), generator voltage magnitudes (V_{gi}) and transformer tap settings (t_k) [12].

The recommended PSO algorithm solution is tried on the typical IEEE 30-Bus test system with both discrete and continuous control variables while keeping the system under safe voltage stability limit. The suggested algorithm shows improved results.

III. Particle Swarm Optimization

Particle Swarm optimization (PSO) is a comparatively new evolutionary algorithm that is used to find optimum/best (or close to optimal) solutions to qualitative and numerical issues. PSO applies the conception of social interaction to problem solving.

Particle swarm optimization was originally established by James Kennedy and Russell Eberhart [20]. The Eberhart and Kennedy model makes an attempt to seek out the most effective compromise between its two main parts, individuality and sociality. Particle swarm optimisation (PSO), that is a population based stochastic optimization technique, shares several similarities with evolutionary computation techniques like genetic algorithms (GA). The system is initialized with a population of random realistic solutions and searches for best by modernizing generations. However, unlike GA, PSO has no evolution operators like crossover and mutation. PSO algorithmic program has additionally been demonstrated to perform well on genetic algorithmic program test function. In PSO, the potential solutions, referred as particles, fly through the problem space by following the present optimum particles.

In a PSO algorithm, particles modify their positions by flying around in multidimensional search area till a comparatively unchanged position has been encountered, or till machine limitations are exceeded. In scientific discipline context, a PSO system combines a social-only model and a cognition-only model. A particle changes its position using these models. Every particle keeps track of its coordinates within the problem space that are related to the most effective solution, fitness; it's achieved to this point. The fitness value is additionally stored that is named P_{best}. Another best value that is traced by the optimizer is the best value, achieved to this point by any particle within the neighbors of the particle. This position is named l_{best}. Once a particle receipts all the population as its topological neighbors, the most effective value could be a global best and is named G_{best}. At each step PSO changes the velocity (accelerates) of every particle toward its P_{best} and l_{best} locations (local form of PSO). Acceleration is weighted by a random term, with discrete random numbers being produced for acceleration toward P_{best} and l_{best} locations. In past proven years, PSO has been successfully applied in research analysis and application areas.

It's incontestable that PSO gets better results in a quicker, cheaper manner compared to alternative methods. Another reason that PSO is eye-catching is that there are not many parameters to regulate. One version, with slight variations, works well in a big range of applications. Particle swarm optimization has been utilized for approaches which can be used across a large range of applications, also as for specific applications centered on a specific demand. In the past many years, PSO has been successfully applied in several research and application areas.

The fundamental terms employed in PSO technique are [23, 24]:

Particle X (i): It is a candidate solution described by a k-dimensional real-valued vector, where k is the no. of optimized parameters.

Population: It is basically a set of n particles at iteration i and at time T.

Swarm: Swarm is defined as an apparently unsystematic population of moving particles that tend to bunch together while each particle appears to be moving in a random direction.

Particle velocity V(i): Particle velocity is the velocity of the moving particles signified by a d-dimensional real valued vector.

Inertia weight w(i): It is a regulation parameter, which is used to regulate the impact of the past (previous) velocity on the present velocity. Hence, it effects the trade-off between the global and local exploration capacities of the particles. For the initial stages of the search method, large inertia weight to reinforce the global exploration is usually recommended while it must be reduced at the last stages for higher local exploration. Therefore, the inertia factor drops linearly from about 0.9 to 0.4 throughout a run.

Individual best X*(i): When particles move through the search space , it matches its fitness value at the existing position to the best fitness value it has ever grasped at any iteration up to the current iteration. The best position that is related with the best fitness faced so far is called the individual best $X^*(i)$.

Global best $X^{**}(t)$: Global best is the finest position amongst all of the individual best positions achieved so far.

Stopping criteria: Termination of the search process will take place whenever optimal control variable settings are obtained.

IV. Problem Formulation

The objective function ‘minimization of real power losses’, by reactive power optimization, is a constrained optimization problem.

$$F = min.\,P_{loss}$$

Here IEEE 30 bus system is used for applying PSO algorithm. The optimal Reactive Power Dispatch problem targets at minimizing the real power loss in a power system while satisfying the unit and system constraints. The purpose is achieved by correct adjustment of reactive power variables like transformer tap settings (T_k), reactive power generation of capacitor banks (Q_{Ci}) and generator voltage magnitudes (V_{Gi})

The minimization of system real power losses (MW) is formulated:

$$F = Min.\,P_{Loss} = \sum_{K=1}^{nl} g_k\left[V_i^2 + V_j^2 - 2V_iV_j\cos(\delta_i - \delta_j)\right] \quad (1)$$

The real power loss given by P_{Loss} is a non-linear function of phase angles and bus voltages that are functions of control variables.

In formulation,

g_k : Conductance of the k^{th} line;

n_l : The number of transmission lines;

V_i &V_j : The voltage magnitude at the end buses i& j,

δ_i&δ_j : The voltage phase angles at end buses i& j.

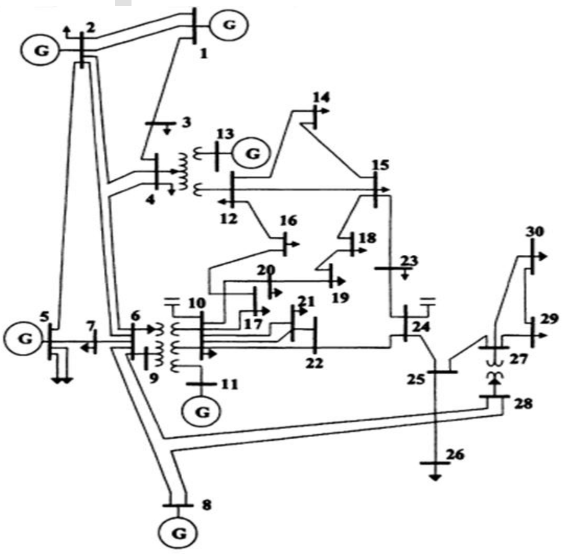

Fig.1: One Line Diagram of IEEE-30 Bus System

The above minimization is subjected to the following equality and inequality constraints:-

Equality constraints:

These constraints are usual load flow equations that are defined as [24]:

1. Real Power Constraints:

$$P_{Gi} - P_{Di} - V_i \sum_{j=1}^{N_B} V_j \left(G_{ij} Cos(\delta_i - \delta_j) + B_{ij} Sin(\delta_i - \delta_j)\right) = 0 \quad (2)$$

$$i = 1,2 \ldots \ldots . N_B$$

2. Reactive Power Constraints:

$$Q_{Gi} - Q_{Di} - V_i \sum_{j=1}^{N_B} V_j \left(G_{ij} Sin(\delta_i - \delta_j) - B_{ij} Cos(\delta_i - \delta_j)\right) = 0, \quad (3)$$

$$i = 1,2 \ldots \ldots . N_{PQ}$$

where,

P_i, Q_i : Real & reactive powers injected into network at bus i

V_i : Magnitude of Voltage at bus i

V_j : Magnitude of Voltage at bus j

δ_{ij} : Voltage angle difference between bus i and bus j

G_{ij}, B_{ij} : Mutual conductance and susceptance between bus i and bus j

Q_{gi} : Reactive power generation at bus i

$N_B - 1$: Total number of buses not including slack bus

N_{PQ} : Number of PQ buses

Inequality constraints:

3. Bus Voltage magnitude constraints:

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

4. Transformer Tap position constraints:

$$t_k^{min} \le t_k \le t_k^{max} \;;\; i\varepsilon N_T \quad (5)$$

5. Generator bus reactive power constraint:

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

6. Reactive power source capacity constraints:

$$Q_{ci}^{min} \le Q_{ci} \le Q_{ci}^{max} \;;\; i\ \varepsilon\ N_c \quad (7)$$

7. Transmission line flow constraints:

$$|s_i| \le |s_i^{max}| \quad (8)$$

$$S_i \le S_i^{max} \;;\; i\ \varepsilon N_l \quad (9)$$

8. Generation capacity constraint:

$$P_{Gi}^{min} \le P_{Gi} \le P_{Gi}^{max} \;;\; i\varepsilon N_B \quad (10)$$

The total power generation is supposed to cover the P_D (the total load demand) and P_L (the real power loss in transmission lines). The relation is regularly expressed as:

9. Power balance constraint:

$$\sum_{i=1}^{NB} P_{Gi} = P_D + P_L \quad (11)$$

The symbols used are as follows:

t_k : Tap setting of transformer at branch k

Q_{Ci} : Reactive power generated by i^{th} capacitor bank

Q_{gi} : Reactive power generation at bus i

S_i : Apparent power flow through the i^{th} branch

N_g : Number of generator buses

N_c : Number of capacitor banks

N_B : Total number of buses

g_k : Conductance of buses

N_T : Number of tap-setting transformer branches

The control variables for voltage-control problem, which is able to be modified by the Particle Swarm optimization process, are:

- Voltages magnitude at voltage-controlled buses (PV-buses) together with the slack bus.
- Adjustable shunt capacitor banks.
- Transformers tap settings.

V. Methodology

The various steps concerned with the implementation of particle swarm optimization to the reactive power optimization problem are [23-24].

Step 1: Primarily the input parameters of the system (bus, line and generator data) are scanned and the lower and upper boundaries of every variable are also identified. For N generators, optimization is applied for N-1 generators and generator of maximum capacity is considered at slack bus.

Step 2: The particles of the population are arbitrarily initialized i.e. are arbitrarily selected between the corresponding minimum and maximum values. Also assign the velocity *V* firstly between [-1 and 1].

Step 3: Achieve power flow solution and calculate losses via Newton-Raphson method.

Step 4: The best fitness is assigned as P_{best}. At this juncture the P_{best} is also the G_{best}.

Step 5: Iteration *i*= *i*+*1* is modernized.

Step 6: Adjust the inertia weight *w* given by

$$W = \frac{(W_{max} - W_{min})}{iter_{max}} \times iter \quad (12)$$

Step 7: Update the velocity *v* of each particle according to the stated equation.

$$V(k,j,i+1) = V(k,j,i) + C_1{}^*rand^*\left(p_{bestx}(j,k) - X(k,j,i)\right) + C_2{}^*rand^*\left(g_{bestx}(k) - X(k,j,i)\right) \quad (13)$$

Step 8: Position of each particle is modified too as per the stated equation. If a particle disrupts the position bounds in any dimension, its position is fixed at the right limit.

$$x(k,j,i+1) = x(k,j-1,i) + v(k,j,i) \quad (14)$$

Step 9: Assessment of each particle is prepared along with its updated position by running power flow and evaluate the fitness function. If the evaluation/assessment value of every particle is improved than the former P_{best} then the present value is fixed to be P_{best}. If the best P_{best} is better than G_{best}, the value is fixed to be G_{best}.

Step 10: If one of the stopping benchmark is fulfilled then we go to Step 11. Else, we go to Step 5.

Step 11: G_{best} is the optimal/best value which is newest generated by the particle.

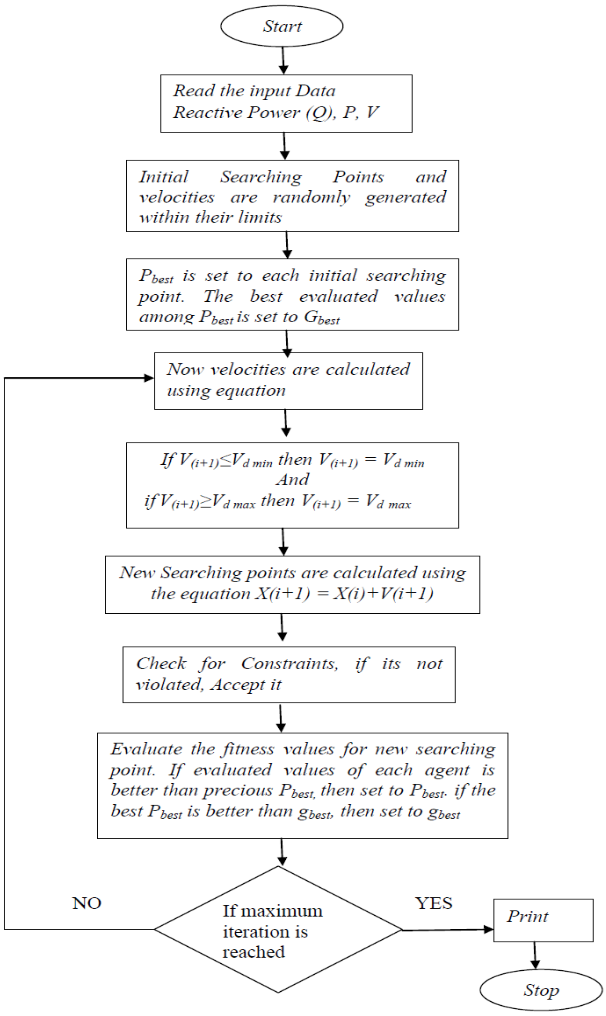

Fig. 2 Detailed flow-chart for applying PSO to RPO

VI. Results

The parameters for PSO are taken as per table:

The anticipated algorithm is run for objective function i.e. minimization of real power losses for different cases. As main objective is reactive power optimization so we deviate generator bus voltages (from 1.0 to 1.1 in case 1 & case 2, from 0.9 to 1.0 in case 3 & case 4) and shunt capacitor bank setting (from 0.0 to 5.0 in case 1, case 3, from 0.0 to 3.0 in case 2, case 4). The consolidated results of various cases are shown below in table

Table: Optimal Parameter Setting for PSO

Number of iterations	300
Cognitive constant, c_1	2.0
Social constant, c_2	2.0
Max. and Min. inertia weights W	0.4 and 0.95
Population size	50

Table : **Results of IEEE-30 Bus System**

Control Parameters	Case 1			Case 2			Case 3			Case 4		
	Constraints			Constraints			Constraints			Constraints		
Gen. Bus Voltage (V)	$1 \le V_i \le 1.1$			$1 \le V_i \le 1.1$			$0.9 \le V_i \le 1.0$			$0.9 \le V_i \le 1.0$		
Trans. Tap Setting (T)	$1.0 \le T_k \le 1.1$			$1.0 \le T_k \le 1.1$			$1.0 \le T_k \le 1.1$			$1.0 \le T_k \le 1.1$		
VAR Inst. (MVAR) (Q_C)	$0.0 \le Q_{ci} \le 5.0$			$0.0 \le Q_{ci} \le 3.0$			$0.0 \le Q_{ci} \le 5.0$			$0.0 \le Q_{ci} \le 3.0$		
Control Parameter	Proposed PSO Algorithm			Proposed PSO Algorithm			Proposed PSO Algorithm			Proposed PSO Algorithm		
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
V_1	1	1.1	1.053	1	1.1	1.0521	0.9	1	0.953	0.9	1	0.951
V_2	1	1.098	1.047	1	1.1	1.0455	0.9	1	0.948	0.901	1	0.95
V_5	1.002	1.1	1.049	1	1.1	1.0429	0.9	1	0.951	0.9	1	0.951
V_8	1	1.1	1.048	1.006	1.1	1.0576	0.9	1	0.949	0.9	1	0.953
V_{11}	1	1.1	1.041	1	1.1	1.052	0.902	1	0.949	0.901	1	0.954
V_{13}	1.003	1.099	1.049	1	1.1	1.0557	0.9	0.997	0.95	0.9	0.998	0.956
T_{11}	1	1.1	1.05	1	1.099	1.0505	1.004	1.1	1.052	1.001	1.1	1.05
T_{12}	1	1.1	1.056	1.001	1.1	1.046	1	1.098	1.046	1	1.1	1.058
T_{15}	1	1.1	1.048	1	1.1	1.0565	1.004	1.099	1.048	1	1.1	1.05
T_{36}	1	1.096	1.047	1	1.098	1.0479	1	1.1	1.043	1	1.1	1.053
Qc_{10}	0	5	2.728	0	2.874	1.4772	0.074	5	2.838	0.135	3	1.457
Qc_{12}	0.052	4.943	2.62	0	3	1.5914	0	5	2.041	0	3	1.586
Qc_{15}	0	4.953	2.223	0.184	2.987	1.5493	0	5	2.822	0.058	2.991	1.771
Qc_{17}	0	4.706	2.546	0	2.958	1.3111	0	5	2.649	0.006	3	1.371
Qc_{20}	0.068	5	2.593	0.028	3	1.5102	0	5	2.553	0.175	3	1.844
Qc_{21}	0.148	5	2.564	0	2.915	1.3708	0	4.917	2.58	0.026	3	1.421
Qc_{23}	0	4.997	2.081	0	3	1.5865	0.037	5	2.579	0	3	1.307
Qc_{24}	0.04	5	2.673	0.014	3	1.4088	0.07	5	3.036	0.088	2.992	1.707
Qc_{29}	0.13	5	2.436	0	2.858	1.3568	0.068	5	2.878	0	3	1.628
Power Loss (in MW)	**5.173**	**7.997**	**6.332**	**5.289**	**7.46**	**6.2285**	**6.346**	**10.47**	**7.74**	**6.609**	**10.18**	**7.85**

VII. Conclusion

For solving ORPD problem, a new improved integer coding Particle Swarm Algorithm is used. The main purpose is to minimize the active power loss in the network, while satisfying all the power system operation constraints. The simulation results show that PSO algorithm always leads to a better result. The detailed results for different cases have been mentioned in table above. As discussed above, the algorithm reaches minimum loss under different boundary conditions. After studying tables for various cases, the optimum values of the control variables are specified in tables in different cases of boundary conditions.

References

[1] SaadatHadi, "Power System Analysis", McGraw-Hill, 1999.

[2] Kothari D.P. and Nagrath I.J., "Modern Power System Analysis", Tata McGraw-Hill, Third Edition, 2003.

[3] H. H. Happ, "Optimal power dispatch-A comprehensive survey", *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-90, pp. 841-854, 1977.

[4] IEEE working group, "Description and bibliography of major economic-security functions part-II and III'', *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-100, pp. 215-235, 1981.

[5] Hong Y. Y., Liao C. M. and Lu T. G. ,"Application of Newton Optimal Power Flow to Assessment of VAR Control Sequences on Voltage Security: Case Studies For A Practical Power System", *IEEE Proceedings on Generation, transmission and distribution*, Vol. 140, No. 6, pp. 539-543, 1993.

[6] Saha T. N. and Maitra A., "Optimal Power Flow Using the Reduced Newton Approach in Rectangular Coordinates", *International generalof Electrical Power&EnergySystems*, Vol. 20, No. 6pp. 383-389, 1998.

[7] N. Grudinin, "Reactive Power Optimization using Successive Quadratic Programming Method", *IEEE Trans. Power Systems*, vol. 13, no. 4, pp. 1219-1225, Nov. 1998.

[8] Torres G.L. and Quintana V. H., "Optimal Power Flow by a Nonlinear Complementarily Method", IEEE Transactions on Power Apparatus and Systems, Vol. 15, No. 3, pp. 1028-1033, 2000.

[9] PudjiantoS. A. and Strbac G., "Allocation of VAR Support Using L P and NLP based Optimal Power Flows", IEEE Proceedings on Generation, Transmission and Distribution., Vol. 149, No. 4, pp. 377-383, 2002.

[10] Rahli M., "Optimal Power Flow Using Sequential Unconstrained Minimization Technique (SUMT) Method Under Power Transmission Losses Minimization", *International Journalof Electric Power System Research* ,Vol. 52, pp. 61-64, 1999.

[11] Liu S., HouZ. and Wang M.,"A Hybrid Algorithm for Optimal Power Flow Using the Chaos Optimization and the Linear Interior Point Algorithm", *Power System Technology, Proceedings of International Conference on Power Control*, Vol.2, 13-17, pp. 793-797, 2002.

[12] Almeida K. C., GalianaF. D. and S. Soares, "A General Parametric Optimal Power Flow", *IEEE Transactions on Power Systems*, Vol. 9, No. 1, pp. 540-547,1994.

[13] L. D. B. Terra and M. J. Short "Security constrained reactive power dispatch," IEEE Trans. on power systems, Vol. 6, No. 1, February 1991.

[14] H. W. Dommel and W. F. Tinny, "Optimal power flow solutions," IEEE 1968, pp 1866-1876.

[15] G. R. M. Da Costa, "Optimal reactive dispatch through primal-dual method," IEEE trans. on power systems, Vol. 12, No. 2, May 1997, pp 669-674.

[16] K. Y. Lee, Y. M. Park, and J. L. Ortiz, "A united approach to optimal real and reactive power dispatch," IEEE trans. on PAS, 104, 1985, pp. 1147-1153.

[17] K. Iba, "Reactive power optimization by genetic algorithm," IEEE trans. on power systems, Vol. 9 No. 2, 1994, pp 685-692.

[18] Q. H. Wu and J. T. Ma , "Power system optimal reactive power dispatch using evolutionary programming," IEEE trans. on power systems, Vol. 10, No. 3, August 1995, pp 1243-1248.

[19] B. Das and C. Patvardhan, "A new hybrid evolutionary strategy for reactive power dispatch," Electric power system research, Vol. 65, 2003, pp 83-90.

[20] Kennedy J., "The Particle Swarm: Social Adaptation of Knowledge", Proceedings of IEEE International Conference on Evolutionary Computation, Indianapolis, USA, pp.303-308, 1997.

[21] Yuhui Shi, Russell C. Eberhart, "Empirical Study of Particle Swarm Optimization", Evolutionary Computation, CEC 99, Vol. 3, 6-9 July 1999

[22] H.D. Chiang, J.C. Wang, O. Cockings, and H.D. Shin, "Optimal capacitor placements in distribution systems: part 2: solution algorithms and numerical results", IEEE Trans. Power Delivery, Vol. 5, No. 2, pp. 634-641, April 1990.

[23] AH. Mantawy, M. S. Al-Ghamdi, "A new reactive power optimization algorithm," *Power Tech Conference Proceedings, 2003 IEEE Bologna* , vol.4, no., pp.6 pp. Vol.4,2003

[24] Manoharan, S. and Marimuthu, A, "Security Constrained Optimal Power Flow Using Particle Swarm Optimization" *The IUP Journal of Electrical & Electronics Engineering*, Vol. IV, No. 3, pp. 49-60, 2011

Mr. Suresh Kumar was born in (Fatehpur) Rajasthan on April 28, 1992. He received his B. Tech. degree in Electrical Engineering from Suresh GyanVihar University, Jaipur in 2012. He started his teaching carrier with Sri Balaji Technical Campus (earlier SBCET) as an Assistant Professor for one year in 2012-13. He is currently working as an Assistant Professor, Department of Electrical Engineering at Jaipur National University, Jaipur since 2013.

Mr. Sunil Kumar Goyal was born in (Alwar) Rajasthan, India on June 25, 1976. He received the B.E. Degree in Electrical Engineering from Malviya Regional Engineering College (MREC) (presently known as Malviya National Institute of Technology (MNIT)), Jaipur in 1998, M.E. Degree in Power System from Malviya Institute of Technology (MNIT), Jaipur in 2000 and pursuing Ph.D. Degree from Rajasthan Technical University, Kota.

He started his teaching carrier with MNIT as a Guest Faculty for one year in 1999-2000. After that he joined Institute of Engineering & Technology (IET), Alwar as lecturer in 2000. He joined GyanVihar School of Engineering & Technology, Jaipur as Associate Professor in 2005. Presently he is working in Manipal University Jaipur since 2014.

His areas of interest are Electrical Power System, Electrical Machines, Isolated Power Generators, Wind and Micro Hydro Power Generation, efficient electric energy utilization.