International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 04 | Apr 2021 www.irjet.net p-ISSN: 2395-0072

OPTIMAL REACTIVE POWER DISPATCH OF POWER SYSTEM WITH DISTRIBUTED GENERATION USING PSO

V.Suvitha[1], Dr.S.Sivananaitha Perumal[2]

[1] PG Research Scholar, Dept. of Electrical and Electronics Engineering, Dr. Sivanthi Aditanar College of Engineering, Tamilnadu, India
[2]HOD, Dept. of Electrical and Electronics Engineering, Dr. Sivanthi Aditanar College of Engineering, Tamilnadu, India

***

Abstract - *Reactive power is critical to the operation of the power networks on both safety aspects and economic aspects. Unreasonable distribution of the reactive power would severely affect the power quality of the power networks and increases the transmission loss. Currently, the most economical and practical approach to minimizing the real power loss remains using reactive power dispatch method.*

Reactive power dispatch problem is nonlinear and has both equality constraints and inequality constraints. In this thesis, PSO algorithm and MATLAB toolbox are applied to solve the reactive power dispatch problem. PSO is a global optimization technique that is equipped with excellent searching capability. The biggest advantage of PSO is that the efficiency of PSO is less sensitive to the complexity of the objective function. MATLAB is an open source MATLAB toolbox focusing on solving the power flow problems. The benefit of MATLAB is that its code can be easily used and modified.

The proposed method in this thesis minimizes the real power loss in a practical power system and determines the optimal placement of a new installed DG. IEEE 14 bus system is used to evaluate the performance.

INTRODUCTION

Reactive power is critical to the operation of the power networks on both safety and economic aspects. Rational reactive power dispatch scheme can improve the power quality as well as reduce the real power loss. On the contrary, if the reactive power is unreasonably allocated, then it will bring great economic losses and might even threaten the security of the power grid.

Reactive power also plays a prominent role in minimizing the real power loss of the power networks. Reactive power dispatch approach can significantly reduce the power factor angle of each bus, thus cutting the overall energy losses. Each year, a large amount of electricity is wasted on the transmission or distribution lines around the world. According to the estimations from the U.S. Energy Information Administration, the annual transmission and distribution losses in the United States can reach as much as 6%. Moreover, most of this loss occurs at the distribution level. This real power loss not only causes energy waste and produces extra carbon emission, but also increase the generation cost.

Along with the development of the economic, the scale of the power grid also keeps growing. In some areas, however, the construction and upgrading of the power grid did not keep pace with the growth of the loads. Then a severe shortage of the reactive power would appear. For the purpose of minimizing the real power loss, utility companies can either change the structure of the power grid or replace the old wiring with lower impedance lines. However, both of these methods require investing large amount of money. The simplest and most economical way remains reactive power dispatch method. In the early days, the starting point of reactive power dispatch is to improve the power factor at each end user by installing reactive power compensators. This approach, of course, can reduce the total power loss. But in order to get the maximum profit, electricity grid designers have to take a more holistic view and calculate the power flow.

Optimal reactive power dispatch (ORPD) is more and more important for system security and operation. Even its generation has no production cost but, it has an effect on the production cost related with active power transmission loss. (ORPD) is a sub-problem of the optimal power flow (OPF) calculation, (ORPD) plays a prominent role in minimizing an interested objective functions such as active power transmission losses and improve voltage profile by adjusting control variables such as generator voltages, transformer tap settings, reactive power output of shunt VAR compensators, while satisfying several equality and inequality constraints.

METHODOLOGY

In general view, formulate the problem ORPD is concerned with optimization of steady-state performance of power system with respect to specific objective function, subject to various equality , inequality constraints and Exterior Penalty Function (EPF) Method.

$$f : P_{loss} = \sum_{k=1}^{N} g_{ij}\left(V_i^2 + V_j^2 - 2V_iV_j\cos\theta_{ij}\right)$$

where N is the number of the branches,

g_{ij} is the conductance of the branch between bus i and bus j,

V_i is the voltage magnitude of bus i,

V_j is the voltage magnitude of bus j,

θ_{ij} is the difference of phase angle between bus i and bus j.

Equality constraints:

The equality constraints are the power balance equations, which can be described by the equations below:

$$h_1 : P_{gi} - P_{di} - V_i \sum V_j\left(G_{ij}\cos\theta_{ij} + B_{ij}\sin\theta_{ij}\right) = 0$$
$$h_2 : Q_{gi} - Q_{di} - V_i \sum V_j\left(G_{ij}\sin\theta_{ij} - B_{ij}\cos\theta_{ij}\right) = 0$$

where P_{gi} is the real power generation at bus i,

P_{di} is the real power demand at bus i,

Q_{gi} is the reactive power generation at bus i,

Q_{di} is the reactive power demand at bus i.

Inequality constraints:

The inequality functions are the ranges of the voltage magnitudes, tap positions of the transformers, and reactive power injection. Some of the parameters are continuous, as the voltage magnitudes. While some are discrete, like the tap positions of the transformers and reactive power injection.

The commonly used method to manage the discrete values is viewing them as continuous values at the beginning of the optimization and then mapping the continuous values back to the discrete values in the end. In this thesis, the discrete variables are seen as continuous variables initially and then keep three decimal places at the end of the search.

$$g_1 : V_i^{\min} < V_i < V_i^{\max}$$
$$g_2 : t_j^{\min} < t_j < t_j^{\max}$$
$$g_3 : Q_{gi}^{\min} < Q_{gi} < Q_{gi}^{\max}$$

Exterior Penalty Function (EPF) Method

Reactive power dispatch problem is a constrained problem. In optimization, the constrained problems are usually converted into unconstrained problems for convenience. One of the commonly used methods to convert the constrained problem is adding exterior penalty function terms to the objective function, which is also known as exterior penalty function method, as represent in the formula

Minimize : F : f + P(x,r_n, r_g)

$x_l^i \leq x_i \leq x_i^u$ i=1,2,….n

Where P (r_h, r_g) is the penalty function

r_h is the penalty multiplier for the equality constraint.

r_g is the penalty multiplier for the inequality constraint.

F is called the augmented function.

The equality constraint in this thesis will be automatically fulfilled by using MATPOWER 5.1 toolbox, so only inequality constraints need to be concerned. Therefore, the final objective function could be described as:

$$V_i^{Lim} = \begin{cases} V_i^{max}, V_i > V_i^{max} \\ V_i^{min}, V_i < V_i^{min} \end{cases}$$

$$T_i^{Lim} = \begin{cases} T_i^{max}, T_i > T_i^{max} \\ T_i^{min}, T_i < T_i^{min} \end{cases}$$

$$Q_{G1}^{Lim} = \begin{cases} Q_i^{max}, Q_i > Q_i^{max} \\ Q_i^{min}, Q_i < Q_i^{min} \end{cases}$$

In EPF, if all the control variables are within the limits, the penalty function terms would be zero. On the contrary, if the control variables exceed the limits, then the penalty function terms would be added to the objective function to penalize the violation. The penalty multipliers are always assigned big numbers in programming. When the penalty multipliers keep increasing until approaching infinity, the constrained problem will transform to the unconstrained problem. In reactive power dispatch, if the control variables exceed the voltage limit, significant damages to the power systems would occur. So the voltage magnitudes, tap positions, and reactive power injection have to be carefully examine.

Reactive power dispatch with dg at rated power:

Wind generator, solar panels, and micro-turbine can all be chosen as an alternative of DG. When the real power output is 0 MW, the wind generator can still deliver as much as 1.2 MVar or absorb -1.0 MVar reactive power.

If the wind turbine is installed on a PV bus (e.g. bus 2), then both real and reactive power capacity of the generator need to be changed. In Fig. 4.6, note that the active power output of the generator at bus 2 is increased from 40 to 42.2, the range of reactive power output is changed from [-40, 50] to [-41, 51.2].

Reactive Power Dispatch with a New DG Operating at Various Power:

In order to evaluate the performance of the proposed method at the various wind speed conditions, the third case study compares the power loss of the modified 14 bus system when the wind turbine delivers 25%, 50%, and 75% of its rated power, respectively.

When the wind speed is at 7 m/s, the output of the wind turbine is 532 W, which is about 25% of its rated power output. When the wind speed is about 9 m/s, the output of wind generator is 1.18 kW, approximately 50% of its rated power output. The wind speed is about 10 m/s, the output of the wind generator is 1.58 kW, about 75% of the rated power output.

Matpower

In this thesis, MATPOWER 5.1 toolbox is introduced to calculate the power flow and to fulfill the equality constraints. The biggest advantages of MATPOWER is its easiness to use and modify the original code.

The loadcase Function

The loadcase function can load the case information from the struct, M-file or MAT-file. The imported information is then saved in a struct. Users can change the structure of the network by modifying the imported data when needed.

The standard format of using loadcase is:mpc=loadcase(casefile)

The savecase Function

The savecase function can save the information of the network to M-file or MAT- file. These files can also be overwritten in case of need. In MATLAB 7.10 environment, if the case file needs to be overwritten more than once in a single run, users need to choose saving the case information in MAT-format. Otherwise, an error message would appear, and the case information would remain unchanged.

The standard format of using savecase is: savecase(fname, mpc).

The runpf Function

The runpf function can calculate the power flow of the network. When calculating the power flow, the runpf function has several different options. 'NR' refers to using Newton's method, 'FDXB' is the fast decoupled method, and 'GS' means using Gauss- Seidel method. 'AC' is calculating the AC power flow of the system, and 'DC' is calculating the DC power flow of the system. By default, runpf works at the AC power flow mode and uses Newton Raphson's method to compute the power flow.

The standard format of using runpf is: results = runpf(casedata).

Procedures of the PSO Based Reactive Power Dispatch

To conclude, the main optimization steps of the PSO based reactive power dispatch are as follows:

1.Load case information: in MATPOWER, IEEE 14 bus system data is saved in case14.m file. Users can also create their personalized case by following the format of the canonical forms of generators, buses, and branches.

2.Initialization: set the total iteration number, particle number, and initial velocity, randomly assign the position of each particle in the design space. Then evaluate the fitness of each particle and save the global best-known position, and the local best-known position of each particle.

3.Update the positions and velocities: updating the position and velocity of each particle by using formula 2.1 and formula 2.2. Then check whether the solution violates the limit or not. If the solution exceeds the limits, use the EPF method to penalize the violations.

4.Evaluate each particle: substitute the position of each particle into the objective function to calculate the evaluation value.

5.Update local best-known position: if the current fitness value is smaller than the historical best fitness value, update the local best-known position.

6.Update global best-known position.

7.Decide stopping criterion: determine if the iteration has reached the maximum iteration number. If so, stop the optimization process and print the result; otherwise, iter=iter+1, and go back to step 3.

DISCUSSION:

By analyzing the results of the three case studies, the following conclusions can be obtained:

1.Before the reactive power optimization, the reactive power in IEEE 14 bus system is unreasonable distributed. Reactive power dispatch can significantly reduce the real power loss of the system and improve the power quality.

2.Satisfying results can be achieved after about conducting 90 iterations, which reflects the excellent searching ability of PSO algorithm for solving nonlinear problems.

3.When a small capacity DG is added into the system, the real power loss would be further reduced. As the output of the DG increases, the real power loss of the system decreases.

CONCLUSIONS:

Reactive power dispatch is a nonlinear optimization problem that contains both continuous and discrete control variables. PSO is a heuristic global optimization algorithm that possess of high efficiency and robustness. PSO is less sensitive to the complexity of the objective functions. Therefore, it shows enormous potential for solving reactive power dispatch problems. In this paper we going to minimize the power loss in power network using PSO.. Simulation was made using MATLAB 14b.Simulation was made. Our project provided better high efficiency and easy to understand.

This thesis uses the IEEE 14 bus system as the test system. Both PSO algorithm and MATPOWER 5.1 toolbox are applied to reduce the real power loss in the power networks. In order to avoid the control variables exceeding the limits, exterior penalty function method is also employed.

REFERENCES:

[1] A. M. Chebbo, M. R. Irving, M. J. H. Sterling, “Reactive power dispatch incorporating voltage stability,” IET Proceedings on Generation, Transmission and Distribution, 1992.

[2] R. Thomas, T. Mount, R. Schuler, W. Schulze, R. Zimmerman, D. Shawhan, and D. Toomey, “Markets for reactive power and reliability: A white paper,” Eng. Econ. Elect. Research Group, Cornell Univ., Ithaca, NY.

[3] J. Hanger, P. Adels, “Reactive Power and the Blackout,” Available: http://www.energycentral.com/articles/article/529

[4] U.S. Energy Information Administration, “How much electricity is lost in transmission and distribution in the United States?” Available: http://www.eia.gov/tools/faqs/faq.cfm?id=105&t=3

[5] PowerWorld Simulator 17, Available: http://www.powerworld.com/download-purchase/demo-software

[6] J. Kepka. “Reactive Power Compensation.” Wroclaw University of Technology.

[7] N. M. Neagle, D. R. Samson, “Loss Reduction from Capacitors Installed on Primary Feeders,” Transaction of the American Institute of Electrical Engineers, Power Apparatus and Systems, Part III, Vol. 75, Issue 3, 1956.

[8] J. A. Momoh, S. X, Guo, E. C. Ogbuobiri, and R. Adapa, “The quadratic interior point method solving power system optimization problems,” IEEE Transaction on Power System, vol. 9, no. 3, 1994.

[9] R. Dubey, S. Dixit, G. Agnihotri, “Optimal Placement of Shunt Facts Devices Using Heuristic Optimization Techniques: An Overview,” Fourth International Conference on Communication Systems and Network Technologies (CSNT), 2014.

[10] T. Sousa, J. Soares, Z.A. Vale, H. Morais and P. Faria,, “Simulated Annealing metaheuristic to solve the optimal power flow,” IEEE Power and Energy Society General Meeting, 2011.

[11] M.R. AlRashidi, M.E. El-Hawary, “A Survey of Particle Swarm Optimization Applications in Electric Power Systems,” IEEE Transactions on Evolutionary Computation, volume 13, issue 4, 2009.

[12] S.S. Sharif, J.H. Taylor, “Dynamic optimal reactive power flow,” Proceedings of the American Control Conference, 1998.

[13] M.M.A. Salama, N. Manojlovic, V.H. Quintana, A.Y. Chikhani, “Real-time optimal reactive power control for distribution networks,” Electrical Power and Energy System, 1996.

[14] C.L. Hwang, F.A. Tillman, W. Kuo, “Reliability Optimization by Generalized Lagrangian-Function and Reduced-Gradient Methods,” IEEE Transactions on Reliability, Volume R-28, Issue 4, 1979.

[15] R. D. Zimmerman, C. E. Murillo-Sánchez, and R. J. Thomas, "MATPOWER: Steady-State Operations, Planning and Analysis Tools for Power Systems Research and Education," Power Systems, IEEE Transactions on, vol. 26, no. 1, pp. 12-19, Feb. 2011.

[16] Iraj Dabbagchi and Rich Christie, 14 Bus Power Flow Test Case, Available: https://www.ee.washington.edu/research/pstca/pf14/pg_tca14bus.htm

[17] T. Ackermann, “Wind Power in Power Systems,” 2nd ed. John Wiley & Sons, Inc., Hoboken, New Jersey, 2012.

[18] ENERCON Wind energy converters Product overview, Available: http://www.enercon.de/p/downloads/EN_Productoverview_0710.pdf.

[19] M. Gitizadeh, M. Kalanar, “Multi-objective fuzzy based reactive power and voltage control in a distribution system using SA,” 11th International Conference on Hybrid Intelligent Systems (HIS), 2011.

[20] Padhy, N.P.; Abdel-Moamen, M.A.; Praveen Kumar, B.J., “Optimal location and initial parameter settings of multiple TCSCs for reactive power planning using genetic algorithms,” IEEE Power Engineering Society General Meeting, 2004.