IMPLEMENTATION OF AN OPTIMIZATION TECHNIQUE FOR IMPROVING POWER QUALITY IN THE DISTRIBUTED SYSTEM

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Abstract

This paper deals with the Distributed Generation (DG) capacity of the electrical power system. DG capacity is formulated as a Mixed Integer Programming (MIP) problem with respect to various operating constraints in power generation. The objective of this model is to minimize the real power loss by increasing the system voltage profile. DG is used to reduce the line losses, improving system voltage profile. The optimum value of this model is obtained by Lagrangian Relaxation (LR) technique. Lagrangian function gives the optimal value of the DG capacity which is connected in the existing system. The proposed methodology is compared with the other optimization technique Particle Swarm Optimization (PSO) and the results tested through IEEE-30 bus system. Based on numerical calculations and graphical representation, the optimum value of DG is obtained by increasing the maximum loadability of the system.

Keywords: Distributed generation; Mixed Integer Programming; Lagrangian Relaxation; Voltage profile.

1. Introduction

In distributed power system, the delivery of electricity to the customer is becoming very difficult task because of increasing demand. Therefore the power system has a renewed interest in small-scale electricity generation. Small-scale generation is also called Distributed Generation (DG), embedded generation (or) decentralized generation.

Distributed power generation is most effective by improving the power transfer capability of the system and its voltage stability. These DG units are operated near the load centres which are closer to consumers than the central generating stations. It helps to meet the increasing demand without expanding the central station power plants. So the distributed power unit can be connected directly to the consumer (or) to a utility’s transmission (or) distribution system to provide peaking services. Distribution generation can enhance the efficiency, reliability and operational benefits of the distribution system.

In past research, many researchers have discussed the power quality, reliability of the distribution system. Ackermann T et al. [1] have discussed the definition of distributed generation. Quantitative techniques for analysis of large data sets in renewable distributed generation was analyzed by Aleksandar et al. [2], Caisheng Wang et al. [3] have proposed the analytical approaches for optimal placement of distributed generation sources in power system. Victor H. et al. [4] have discussed assessment of energy distribution losses for increasing penetration of distributed generation. Benefit of distributed generation, a line loss reduction analysis was discussed by P. Chiradeja et al. [5]. G. Calli et al. [6] have allocated the optimal distributed generation in MV distribution networks. Voltage collapse prediction based on line voltage stability index was analyzed by S.C. Choube et al. [7]. S. Maheswari et al. [8] have designed the optimization model for electricity distribution system control using communication system by Lagrangian Relaxation technique. The optimal power flow for power system using Lagrangian relaxation technique was analyzed by S. Maheswari et al. [9]. Distribution generation is economically viable, this was discussed by P. Chiradeja et al. R.C. Dugan et al., T. Gracy, W.G. Scott, T. Raissi et al. S. Rahman in [10]-[18]. S. Maheswari et al. [19] were optimizing the reactive power distribution using LR technique. P. Ajay-D-Vimal Raj et al. [20] have proposed PSO for optimization of distributed generation capacity.

2. Model Formulation

Distributed Generation capacity is designed as a MIP problem with respect to various parameters. This model gives the active power losses in the electrical system.

2.1. *Parameters*

i, j – number of buses
N – total number of buses
PG_i – generated active power output at bus i
QG_i – generated reactive power output at bus i
P_L – real power loss in the distributed system
g_{ij} – conductance between buses i and j
b_{ij} – susceptance between buses i and j
V_i – voltage magnitude at bus i
V_{P_i} – voltage profile at the buses.
L_i – load at the bus i
A – number of adjacent buses
N_A – total number of adjacent buses
W_i – Waiting factor at bus i
θ_{ij} – voltage phase angle difference between i and j
V_i^{max} – maximum voltage magnitudes at the bus i
V_i^{min} – minimum voltage magnitudes at the bus i
QG_i^{max} – maximum generated reactive power output at the bus i
QG_i^{min} – minimum generated reactive power output at the bus i
T_i – number of transformer tap settings
NT – total number of transformer tap settings
T_i^{max} – maximum transformer tap settings
T_i^{min} – minimum transformer tap settings
QC_i – installation of reactive power for shunt VAR compensators
NC – total number of shunt VAR compensators
QC_i^{max} – maximum shunt VAR compensators
QC_i^{min} – minimum shunt VAR compensators
ℓ – number of load buses
NL – total number of load buses
PD_i – active power demand at bus i
QD_i – reactive power demand at bus i
G – number of generated buses
NG – total number of generated buses

2.2. *Objective Function*

$$P_L = \min \sum_{j=1}^{NA} g_{ij}(V_i^2 + V_j^2 - 2V_iV_j\cos\theta_{ij}), \quad i = 1,2,...,N$$

subject to

$$PG_i - PD_i = V_i \sum_{j=1}^{NA} V_j(g_{ij}\cos\theta_{ij} + b_{ij}\sin\theta_{ij}) \quad i = 1,...,NG \qquad (a)$$

$$QG_i - QD_i = V_i \sum_{j=1}^{NA} V_j(g_{ij}\sin\theta_{ij} + b_{ij}\cos\theta_{ij}) \quad i = 1,...,NL \qquad (b)$$

$$V_{P_i} = \sum_{i=}^{N} V_i L_i W_i \quad \text{with} \quad \sum_{i=1}^{N} W_i = 1, \quad i = 1,\ldots, N \tag{c}$$

$$\sum_{i=1}^{N} V_{P_i} = 1 \tag{d}$$

$$V_i^{min} \le V_i \le V_i^{max}, \quad i = 1,\ldots, N \tag{e}$$

$$T_i^{min} \le T_i \le T_i^{max}, \quad i = 1,\ldots, NT \tag{f}$$

$$QG_i^{min} \le QG_i \le QG_i^{max}, \quad i = 1,\ldots, NL \tag{g}$$

$$QC_i^{min} \le QC_i \le QC_i^{max}, \quad i = 1,\ldots, NC \tag{h}$$

3. Proposed Model

Relaxing (c) and (d)

3.1. *Lagrangian Function*

$$L[P_L, V_{P_i}, \lambda_{P_i}] = \min\left[P_L + \sum_{i=1}^{N} \lambda_{P_i} (1 - V_{P_i})^2 \right]$$

subject to

$$PG_i - PD_i = V_i \sum_{j=1}^{NA} V_j (g_{ij} \cos\theta_{ij} + b_{ij} \sin\theta_{ij}) \quad i = 1,\ldots, NG \tag{a}$$

$$QG_i - QD_i = V_i \sum_{j=1}^{NA} V_j (g_{ij} \sin\theta_{ij} + b_{ij} \cos\theta_{ij}) \quad i = 1,\ldots, NL \tag{b}$$

$$V_i^{min} \le V_i \le V_i^{max}, \quad i = 1,\ldots, N \tag{e}$$

$$T_i^{min} \le T_i \le T_i^{max}, \quad i = 1,\ldots, NT \tag{f}$$

$$QG_i^{min} \le QG_i \le QG_i^{max}, \quad i = 1,\ldots, NL \tag{g}$$

$$QC_i^{min} \le QC_i \le QC_i^{max}, \quad i = 1,\ldots, NC \tag{h}$$

Here the λ_{P_i} is the penalty factor of the voltage buses.

Lagrangian Relaxation Method:

Lagrangian relaxation replaces the original problem with an associated Lagrangian problem whose optimal solution will provide a bound on the objective function of the original problem. This is achieved by eliminating (i.e., relaxing one or more) of the constraints of the original model and adding these constraints, multiplied by an associated Lagrange multiplier, to the objective function. The idea is to relax constraints that will result in a relaxed problem that given values of the multipliers, is much easier to solve optimally. The role of these multipliers is to drive the Lagrangian problem toward a solution that satisfies the relaxed constraints. Unfortunately, determining the values of the optimal Lagrangian multipliers is generally very difficult.

The Lagrangian relaxation approach replaces the problem of identifying the optimal values of all of the decision variables with one of finding optimal or good values for the Lagrangian multipliers. Most Lagrangian-based heuristics use a search heuristic to identify the optimal multipliers. A major benefit of Lagrangian-based heuristics is that they generate bounds (i.e., lower bounds on minimization problems and upper bounds on maximization problems) on the value of the optimal solution of the original problem. For any set of values for the Lagrangian multipliers, the solution to the Lagrangian model is less than or equal to the solution to the original model. Therefore, the Lagrangian solution is a lower bound on the solution to the original problem.

The solution to the Lagrangian problem for any given values of the Lagrangian multipliers will generally violate one or more of the relaxed constraints. Many Lagrangian based algorithms incorporate additional heuristics to convert these infeasible solutions to feasible ones. In this way, the researchers can produce good solutions to the original model. The best feasible solution among those found by the procedure at any point, represents the upper bound on the value of the true optimal solution. The difference between the upper and lower bounds is referred to as the "gap". If the gap reaches zero (or some minimum value based on the integer properties of the model) then it should be found the optimal solution. Otherwise, when the gap gets sufficiently small (e.g. less than 1%), the analyst may stop the procedure and be satisfied that the current best solution is within 1% of optimality.

An excellent tutorial on the general application of Lagrangian relaxation can be found in Fisher (1985). An exposition of its use in location models is in the text by Daskin (1995).

In this paper Lagrangian function minimizes the active power loss with respect to the Lagrangian multiplier λ_{P_i}. Here this multiplier is used as a penalty factor of the voltage profile at the buses. It helps to obtain the optimal value of MIP and for faster convergence.

4. Numerical Calculations and Graphical Representation

Load flow studies have been conducted on an IEEE-30 bus system shown in Fig. 1. Based on the conventional method (Newton Raphson) which buses having less voltage profiles. It helps to install the DGs. The DGs are installed in the following buses 30, 37, 7 and 29 from [20].

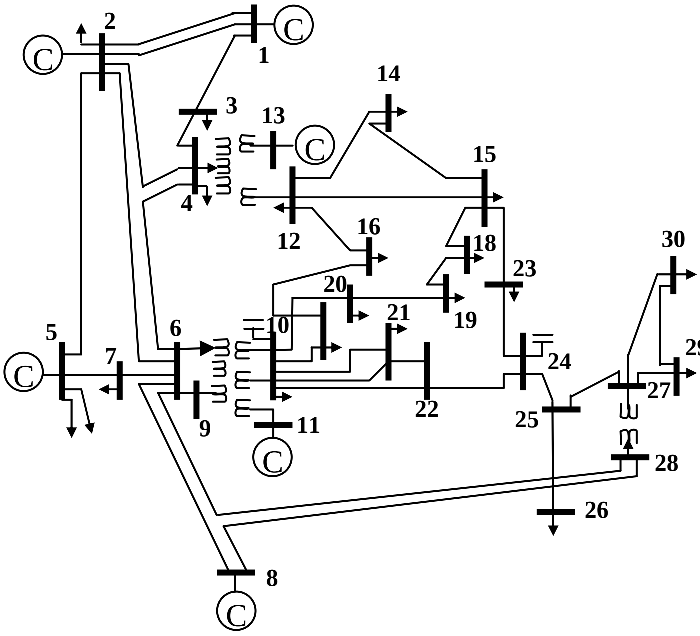

Fig. 1. Standard IEEE 30 bus system

Table 1. Optimization Table

Methods	Newton Raphson	Particle Swarm Optimization Method	Lagrangian Relaxation Technique
Active power loss in the Distributed System	0.7309	0.7193	0.6907

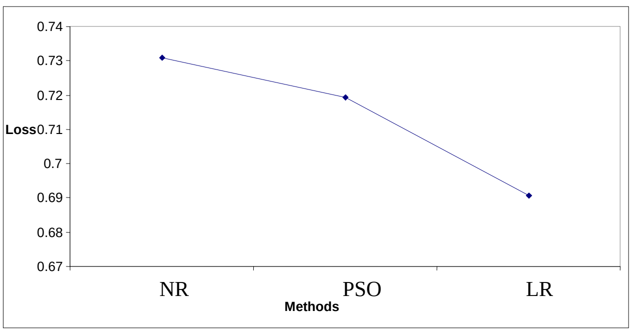

Fig. 2 Optimization Graph

From the table 1 and fig. 2, the minimum active power loss is obtained by LR technique and it increases the power quality of the system.

5. Conclusion

The Distribution Generation capacity has been modeled as a Mixed Iinteger Programming problem. This model can be decomposed by Lagrangian Relaxation technique. The optimal value of the DG design is obtained by the Lagrangian Function. The proposed technique minimizes the active power loss in the power system by optimizing the amount of active power delivered from DG capacity. Based on the numerical calculations and graphical representations, the minimum active power loss is obtained by Lagrangian function with respect to line loss reduction and improving voltage profile at the buses.

The optimum value of DG capacity improves the efficiency of energy delivery on the distribution network which is based on rating a DG considered. DG in a distributed system offers several benefits such as voltage profile improvement line loss reduction, improvement in system and enhanced utility system reliability.

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