Incorporation of distributed generation and shunt capacitor in radial distribution system for techno-economic benefits

Mukul Dixit*, Prasanta Kundu, Hitesh R. Jariwala
Department of Electrical Engineering, S. V. National Institute of Technology, Surat, India

1. Introduction

In electrical power system distribution system is a more complex network and having a higher power loss as compared to transmission network due to high R/X ratio. Reduction of such power loss is a major challenge in front of distribution companies. The major outlooks for power loss reduction are Dispersed Generation (DG) placement, capacitor placement and system re-configuration. In the last few years, DG placement has become a very renowned research area. After incorporating DG into a system, it provides several potential benefits such as voltage level enhancement, reduction of power loss and improve system stability[1,2]. Combination of both DG and shunt capacitor can play important role for reducing power loss and enhance voltage level to a great extent, if these are properly located with optimum size.

In last few years, the researchers have been utilized various meta-heuristic based intelligent techniques[3–10] for solving DG and shunt capacitor placement problem. In [3], presented an Evolutionary Programming (EP) approach for power loss and THD minimization through optimal placement of DG units. Ref [4], presented an optimal installation of DGs in a distribution system using Artificial Bee Colony (ABC) algorithm. In [5], multi-objective based capacitor placement problem has been solved by Heuristic Search (HS) approach. A Cuckoo Search Algorithm (CSA) demonstrated for reducing power loss and improved voltage level by incorporating shunt capacitor at optimal location [6]. In [7,8], a multi-objective function has been formulated for the purpose of incorporating multiple DG units at multiple locations through Backtracking Search Algorithm (BSA). Ref [9], presented an Artificial Bee Colony (ABC) algorithm for determining exact positions and ratings of shunt capacitors for the purpose of power loss minimization and increment in cost savings. Tabu search (TS) [10] and Immune optimization (IO) [11] Algorithm has been utilized to reduce active power loss of a network through optimal capacitor placement. Ref [12], suggested a fuzzy Shuffled Frog Leaping Algorithm (SFLA) to solve multi objective network re-configuration problem in the availability of reactive power support compensators. In [13], GA has been employed for determining optimal allocation and size of fixed and switched capacitors under load uncertainty. In present work, the allocations/positions of DGs and capacitors are found through two different approaches while the optimal sizes/capacities are determined using GABC algorithm.

This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Nomenclature

- \( \cos \varphi \) power factor
- \( DG_{\text{cap},i} \) DG capacity (kVA)
- \( I_p(m) \) real part of current in mth segment
- \( I_q(m) \) imaginary part of current in mth segment
- \( I_p,i+1 \) current value between ith and \((i+1)\)th bus
- \( I_q,i+1 \) rated value of current between ith and \((i+1)\)th bus
- \( infR \) inflation rate (9%)
- \( K_{\text{cap}} \) capacitor fixed cost (1000 $)
- \( P_{\text{DG}} \) real power of DG (kW)
- \( P_l \) active power flow from ith bus
- \( P_{L,i+1} \) active load of \((i+1)\)th bus (kW)
- \( Q_C \) capacitive compensation (kVar)
- \( Q_{L,i} \) reactive load at ith bus
- \( Q_{L,i+1} \) reactive power flow from ith bus
- \( Q_{C,i} \) capacitor rating (kVar)
- \( Q_{DG} \) reactive power of DG (kVar)
- \( R_{L,i+1} \) branch reactance between bus ith and \((i+1)\)th
- \( S_R \) set of all buses
- \( S_{DG} \) total DG capacity
- \( S_{\text{Load}} \) total kVA load of the system
- \( Total \ Q \) total reactive load of a network (kVar)
- \( T_{\text{Load}} \) purchase active power cost from grid
- \( V_{\text{deviation}} \) voltage deviation
- \( V_I \) voltage of ith bus (pu)
- \( V_{min} \) minimum voltage of ith bus (pu)
- \( V_{max} \) maximum Voltage of ith bus (pu)
- \( V_{\text{rated}} \) rated voltage 1 p.u.
- \( V_{\text{S}}(i) \) voltage stability index of \((i+1)\)th bus
- \( X_{L,i+1} \) branch reactance between bus ith and \((i+1)\)th

Abbreviations

- ABC Artificial Bee Colony
- DG Distributed Generation
- GA Genetic Algorithm
- GABC Gbest-guided Artificial Bee Colony
- IVM Index Vector Method
- LR Loss Reduction
- NB Number of Buses
- O&M Operation and Maintenance
- PLI Power Loss Index
- PLI Power Loss Index
- VSI Voltage Stability Index
- THD Total Harmonic Distortion

2. Power Loss Index (PLI)

This approach is implemented for identifying suitable buses for placement of shunt capacitor and it is also helpful for shrinking the search space during optimization procedure. In addition, power flow calculations are required to calculate the loss reduction (LR) values by providing reactive power compensation at each bus, which is equal to a total reactive load of a network. At a time one bus is considered [5]. The relation for evaluating PLI value of ith bus is formulated using (1).

\[
PLI(i) = \frac{LR(i) - LR_{\text{min}}}{LR_{\text{max}} - LR_{\text{min}}}
\]

Those buses which are having higher PLI values and system voltage below 0.95 pu are chosen as candidature buses for capacitor installation. These are the following steps for implementation of PLI approach to identify candidate buses for capacitor placement.

Step 1: Run load flow and compute real power loss.
Step 2: Provide reactive power compensation across each bus, which is equal to the total system reactive load of a network. And then execute load flow program and evaluate system real power loss for all the buses except slack bus and store the values.
Step 3: Calculate LR = (Base case system active power loss – system active power loss obtained for each bus compensation) and store.
Step 4: Determine maximum and minimum LR. Then evaluate PLI values using (1). Sort these PLI values in descending order. Those buses which are having higher PLI values and lower voltage under 95% are preferred as most suitable buses for placement of capacitor.

3. Index Vector Method (IVM)

This method is being utilized for incorporating DG units in a distribution system and also very useful for reducing the search space during optimization procedure. The base case load flow program of considered test network is required for evaluating necessary component like imaginary and real part of current in each feeder segment to formulate IVM approach [14]. Based on the IVM values, this method identifies candidate buses for DG placement. The expression for computing IVM values of ith bus may be expressed as

\[
IVM(i) = \frac{1}{V_i^2} + \frac{I_p(m)}{I_p(m)} + \frac{Q(i)}{\text{total } Q}
\]

The steps for implementation of IVM approach are as follows.

Step 1: First of all, run base case load flow program.
Step 2: Store the values of voltage for every bus, real and imaginary component of current across each branch.
Step 3: Calculate index vector values of all the buses using (2) and sort these values in decreasing mode. Then, evaluate normalized voltage norm(i) = \( V_i / 0.95 \) @ all buses.
Step 4: At last, those buses which are having higher IVM values and lower normalized voltage under 1.01 are chosen as optimal locations/positions for DG installation.

Please cite this article in press as: M. Dixit et al., Incorporation of distributed generation and shunt capacitor in radial distribution system for techno-economic benefits, Eng. Sci. Tech., Int. J. (2017), http://dx.doi.org/10.1016/j.jestch.2017.01.003
دریافت فوری متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات