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Optimal capacitor allocation in radial distribution systems for loss reduction: A two stage method

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ABSTRACT

This paper presents an efficient approach for capacitor allocation in radial distribution systems that determine the optimal locations and sizes of capacitors with an objective of reduction of power loss and improving the voltage profile. A loss sensitivity technique is used to select the candidate locations for the capacitor placement. The size of the optimal capacitor at the compensated nodes is determined simultaneously by optimizing the loss saving equation with respect to the capacitor currents. The performance of the proposed method (*PM*) was investigated on several distribution systems and it was found that significant voltage profile improvement and loss saving can be achieved by optimal allocation of capacitors in the system. However this method is sensitive to the distribution network configuration. In a 28 node feeder the matrix of capacitor sizing becomes close to singular or badly scaled and results may be inaccurate. In 85 node feeder the same matrix becomes singular and no solution obtained. For the 28 node feeder a two stage technique is proposed: a reconfiguration of the feeder in the first stage followed by optimal capacitor allocation as a second stage. For the 85 node feeder a slight movement of the capacitor location was sufficient to reach optimal capacitor allocation. The proposed two stage technique is also applicable to the 85 node feeder for given optimum configuration of the tie switches. Simulations, using genetic algorithm are conducted for the two (28 and 85 nodes) systems allowing detection of loss reduction and voltage improvement due to capacitor placement.

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1. Introduction

Optimal allocation of shunt capacitors on radial distribution systems is essential for power flow control, improving system stability, power factor correction, voltage profile management, and losses minimization. The solution techniques for the capacitor allocation problem can be classified into four categories [1]: analytical, numerical programming [2], heuristic [3,4], and artificial intelligence-based (AI-Based). AI-Based methods include genetic algorithms [5,6], simulated annealing [7], expert systems [8], artificial neural networks, and fuzzy logic [9,10]. A survey of all capacitor allocation categories has been presented in [1,11]. Haque [12] proposed a method for minimizing the loss associated with the reactive component of branch currents by placing optimal capacitors at proper locations. The method first finds the location of the capacitors in a sequential manner (loss minimization by a singly located capacitor). The optimal capacitor size at each selected location for all capacitors are determined simultaneously, to avoid over compensation at any location, through optimizing the loss saving equation. Other publications found optimal capacitor size through optimizing cost saving [13,14]. Capacitor locations are determined by two methods: Loss Sensitivity Factor and Index Vector. Capacitor sizes are determined by PSO. Capacitor locations given by two methods are not same and the sizes are also different in both the methods. But, total reactive power used for compensation is almost nearer to each other. Location of the capacitors may be found in sequential manner by loss minimization by a singly located capacitor [12,15]. Also fuzzy expert system may be used for extracting suitability of capacitor location from power loss reduction index and voltage profile [10]. Hsiao et al. [16] present a combination fuzzy-GA method to resolve the capacitor placement problem. The problem formulation considers three distinct objective functions related to minimize the total cost for energy loss and capacitors to be installed, as well as decreasing the deviation of bus voltage and improving the margin loading of feeders. Das [17] presents a genetic algorithm (GA) based fuzzy multi-objective approach for determining the optimum values of fixed and switched shunt capacitors to improve the voltage profile and maximize the net savings in a radial distribution system.

This paper, extending the problem formulation of previous researches on capacitor optimization presents an efficient approach for capacitor placement in radial distribution systems that determine the optimal locations and size of capacitor with an objective of reduction of power loss and improving the voltage

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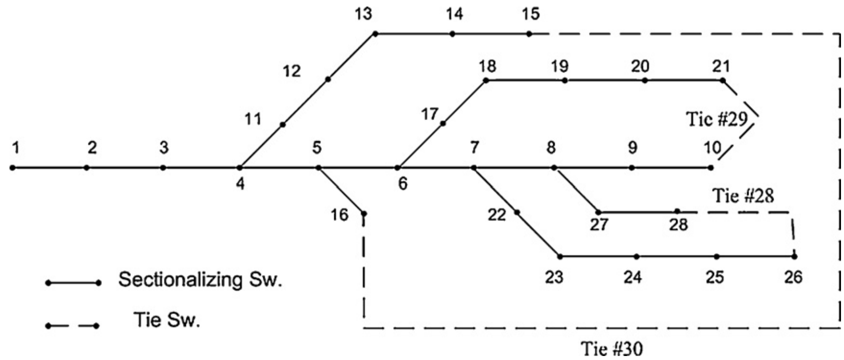

Fig. 1. Single line diagram of 28 node radial distribution feeder.

profile. A loss sensitivity technique is used to select the candidate locations. The size of the optimal capacitor at the compensated nodes is determined simultaneously by optimizing the loss saving equation with respect to the capacitor currents. Sensitivity measured through sequential loss minimization or suitability index extracted from fuzzy expert system gave same location of capacitors along distribution feeders. The performance of the *PM* was investigated on several distribution systems (15 node [18], 28 node [19], 33 node [15], 34 node [1], 69 node [3] and 85 node [18] feeders) and it was found that significant voltage profile improvement and loss saving can be achieved by optimal allocation of capacitors in the system. Two incidents were met where the configuration of distribution network may hinder the solution of capacitor allocation problem. In a 28 node feeder the matrix of capacitor sizing becomes close to singular or badly scaled and results may be inaccurate. In 85 node feeder the same matrix becomes singular and no solution obtained. For the 28 node feeder a two stage capacitor allocation technique is applied: a reconfiguration of the feeder in the first stage [20] followed by optimal capacitor allocation as a second stage resulting in problem solution. For the 85 node feeder a slight movement of the capacitor location is proposed to avoid matrix singularity. The proposed two stage technique is also applicable to the 85 node feeder for given optimum allocation of the tie switches.

2. Proposed method

The load flow algorithm described in [21] is used for calculation of active and reactive power loss. Note that for a given configuration of a single-source radial network, the active power loss cannot

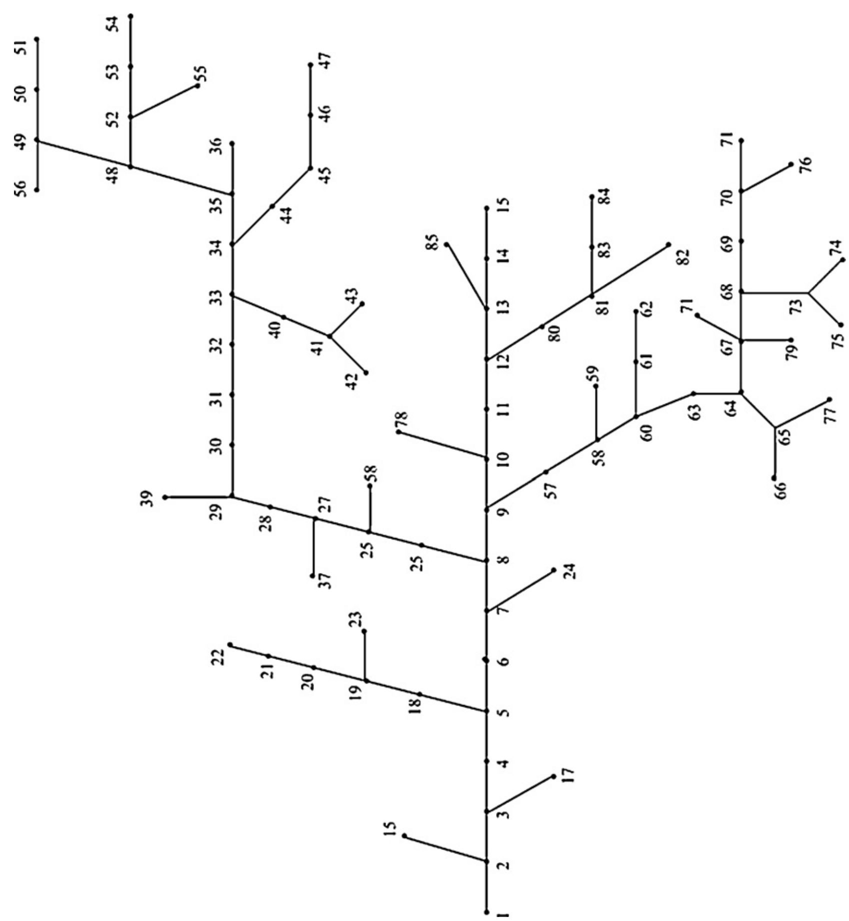

Fig. 2. Single line diagram of 85 node radial distribution feeder.

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