ISSN 2349-7815

International Journal of Recent Research in Electrical and Electronics Engineering (IJRREEE)
Vol. 1, Issue 3, pp: (11-16), Month: October - December 2014, Available at: www.paperpublications.org

A Review On Voltage Regulators Placement In Unbalanced Radial Distribution System Using PSO

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***Abstract*: This paper covers various approaches for modelling of automatic voltage regulator for unbalanced radial distribution systems. Power loss indices are first found at each branch except source bus. The bus that has the highest power loss index will picked as the best location for the voltage regulators placement. To obtain the tap position of the voltage regulators that maintain the voltages within the limits of the unbalanced radial distribution systems by minimizing an objective function, consisting of power loss. Various techniques are used to find the selection of tap position of the voltage regulators. We have also cover the loss minimization using various techniques in unbalance radial distribution system.**

***Keywords:* Unbalanced radial distribution systems, Voltage regulator placement, Loss minimization.**

I. INTRODUCTION

Voltage Regulator (VR) or Automatic Voltage Booster (AVB) is essentially an auto transformer consisting of a primary or existing winding connected in parallel with the circuit and a secondary winding with taps connected in series with the circuit. Taps of series winding are connected to an automatic tap changing mechanism. Voltage regulators are also considered a tool for loss reduction and voltage control. When a voltage regulator is installed at a node, it causes a sudden voltage rise at its point of location and improves the voltage at the nodes beyond the location of voltage regulator. The percentage of voltage improvement is equal to the setting of percentage boost of voltage regulator. The increase in voltage in turn causes the reduction in losses in the lines beyond the location of voltage regulator. Multiple units can be installed in series to the feeder to maintain the voltage within the limits and to reduce the line losses. It can be removed and relocated easily whenever it is required [2].

The distribution system provides the link between bulk power system and consumer. A distribution circuit normally uses primary or main feeders and lateral distributors. A main feeder originates from the substation and passes through the major load centers. Lateral distributors connect the individual load points to the main feeder and are defined as radial distribution systems. The biggest advantages of the radial system configuration, in addition to its lower cost, are the simplicity of analysis and predictability of performance.

Distribution networks are well known for their high R /X ratio and significant voltage drop that could cause substantial power losses along the feeders. It is estimated that as much as 13% of the total power generation is lost in the distribution networks. Portion of this loss is caused by the reactive current flowing in the network. Voltage profiles throughout the network have to be kept at acceptable levels to ensure service reliability among other. Capacitors have been commonly used to provide reactive power in distribution systems. Shunt capacitors in distribution networks are used for various purposes: reducing power loss, improving the voltage profile along feeders, and increasing the maximum transmitted power in cables and transformers. To reduce power loss, shunt capacitors, which are commonly installed in power distribution networks, are used to compensate for reactive power. However, the installation of shunt capacitors in distribution networks requires consideration of their appropriate location and size.

Capacitor placement is important to maximize loss reduction by properly installing shunt capacitors while minimizing shunt capacitor costs. Many heuristic techniques have been reported in the literature to solve the optimal placement problem in distribution systems [5].

1.1 Particle Swarm Optimization (PSO)

The optimal voltage regulator tap setting at candidate node of the unbalanced radial distribution system is selected using PSO.

1.1.1 Initialization of PSO Parameters

The control parameters such as lower and upper bounds of node voltage and tap setting of voltage regulators are selected as initialize parameters. Randomly generate an initial swarm (array) of particles with random positions and velocities.

1.1.2 Evaluation of Fitness Function

The fitness function should be capable of reflecting the objective and directing the search towards optimal solution. Since the PSO proceeds in the direction of evolving best-fit particles and the fitness value is the only information available to the PSO, the performance of the algorithm is highly sensitive to the fitness values. For each particle or swarm, the voltage regulators are placed at the sensitive nodes and run the load flow to calculate the losses, net saving and these net saving becomes the fitness function of the PSO (as saving are maximized).

1.1.3 Optimal Solution

Optimal solution (the best position and the corresponding fitness value) to the target problem. Information of the best position includes the optimal location and number of voltage regulators, and the corresponding tap setting value represents the maximizing the total saving of the system. Accordingly, the optimal location and number of voltage regulators with tap setting at each node can be determined [3].

In order to maintain the voltage profile and to reduce the power losses, these voltage regulators are installed in the distribution system. The optimization problem has been presented into two sub problems: Locating the AVRs on the network and the selection of the tap position of AVRs.

1.2 Optimal location of Automatic Voltage Regulators (AVR)

The optimal location of voltage regulator (AVR) is defined as function of two objectives, one representing power loss reduction and the other one representing the voltage deviations but both are essential to secure the power supply. It is difficult to formulate the problem in terms of cost incidence of these objectives over the system of operation because even when the cost incidence of power losses is clear it is not the same for keeping the voltage values at the buses close to the rated value.

1.3 Tap Position Selection

Tap position (tap) can be calculated by comparing voltage obtained before VR installation with the lower and upper limits of voltage.

'+' for boosting of voltage

'-' for bucking of voltage

The bus voltages are computed by load flow analysis for every change in tap setting of voltage regulators, till all bus voltages are within the specified limits [3].

II. RELATED WORK

This paper describes an approach for modeling of automatic voltage regulator using the forward/backward sweep-based algorithms for unbalanced radial distribution systems. Power loss indices are first found at each branch except source bus and the bus that has the highest power loss index are picked as the best location for the voltage regulators placement. To obtain the tap position of the voltage regulators that maintain the voltages within the limits of the unbalanced radial distribution systems by minimizing an objective function, consisting of power loss. PSO is used to find the selection of tap position of the voltage regulators. This algorithm makes the initial selection, installation and tap position setting of the voltage regulators to provide a good voltage profile and to minimize power loss along the distribution network. The effectiveness of the proposed method is illustrated on a test system of 25 bus unbalanced radial distribution systems [1].

This papers aims at discussing the maintenance of voltage levels by using voltage regulators in order to improve the voltage profile and to maximize the net savings. The proposed method deals with initial selection of nodes by using power loss index (PLI) and then Discrete Particle Swarm Optimization (DPSO) has been used for optimal tap setting of the voltage regulators to maintain voltage profile within the desired limits and reduce the losses. The proposed algorithm is tested with two systems consisting of 15 nodes, and 33 node RDS. From the results, several important observations can be concluded as follows.

• The power losses of distribution system can be effectively reduced by proper placement of voltage regulator.

• In addition of power loss reduction, the voltage profile can be improved as well by the proposed method [2].

This paper presents selection of optimal location and selection of tap setting for voltage regulators in Unbalanced Radial Distribution Systems (URDS). In rural power systems, the Automatic Voltage Regulators (AVRs) help to reduce energy loss and to improve the power quality of electric utilities, compensating the voltage drops through distribution lines. PSO is used for selecting the voltage regulator tap position in an unbalanced radial distribution system. An algorithm makes the initial selection, installation and tap position setting of the voltage regulators to provide a good voltage profile and to minimize power loss along the distribution network. The effectiveness of the proposed method is illustrated on a test system of 25 bus unbalanced radial distribution systems [3].

This paper presents a simple approach for load flow analysis of a radial distribution network. The proposed approach utilizes forward and backward sweep algorithm based on Kirchhoff-s current law (KCL) and Kirchhoff-s voltage law (KVL) for evaluating the node voltages iteratively. In this approach, computation of branch current depends only on the current injected at the neighboring node and the current in the adjacent branch. This approach starts from the end nodes of sub lateral line, lateral line and main line and moves towards the root node during branch current computation. The node voltage evaluation begins from the root node and moves towards the nodes located at the far end of the main, lateral and sub lateral lines. The proposed approach has been tested using four radial distribution systems of different size and configuration and found to be computationally efficient [4].

In this paper various optimization techniques that are adopted for the optimal placement of capacitor to minimize the losses, in the standard test system are reviewed. Finally it has been observed that heuristic optimization techniques are giving better solution quality at a faster convergence in comparison to the available conventional approach of the optimization [5].

Yann-Chang Huang et al. [6] suggested Tabu Search based algorithm to solve the problem of capacitor placement in radial distribution system. The candidate nodes are determined by using sensitivity analysis to reduce the search space for capacitor installation. Tabu search is a strategy for solving optimization problem and is capable of obtaining high quality solutions. The control parameters of Tabu Search such as the tabu list size, the reduction rate of search neighborhood, and the frequency counter threshold are easily tuned in the solution process. 69-bus radial distribution system is used as test bus system on which Tabu Search is applied and results are compared with Simulated Annealing. In comparison of Simulated Annealing, the proposed Tabu Search method gives the nearly optimal solution to the capacitor placement problem within less computing time.

M. H. Haque [7] presented the method for loss reduction in distribution system by placing a single and multiple capacitor and was tested on two distribution systems consisting of 15 and 33 buses. The methodology obtained for loss minimization associated with the reactive component of branch currents by placing shunt capacitors.

In formulation of this method, first finding the sequence of buses that provides the highest loss saving then the optimal value of capacitors is determined by minimising the loss saving equation with respect to the capacitor currents.

Neagle and Samson [8] considered loss reduction by one capacitor bank placed along the feeder by considering uniformly distributed loads, uniformly decreasing loads and equally distributed loads along the feeder. A general application curves for selecting location and size of single capacitors to minimize loss has been presented.

Grainger and Lee [9] considered the problem as non-linear programming problem, the capacitor sizes have been considered as continuous variables and iterative solution scheme has been proposed. The optimal sizes, locations and switching times of fixed and/or switched capacitors can be iteratively determined for primary distribution feeders of non-uniform wire sizes. The time varying, non-uniform, distributed reactive load along the feeder is accommodated within the modeling. Voltage profile maintenance under variable load conditions.

Sattianadan et al. [10] have used Particle Swarm Optimization method for solving the problem of capacitor placement in radial distribution network. Loss sensitivity factors are used to select the candidate installation locations of the capacitors. The overall economy is improved by reducing energy loss cost and capacitor cost.

Rahmat-Allah Hooshmand and Mohammad Ataei [11] presented real coded genetic algorithm (RCGA) for loss reduction and controlling the voltages of distribution systems by the fixed and switched capacitors. For achieving this real modelling of the system in actual operational conditions including unbalanced or balanced loading and for actual feeder structure, i.e., radial/meshed configuration, are required. By using this algorithm reduction in energy loss and annual energy consumption is achieved which is good from economic point of view.

Srinivasan Sundhararajan and Anil Pahwa [12] have used optimization method for capacitor placement problem in distribution system. Loss sensitivity analysis and genetic algorithm is used for capacitor location and sizing in radial distribution network. Genetic algorithms are capable of handling both continuous and discrete variables efficiently without any change in the search mechanism.

S. Ghosh and D. Das [13] introduced the efficient load flow method for radial distribution system using evaluation based on algebraic expression of receiving-end voltages.

Jen-Hao Teng [14] presented a load flow solution for radial distribution system by using topological characteristics of distribution networks. Two matrices are developed for the load flow solution which is BIBC represent the relation between bus current injections and branch current whereas BCBV represent the relation between branch currents and bus voltages. These two matrices are multiply to obtain load flow solutions.

Roberto S. Aguiar, Pablo Cuervo [15] have used a strategy of linear approximations and new variable representation for reducing investment costs and energy loss in radial distribution networks. Linear approximation of the problem is in two ways such as Support Hipper-planes (SH) allowing the approximation of the loss function and other is related to the product of integer variables and continuous variables. The classical problem is become a new mixed linear integer optimization problem which is easy to solve.

S. G. Saranya [17] suggested Fuzzy-Differential Evolution method to improve voltage profile and reduce real power loss in radial distribution system. Candidate buses are determined by fuzzy expert system and Differential Evolution is used to find size of capacitors to get maximum saving.

Rosana Satie Takehara, and Rubén Romero [18] presented Artificial Immune Systems applied to capacitor placement problem in radial distribution system. The problem can be formulated as mixed integer nonlinear program. And good performance was obtained during experimental test from this method.

This paper presents selection of optimal locations and sizes of voltage regulators in radial distribution system using Plant Growth Simulation Algorithm (PGSA). Voltage has always been considered as an integral part of the power system response.

There are several factors, which contribute to voltage collapse such as increased loading on distribution feeders, reactive power constraints, on load tap changer dynamics and load characteristics. The proposed method for voltage regulator placement is suitable for large radial distribution network. The VR problem consists of two sub problems, that of optimal placement and optimal choice of tap setting. The proposed method deals with initial selection of voltage regulator buses by using power loss indices (PLI). The candidate node identification technique and Plant Growth Simulation Algorithm

(PGSA) are used for optimal location and number along with tap setting of the voltage regulators that maintain a smooth voltage profile throughout the network. The aim of this paper is to obtain optimal voltage control with voltage regulators and then to decrease the total cost and losses, to obtain the maximum net savings. The effectiveness of the proposed method is illustrated with 33 bus and 69 bus radial distribution systems and these results are compared with Discrete Particle Swarm Optimization method [19].

Future Work

We have studied various techniques such as Swarm Optimization, Plant Growth Simulation algorithm etc. for loss minimization in unbalanced radial distribution network. We can use Particle swarm optimization (PSO) to minimize the power loss in unbalanced radial distribution network.

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