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GA BASED CAPACITOR PLACEMENT FOR VOLTAGE OPTIMIZATION IN 33-BUS RADIAL DISTRIBUTION SYSTEM

(A REVIEW)

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Missing Abstract

1. Introduction

Genetic Algorithms (GAs) are adaptive heuristic search algorithms based on the evolutionary ideas of natural selection and natural genetics. The coding and manipulation of search data is based upon the operation of genetic DNA and the selection process is derived from Darwin's survival of the fittest'. Evolutionary computing was introduced in the 1960s by I. Rechenberg in his work "Evolution strategies". His idea was then developed by other researchers. Genetic Algorithms (GAs) were invented by John Holland at the University of Michigan. This lead to Holland's book "Adaptation in Natural and Artificial Systems" published in 1975. The goals of their research have been two fold: (1) to abstract and rigorously explain the adaptive processes of natural systems and (2) to design artificial systems software that retains the important mechanisms of natural systems. In 1992 John Koza has used genetic algorithm to evolve programs to perform certain tasks. He called this method "Genetic Programming" (GP).

Genetic Algorithms are different from normal optimization and search methods in four ways:

GAs work with coding of the parameter set, not the parameters themselves. GAs search from a population of points, not a single point.

GAs use payoff (objective function) information, not derivatives or other auxiliary knowledge. GAs use probabilistic transition rules, not deterministic rules.

A simple genetic algorithm that yields good results in many practical problems is composed of three operators:

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1. Reproduction: This operator is an artificial version of natural selection based on Darwinian survival of the fittest among string creatures.
2. Crossover: It occurs after reproduction or selection. It creates two new population or strings from two existing ones.
3. Mutation: It is the occasional random alteration of the value of a string position. Mutation creates a new string by altering value of existing string.

2. Literature Survey

Nallagownden et al in their paper entitled "Application of Genetic Algorithm for the Reduction of Reactive Power Losses in Radial Distribution System" have described that power losses in distribution system have become the most concerned issue in power losses analysis in any power system. In the effort of reducing power losses within distribution system, reactive power compensation has become increasingly important as it affects the operational, economical and quality of service for electric power systems. This paper presents the application of genetic algorithm approach for reactive power loss reduction in radial distribution system. IEEE 34-bus Standard Test System is used together with the ERACS and MATLAB as powerful tools for the analysis and simulation work. ERACS is used to perform load flow analysis while MATLAB is used for the identification of capacitor current via GAtool, and algorithm for the calculation of loss savings, its particular capacitor size and location. The result is then compared with the heuristic search strategies to evaluate the performance of genetic algorithm. [1]

Reddy et al in their paper entitled "2Index and GA based Optimal Location and Sizing of Distribution System

Capacitors" have emphasized that shunt capacitors can be installed in a distribution system to a required level of reactive power support to reduce energy and peak power losses. The amount of compensation to be provided is linked with the desirable objectives subject to the operational constraints. Thus optimal capacitor placement problem aims at determination of capacitor locations and their respective sizes. This paper presents a power loss based approach to determine suitable capacitor locations and an index and genetic algorithm based approach for optimal capacitor sizing. Highest suitability of nodes for capacitor placement and the corresponding sizes are determined. The proposed method has been tested on 15, 31, 34, 69 and 85-bus distribution networks and the results are found to be very promising with considerable reduction in active power loss and improvement in voltage profile. Results for an 85-bus radial distribution system are presented. [2]

Rojas et al in their paper entitled "Optimal Capacitor Location for Radial Systems using Genetic Algorithms" have described a new technique for placing fixed capacitors in radial distribution systems based on genetic algorithms (GA). Current optimization models of capacitor placement only consider losses reduction and voltage profile simultaneously, but the compensation cost and the load changes are not taken into account as part of the objective function. Also, the result may be not the best choice because this is a very large optimization problem and there are too many combinations. They present a general approach for the optimal solution of this problem considering all the parameters of the distribution system involved: capacitor cost, voltage, angle and load changes. An exhaustive search through all possible solutions is needed. Therefore, GA is an ideal candidate to solve this situation, Working with this algorithm, a Microsoft Excel program has been developed in order to answer the capacitor placement problem for any kind of radial distribution system. [3]

Kyu-Ho Kim et al in their paper entitled "Voltage profile improvement by capacitor placement and control in unbalanced distribution systems using GA" have presented an efficient algorithm for determining the location, size and number of capacitors in unbalanced radial distribution system. The objective function formulated consists of two terms: cost for energy loss and cost related to capacitor purchase and capacitor installation. The cost function associated with capacitor placement is considered as a step function due to banks of standard discrete capacities. Genetic algorithms (GA) are used to obtain the solution of the proposed problem. In GA application, multi-population formulations that each load level is assigned to each subpopulation are derived. The strings in each population consist of the bus number index and size of capacitors to be installed. In order to determine the number of capacitor placement, the length mutation operator is used. Its efficiency is proved through the application in 10 buses and 25 buses unbalanced radial distribution systems. [4]

Niknam et al in their paper entitled "Impact of distributed generation on volt/Var control in distribution networks" have realized that as the power system in many countries is going to be restructured and deregulated. After deregulation, because of numerous advantageous of distributed generation (DG), the number of this kind of generators are going to be increased. DGs can affect entire system and especially distribution networks. One of the important control schemes at distribution system that DGs can change it is volt/Var control. This paper presents an efficient approach for volt/Var control in radial distribution networks takes DGs performance into consideration. In general distributed generations can be considered as PV or PQ nodes. In this paper DGs are modeled as PV nodes. The goal of this approach is to minimize power losses at distribution system through controlling the tap of load tap changer (LTC), size of substation capacitor, local controller settings and voltage amplitude of DGs. DGs, voltage regulators, local controllers, and load tap changer (LTC) are modeled completely and the optimization problem has been solved by using genetic algorithm. Finally the method is tested on IEEE 34 bus radial distribution feeders. [5]

Sundhararajan et al in their paper entitled "Optimal selection of capacitors for radial distribution systems using a genetic algorithm" have presented a new design methodology for determining the size, location, type and number of capacitors to be placed on a radial distribution system.The objective is to minimize the peak power losses and the energy losses in the distribution system considering the capacitor cost. A sensitivity analysis based method is used to select the candidate locations for the capacitors. A new optimization method using a genetic algorithm is proposed to determine the optimal selection of capacitors. Test results have been presented along with the discussion of the algorithm. [6]

Mady et al in their paper entitled, "Optimal sizing of capacitor banks and distributed generation in distorted distribution networks by genetic algorithms" have presented a new genetic algorithm (GA)- based approach for the simultaneous power quality improvement and optimal placement and sizing of fixed capacitor banks and distributed generation DGs in radial distribution networks in the presence of voltage and current harmonics. The objective function includes the cost of power losses, energy losses, capacitor banks. Constraints include voltage limit, voltage THD, number/ size of (capacitor and generator) and power quality limit Candidate buses for capacitor placement and distributed generation are selected using the sensitivities of constraints and the objective function with respect to reactive power injection at each bus The effect of harmonics on reactive power compensation of radial distribution systems is studied in this paper. The problem of optimal capacitor and distributed generation sizing and placement is solved for a non-uniform radial distribution system with lateral sub-feeders with linear and non-linear loads distributed along the feeder. The voltage at each bus along the feeder after capacitor and DGs installation is calculated for each harmonic order. [7]

Fu-Yuan Hsu et al in their paper entitled "A Multi-Objective Evolution Programming Method for Feeder Reconfiguration of Power Distribution System" have emphasized on the use of soft computing for solving distribution reconfiguration problems. Genetic algorithm (GA) is one of the most popular technologies in the soft computing area for solving distribution system problems. However, due to the radial structure of power distribution system, traditional GAs may encounter some difficulties when searching for the optimal solution. Evolutionary programming (EP) was also being used to solve some distribution system problems, for example, loss minimization, service restoration, capacitor placement and many others. Hence, the EP is applied in this paper in order to overcome the weakness of traditional GAs (Fudou et. al, (1997); Miranda et al., (1994); Nara et al., (2003); Ying-Tung Hsiao, (2004), Back et al., (2004); Ying-Tung Hsiao and Ching-Yang Chien, 2000). One of the differences between GA and EP is that the weighting of chromosomes is used for selection operator. The weighting calculation of this paper is based on the characteristics of feeder losses and load balancing on distribution feeders. The results show that the proposed EP with adapted weight calculation performs better than traditional Gas. [8]

M.-R. Haghifam et al in their paper entitled "Genetic algorithm-based approach for fixed and switchable capacitors placement in distribution systems with uncertainty and time varying loads" have realized that installation of capacitors in primary and secondary networks of distribution systems is one of the efficient methods for energy and peak load loss reduction. Also voltage profile in the feeder is improved and static voltage stability is enhanced. The main challenge is the determination of optimal location and size of fixed and switchable capacitors with respect to network configuration, distribution of load in the feeder, time variation of load and uncertainty in load forecasting or load allocation process. To solve this complex problem, an efficient method for simultaneous allocation of fixed and switchable capacitors in radial distribution systems is presented. Energy and peak load loss reduction, and capacitor cost are considered in the cost function. Time variation and uncertainty of load are also involved in problem formulation. Genetic algorithm with a new coding as two rows chromosomes is used for optimisation. Numerical studies show the effectiveness of the proposed procedure. [9]

In the paper entitled "Distribution systems operation optimisation through reconfiguration and capacitor allocation by a dedicated genetic algorithm" an efficient algorithm for optimisation of radial distribution systems by a network reconfiguration and capacitor allocation is discussed. An important outcome of the proposed approach is the cost savings related to purchasing new capacitor banks. Several reconfiguration and capacitor allocation methods can be found in the literature, but just a few approach the problem by a joint strategy. A modified, dedicated genetic algorithm-based approach has been successfully developed and implemented. It presents low computational effort and is able to find good quality configurations. Simulation results for a radial 69-bus and a radial, realistic 135-bus systems are presented and commented. [10]

De Souza et al in the paper entitled "Multiobjective Optimization and Fuzzy Logic Applied to Planning of the Volt/Var Problem in Distributions Systems" deals with integrated voltage and reactive power control (volt/var) for radial distribution feeders in planning issues, by means of the application of automatic voltage regulators (AVRs) banks and capacitors. A multiobjective genetic algorithm (SPEA2) improved using fuzzy logic is presented to solve the volt/var problem, since it is a combinatorial multiobjective optimization problem. The expert knowledge is taken into account via fuzzy logic in order to reduce the search space using voltage regulators in standard units. According to the multiobjective optimization fundamentals, an optimal solution ensemble is obtained, which concomitantly represents the solutions to both objectives, in such way that the operational restrictions of systems are satisfied. The algorithm is evaluated for a known 69-bus feeder in the literature of the subject. The obtained results demonstrate that the proposed method provides good concordance between the obtained solution and the Pareto front. [11]

Azim et al in their paper entitled "Optimal Capacitor Allocation in Radial Distribution Systems under APDRP" have presented the optimum location and size of capacitors for a distribution system under APDRP (Accelerated Power Development Programme). In the present study capacitor sizes are assumed as discrete known variables, which are to be placed on the buses such that it reduces the losses of the distribution system to a minimum. Genetic algorithm is used as an optimization tool, which obtains the optimal values and location of capacitors and minimizes the objective function, which is the power loss in the distribution network under study. A dedicated distribution system load flow is used to calculate power loss and voltage profile of the distribution system. Implementation aspects and important results for a 33 bus, 29 Indian power distribution system and practical 34 bus system have been presented to highlight the working of the algorithm. [12]

Masoum et al in their paper entitled "Optimal placement, replacement and sizing of capacitor Banks in distorted distribution networks by genetic algorithms" have discussed about a new genetic algorithm (GA)-based approach for the simultaneous power quality improvement and optimal placement and sizing of fixed capacitor banks in radial distribution networks in the presence of voltage and current harmonics. The objective function includes the cost of power losses, energy losses and that of the capacitor banks. Constraints include voltage limits, number/size and locations of installed capacitors (at each bus and the entire feeder) and the power quality limits of standard IEEE-519. Candidate buses for capacitor placement are selected based on an initial generation of chromosomes. Using a proposed fitness function, a suitable combination of objective and constraints is defined as a criterion to select (among the candidates) the most suitable buses for capacitor placement. A genetic algorithm computes improved generations of chromosomes and candidate buses until the solution is obtained. Simulation results for two IEEE distorted networks are presented and solutions of the genetic algorithm are compared with those of the maximum-sensitivities-selection (MSS), the maximum sensitivities selection-local variations (MSS-LV), and the fuzzy set algorithms. The main contribution of this paper is the computation of the near global solution, with weak dependency on initial conditions. [13]

Seifi et al in their paper entitled "Application of a new hybrid optimization method for optimum distribution capacitor planning" have presented a new algorithm based on a combination of fuzzy (FUZ), dynamic programming (DP), and genetic algorithm (GA) approach for capacitor allocation in distribution feeders. The problem formulation considers two distinct objectives related to total cost of power loss and total cost of capacitors including the purchase and installation costs. The novel formulation is a multi-objective and non-differentiable optimization problem. The proposed method of this article uses fuzzy reasoning for sitting of capacitors in radial distribution feeders, DP for sizing and finally GA for finding the optimum shape of membership functions which are used in fuzzy reasoning stage. The proposed method has been implemented in a software package and its effectiveness has been verified through a 9-bus radial distribution feeder for the sake of conclusions supports. A comparison has been done among the proposed method of this paper and similar methods in other research works that shows the effectiveness of the proposed method of this paper for solving optimum capacitor planning problem. [14]

Masoum et al in their paper entitled "Optimal placement and sizing of capacitor banks in distorted distribution networks by genetic algorithms" describes about a new genetic algorithm based approach for the simultaneous power quality improvement and optimal placement and sizing of fixed capacitor banks in radial distribution networks in the presence of voltage and current harmonics. The objective function includes the cost of power losses, energy losses and that of the capacitor banks. Constraints include voltage limits, number/size and locations of installed capacitors (at each bus and the entire feeder) and the harmonic limits of standard IEEE-519. Candidate buses for capacitor placement are selected based on an initial generation of chromosomes. Using a proposed fitness function, a suitable combination of objective and constraints is defined as a criterion to select the most suitable buses for capacitor placement. A genetic algorithm computes improved generations of chromosomes and candidate buses until the solution is obtained. Simulation results of the genetic algorithm are compared with those of the MSS, the MSS - LV, and the fuzzy set algorithms. The main contribution of this paper is the computation of the near global solution, with weak dependency on initial conditions. [15]

Vahid et al in their paper entitled "Combination of optimal conductor selection and capacitor placement in radial distribution systems for maximum loss reduction" have described an approach for optimal placement and sizing of fixed capacitor banks and also optimal conductor selection in radial distribution networks for the purpose of economic minimization of loss and enhancement of voltage. The objective function includes the cost of power losses, capacitors and conductors. Constraints include voltage limit, maximum permissible carrying current of conductors, size of available capacitors and type of conductors. The optimization problem is solved by the genetic algorithm method and the size and the type of the capacitors and conductors is determined. By applying the proposed method, the economic costs and power losses are reduced to a considerable degree while enhancing the voltage profile. Simulation results are investigated on a radial distribution network consisting of 27 buses. [16]

Paar et al in their paper entitled "Optimization of the compensation of a meshed MV network by a modified Genetic Algorithm" discusses about the utilization of a modified genetic algorithm (GA) for the optimization of the shunt compensation in meshed and radial MV distribution networks. The algorithm looks for minimum costs of the network power losses and minimum capital and operating costs of applied capacitors, all of this under limitations specified by a multicriteria penalization function. The parallel evolution branches in the GA are used for the purpose of the optimization acceleration. The application of this GA has been implemented in Matlab. The evaluation part of the GA implementation is based on the steady-state analysis using a linear one-line diagram model of a power network. The results of steady-state solution are compared with the results from the DIgSILENT Power Factory program. Its practical applicability is demonstrated on examples of 22 kV radial and meshed overhead distribution networks. [17]

Gallego et al in their paper entitled "Optimal capacitor placement in radial distribution networks" have described that the capacitor placement (replacement) problem for radial distribution networks determines capacitor types, sizes, locations and control schemes. Optimal capacitor placement is a hard combinatorial problem that can be formulated as a mixed integer nonlinear program. Since this is a NP complete problem (nonpolynomial time) the solution approach uses a combinatorial search algorithm. The paper proposes a hybrid method drawn upon the Tabu Search approach, extended with features taken from other combinatorial approaches such as genetic algorithms and simulated annealing, and from practical heuristic approaches. The proposed method has been tested in a range of networks available in the literature with superior results regarding both quality and cost of solutions. [18]

Mady et al in their paper entitled "Fuzzy sets- based voltage control strategy for radial distribution systems by genetic algorithm" have discussed about new genetic algorithm (GA) by Fuzzy-based and voltage control in a realistic distribution system that is a part of the North Delta Electricity Distribution Company network in Egypt. This system includes tap-changed main transformer, substation switched capacitors and feeders switched capacitors whose operation is to be coordinated. The unprecise linguistic expressions associated to practical operation are treated via fuzzy sets. First, the objective function and constraints are formulated in terms of fuzzy sets. Then, a genetic algorithm technique is adopted to solve the problem to determine the optimal dispatching schedule of the main transformer tap position and capacitors on/off status. Extensive results are discussed while comparing the proposed voltage control strategy versus two others. [19]

Shyh-Jier Huang et al in their paper entitled "An immune-based optimization method to capacitor placement in a radial distribution system" have proposed an immune algorithm (IA) based optimization approach for solving the capacitor placement problem. In the capacitor placement problem, those practical capacitor operating constraints, load profiles, feeder capacities and allowable voltage limits at different load levels are all considered while the investment cost and energy loss are minimized. In the proposed method, objective functions and constraints are represented as antigens. Through the genetic evolution, an antibody that most fits the antigen becomes the solution. In this IA computation, an affinity calculation process is also embedded to guarantee the diversity. The process stagnation can be thus better prevented. The proposed method has been applied to a test system and the results are compared with other published techniques. [20]

3. Gaps in Present Study

1. To identify the location and sizes of capacitors to be placed in 11 bus radial distribution system which is more prevalent in rural India.
2. The sizes of the capacitors have been not been found using Genetic Algorithm, while optimizing the overall economy calculated considering the energy loss cost and capacitor cost for 11 bus Radial Distribution System.

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