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Optimal Capacitor Placement in Radial Distribution System using Adaptive Genetic Algorithm

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Abstract: This paper presents an approach that determines the optimal location and size of capacitors on radial distribution systems to improve voltage profile and reduce the active power loss using genetic algorithm. To reduce the losses in distribution systems, various capacitor placement techniques have been studied so far. This paper focuses on both classical and artificial intelligence methods. This survey helps the researchers to know about all these methods so that further work on optimal capacitor placement can be carried to improve the results.

Keywords: adaptive genetic algorithm, optimal, placement, radial, distribution system.

I. INTRODUCTION

The term reactive power compensation corresponds to compensate the lagging reactive current of the power system by supplying leading reactive current to the power system. This leading reactive power is supplied by shunt capacitors to the power system. The pioneers of optimal capacitor placement, Neagle and Samson [1] used analytical approaches for capacitor placement. They gave two-third rule for capacitor placement. The two-third rule says that for maximum loss reduction capacitor should be installed at a position two thirds of the distance along the total feeder length. The method was based on assumption of a feeder with a uniformly distributed load. At present, Taiwan Power Company has been actively promoting the use of the loop type distribution system to satisfy the demand of users in general, and those in high-tech industry, in particular, for reliable power supply, and to prevent the occurrence of instantaneous blackouts caused by maintenance, switching operation, and single incidents of the distribution system.

The capacitor placement problem is a well-researched topic. Earlier approaches differ in problem formulation and the solution methods. In some approaches, the objective function is considered as an unconstrained problem. The objectives for determination of capacitor sizing consist of two important terms, which are reduction of power losses and reduction of capacitor purchasing cost. These objectives conflict with each other in the sense that any improvement in one objective results into the decrement of the other objective. The aim of this problem is to find a compromise between the objectives for the satisfying solution of the problem. Optimization problem is solved by the goal-attainment method in this paper. Two types of capacitors are usually considered: fixed and switched capacitor banks. Fixed banks are operating on the feeder all the time. In this paper, fixed capacitor banks are taken into account, optimal placement is determined using Loss Sensitivity Factors method, sizing is determined using Goal Attainment method with the help of MatLab and load flow is carried out in MiPower [3] software.

The modern power distribution network is constantly being faced with an ever growing load demand, this increasing load is resulting into increased burden and reduced voltage. The distribution network also has a typical feature that the voltages at buses (nodes) reduces if moved away from substation. This decrease in voltage is mainly due to insufficient amount of reactive power. Even in certain industrial areas under critical loading, it may lead to voltage collapse. Thus to improve the voltage profile and to avoid voltage collapse reactive compensation is required. It is well known that losses in a distribution system are significantly high compared to that in a transmission system. The need of improving the overall efficiency of power delivery has forced the power utilities to reduce the losses at distribution level. Many arrangements can be worked out to reduce these losses like network reconfiguration, shunt capacitor placements etc. The shunt capacitors supply part of the reactive power demand, thereby reducing the current and MVA in lines. Installation of shunt capacitors on distribution network will help in reducing energy losses, peak demand losses and improvement in the system voltage profile, system stability and power factor of the system.

II. LITERATURE REVIEW

Many authors have taken into account the presence of distorted voltages for solving the capacitor sizing problem. These investigations include: exhaustive search, local variations, mixed integer-nonlinear programming heuristic methods for simultaneous capacitor and filter placement maximum sensitivities selection and fuzzy set theory genetic Algorithm partial swarm optimization. All above authors have discussed on radial networks, the present paper GA employed to determine the optimal sizing of fixed capacitor banks in an interconnected distribution network with non sinusoidal substation voltages, Commercial package ETAP Power Station program is used for harmonic load flow analysis.
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Grainger et al formulated the capacitor placement and voltage regulators problem and proposed decoupled solution methodology for general distribution system. Baran and Wu presented a method with mixed integer programming. Sundharajan and Pahwa [8], proposed the genetic algorithm approach to determine the optimal placement of capacitors based on the mechanism of natural selection. In most of the methods mentioned above, the capacitors are often assumed as continuous variables. However, the commercially available capacitors are discrete. Selecting integer capacitor sizes closest to the optimal values found by the continuous variable approach may not guarantee an optimal solution.

Chin uses a fuzzy dynamic programming model to express real power loss, voltage deviation, and harmonic distortion in fuzzy set notation. Sundharajan and Pahwa used genetic algorithm for capacitor placement. Simulated Annealing, Tabu Search, Ant colony optimization and Particle Swarm Optimization searches are used for optimal capacitor placement problems. Salem Arif and Abdelhafid Hellal have also used various meta- heuristic techniques for reactive power optimization problem.

Optimal Sizing of Capacitors placed on a radial distribution system is explained by M.e. Baran and F.F Wu the reference. The capacitor-sizing problem is a special case of the general capacitor placement problem. The problem is to determine the optimal size of capacitors placed on the nodes of a radial distribution system so that the real power losses will be minimized for a given load profile. This problem is formulated as a nonlinear programming problem. The ac power flow model of the system, constraints on the node voltage magnitudes, and the cost of capacitors are explicitly incorporated in the formulation. This paper gives a new formulation of the power flow equations in a radial distribution network and a numerically robust, computationally efficient solution scheme.

A simplified Network approach to the VAR control problem for radial distribution system is considered in the reference. .According to this method proposed by M. M. A. Salma and A. Y. Chikhani, the capacitors are assumed to be located optimally at the feeder branches. The optimal compensation levels (capacitor size) are represented by dependent current sources located at the branch connected bus. The solution of the equivalent circuit for the distribution system yields the values of the voltage at any bus. The actual compensation level is then determined by substituting the bus voltage in the dependant current source formula. The method is simple and needs no sophisticated optimization technique. It can be used as on-line controller and as well as in the planning stage. It can be easily adapted in the expert system configuration.

Cook considered the effects of fixed capacitors on radial distribution network with distributed loads and considered the reduction in energy loss. A methodology has been used to determine the ratings and location of fixed capacitors on the radial feeder for periodic load cycle. Cook considered fixed and switched capacitors and discussed the methodology to decide the timing for the operation of switched capacitors.

Neagle and Samson 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.

Genetic Algorithms offer a 'one size fits all' solution to problem solving involving search. Unlike other conventional search alternatives, GA's can be applied to most problems, only needing a good function specification to optimize and a good choice of representation and interpretation. This, coupled with the 6exponentially increasing speed/cost ratio of computers, makes them a choice to consider for any search problem. Genetic algorithms are inspired by Darwin's theory of evolution. Problems are solved by an evolutionary process resulting in a best (fittest) solution (survivor) - in other words, the solution is evolved.

Ghosh and Das have proposed a method for the load flow of radial distribution network using the evaluation based on algebraic expression of receiving end voltage. Teng has proposed the load flow of radial distribution system employing bus-injection to branch-current (BIBC) and branch-current to bus-voltage (BCBV) matrices.

III. ADAPTIVE GENETIC ALGORITHM

Adaptive Genetic Algorithms (GAs) are adaptive heuristic search algorithms based on the evolutionary ideas of natural selection and natural genetics. A genetic algorithm is a heuristically guided random search technique that concurrently evaluates thousands of postulated solutions. Biased random selection and mixing of the evaluated searches is then carried out in order to progress towards better solutions. 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'. Search data are usually coded as binary strings called chromosomes, which collectively form populations. Evaluation is carried out over the whole population and involves the application of, often complex 'fitness' functions to the string of values (genes) within each chromosome. Typically, mixing involves recombining the data that are held in two chromosomes that are selected from the whole population.

GAs vs Conventional Algorithms:

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

1. GAs work with coding of the parameter set, not the parameters themselves.
2. GAs search from a population of points, not a single point.
3. GAs use payoff (objective function) information, not derivatives or other auxiliary knowledge.
4. GAs use probabilistic transition rules, not deterministic rules.

The genetic algorithm is a search algorithm that iteratively transforms a set (called a population) of mathematical objects (typically fixed-length binary character strings), each with an associated fitness value, into a new population of offspring objects using the Darwinian principle of natural selection and using operations such as crossover (sexual recombination) and mutation[26]. Algorithm begins with a set of solutions (represented by chromosomes) called population. Solutions from one population are taken and used to form a new population. This is motivated by a hope, that the new population will be better than the old one. Solutions which are then selected to form new solutions (offspring) are selected according to their fitness - the more suitable they are the more chances they have to reproduce. This is repeated until some condition is satisfied. The space of all feasible solutions (the set of solutions among which the desired solution resides) is called search space (also state space). Each point in the search space represents one possible solution. Each possible solution can be "marked" by its value (or fitness) for the problem. With GA we look for the best solution among a number of possible solutions. The problem is that the search can be very complicated. One may not know where to look for a solution or where to start. There are many methods one can use for finding a suitable solution, but these methods do not necessarily provide the best solution.

IV. METHOD FOR OPTIMAL LOCATION OF CAPACITOR USING ADAPTIVE GENETIC ALGORITHM

Many methods are used to determine capacitor sizing. Here, we have described a method for optimal location of capacitor using adaptive genetic algorithm.

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

1. Reproduction: This operator is an artificial version of natural selection based on Darwinian survival of the fittest among string creatures. Reproduction operator can be implemented in algorithmic form in a number of ways.
2. Crossover: It occurs after reproduction or selection. It creates two new population or strings from two existing ones by genetically recombining randomly chosen parts formed by randomly chosen crossover point.
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.

Steps in Basic Genetic Algorithm

1. [Start] Generate random population of n chromosomes (suitable solutions for the problem)

2. [Fitness] Evaluate the fitness f(x) of each chromosome x in the population
3. [New population] Create a new population by repeating following steps until the new population is complete
    a. [Selection] Select two parent chromosomes from a population according to their fitness (the better fitness, the bigger chance to be selected)
    b. [Crossover] With a crossover probability cross over the parents to form new offspring (children). If no crossover was performed, offspring is the exact copy of parents.
    c. [Mutation] With a mutation probability mutate new offspring at each locus (position in chromosome).
    d. [Accepting] Place new offspring in the new population
4. [Replace] Use new generated population for a further run of the algorithm
5. [Test] If the end condition is satisfied, stop, and return the best solution in current population
6. [Loop] Go to step 2

Applications of GA: Since GAs are mainly used in optimization and give outstanding performance, GAs are treated as function optimiser. But there are many other ways to view genetic algorithms in different areas such as:

- GAs as problem solvers
- GAs as challenging technical puzzle
- GAs as basis for competent machine learning
- GAs as computational model of innovation and creativity
- GAs as computational model of other innovating systems
- GAs as guiding philosophy

Genetic algorithms have been used for difficult problems (such as NP-hard problems), for machine learning and also for evolving simple programs. They have been also used for some art, for evolving pictures and music. Some of the applications of GAs are:

- Nonlinear dynamical systems - predicting, data analysis
- Designing neural networks, both architecture and weights
- Robot trajectory
- Evolving LISP programs (genetic programming)
- Strategy planning
- Game Playing
- Finding shape of protein molecules
- Signal Processing
- TSP and sequence scheduling
- Functions for creating images

V. CAPACITOR ALLOCATION USING ADAPTIVE GA

The developed algorithm for identifying the sizing and location is based on Adaptive Genetic Algorithm (GA). The development of algorithm is explained with a review on GA. A GA is an iterative procedure which begins with a randomly generated set of solutions referred as initial population. For each solution in set, objective function and fitness are calculated. On the basis of these fitness functions, pool of selected population is formed by selection operators, the solution in this pool has better average fitness then that of initial population. The crossover and mutation operator are used generate new solutions with the help of solution in the pool. The process is repeated iteratively while maintain fixed number of solutions in pool of selected population, as the iteration progress, the solution improves and optimal solution is obtained. During the selection process of the GA, good solutions are selected from the initial generated population for producing offspring. Good solutions are selected randomly from the initial generated population using a mechanism which favours the more fit individuals. Good individuals will probably be selected several times in a generation but poor solutions may not be selected at all.

CONCLUSION

The work has been carried out to find the optimal locations and sizes (kVAr) of capacitors to be placed in radial distribution system. Such problems have been solved by two step methodology, the candidate locations for compensation are found using loss sensitivity factor calculated from base case load flow. The sizing has been attempted using Genetic Algorithm. In GA, coding scheme are usually developed to carry out the allocation problem, which is identification of location and size by one dimensional array.

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