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Reactive power compensation for radial distribution networks using genetic algorithm

D. Das*

Department of Electrical Engineering, Indian Institute of Technology Kharagpur, W.B. 721302, India

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Abstract

In the present work, genetic algorithm is applied to select the optimum values of fixed and switched shunt capacitors required to be placed on a radial distribution network under varying load conditions so as to minimize the energy loss while keeping the voltage at load buses within the specified limit by taking the cost of the capacitors into account. Both fixed and marginal costs of the capacitors are considered to obtain the best overall performance. The voltage constraint is included as penalty term in the objective function.

Further, instead of only assuming the capacitors as a constant reactive power load, it is also been considered as a constant impedance load in optimization problem itself and comparison of performances for both considerations are also presented.

Also possible convergence criteria of genetic algorithm based on 'the difference between best fitness and average fitness' of population is suggested to reduce the CPU time required to a great extent with a very small sacrifice in overall savings.

Keywords: Distribution networks; Shunt capacitors optimization; Genetic algorithm

1. Introduction

As the cost of constructing a new power plant has skyrocketed, the electric power industry is making every effort to reduce the growth of electricity demand. Since a substantial amount of generated power is being wasted as losses, reduction in losses has been recognized as a viable option to eliminate to some degree the need for unnecessary additional generating capacity. It is acknowledged that much of this power loss occurs in the distribution system. To date, volt-var control has been a commonly implemented control practice to reduce distribution feeder losses while maintaining acceptable feeder voltage profile.

In the past, a lot of work has been carried out in the area of reactive power compensation for radial distribution networks [1–16]. These methods are based on different non-linear programming techniques and provide only a local optimum solution with a lesser computer burden. Recently, researchers have attempted to obtain optimum values of shunt capacitors for radial distribution networks using simulated annealing and genetic algorithm (GA). Because these two techniques have the capability to search a near global optimum solution. Chiang et al. [17] have used the method of simulated annealing to obtain the optimum values of shunt capacitors for radial distribution networks. Sundhararajan and Pahwa [18] have used genetic algorithms for obtaining the optimum values of shunt capacitors. They have [18] treated the capacitors as constant reactive power load and no method is suggested to reduce the CPU time. Genetic algorithm based solution is capable of determining a near global solution with lesser computational burden than the simulated annealing method [18]. An optimization method is judged for its efficiency by the quality of the resulting solution and the number of function evaluation required to arrive at the quality solution. In the present paper, the final solutions, cost savings and computer run time are presented and the proposed method has also been compared with two other existing methods.

Genetic algorithm is becoming popular to solve the optimization problems in different fields of applications mainly because of its robustness in finding optimal solution and ability to provide near optimal solution close to global minimum [19,20,22]. Genetic algorithms employ search procedures based on the mechanics of natural selection and survival of the fittest. In the GAs, which uses multiple point search instead of single point search and work with the coded structure of variables instead of the actual variables

* Tel.: +91-3222-79507; fax: +91-3222-55303.
E-mail address: ddas@ee.iitkgp.ernet.in (D. Das).

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themselves, the only information required is the objective function thereby making the searching for global optimum simpler.

In the present work, GA is implemented to determine the optimal sizes of fixed and switched capacitors under varying load conditions. The objective is to minimize the energy losses in the distribution network by taking the cost of capacitors into account. Also the voltage constraint is formulated as a penalty function to the objective function.

Further important contribution of the present work is, instead of only assuming the capacitor as a constant reactive power (KVAr) load (which has been assumed in all of the previous work), it is also been considered as constant impedance load which can be thought as an approach to make the problem formulation more realistic from practical point of view. A comparative study of both considerations (i.e. consideration of capacitors as constant power and constant impedance load) in problem formulation is also highlighted.

Another important aspect of the present work is to propose a secondary convergence criteria. The criteria for termination of genetic algorithm used was maximum number of generation reached [18,19]. If a secondary convergence criteria (based on 'the difference between best fitness and average fitness' of population) is used, it could reduce a lot of computational time with only a slight reduction in overall savings.

2. Genetic algorithm

Genetic algorithms (GAs), a way to search for the best answers to tough problems, were first suggested by John Holland in his book 'Adaptation in Natural and Artificial Systems' [20]. Over the last few years, it is becoming popular to solve a wide range of search, optimization and machine learning problems. As their name indicates, genetic algorithm attempts to solve problems in a fashion similar to the way in which human genetic processes seem to operate. It's fundamental principle is the fittest member of population has the highest probability for survival [22].

A GA (multi path search scheme) is an iterative procedure which maintains a constant size population $p(t)$ of candidate solutions. The initial population $p(0)$ can be chosen heuristically or at random [19]. The structures of the population $p(t+1)$ (i.e. for next iteration called generation) are chosen from $p(t)$ by randomized selection procedure that ensures that the expected number of times a structure is chosen is approximately proportional to that structure's performance relative to the rest of the population. In order to search other points in a search space, some variation is introduced into the new population by means of genetic operators (crossover and mutation).

While it may seem to be a random search, in fact, the improvement in each generation indicates that the algorithm produces an effective directed search technique [22]. The power of GAs derives largely from their ability to exploit efficiently this vast amount of accumulating knowledge by means of relatively selection mechanisms.

2.1. How genetic algorithm works

A GA is an iterative procedure which maintains a constant size population $p(t)$ of candidate solutions. The algorithm begins with a randomly selected population of function inputs represented by strings of bits. During each iteration step, called a generation, the structure in the current population is evaluated and on the basis of those evaluations, a new population of candidate solution is formed. That is GA uses the current population of string to create a new population such that the string in the new population are, an average 'better' than those in the current population. The idea is to use the best elements from the current population to help form the new population. If this is done correctly, then the new population will, on average, be 'better' than the old population. Three processes — selection, crossover, and mutation are used to make the transition from one population generation to the next. The basic genetic algorithm cycle based on these is shown in Fig. 1. These three steps are repeated to create each new generation and it continues in this fashion until some stopping condition is reached (such as maximum number of generations or resulting new population not improving fast enough).

2.2. Initialization

GAs operate with a set of strings instead of a single string. This set or population of string goes through the process of evolution to produce new individual strings. To begin with, the initial population could be seeded with heuristically chosen strings or at random [19]. In either case, the initial population should contain a wide variety of structures.

2.3. Evaluation function

The evaluation function is a procedure to determine the fitness of each string in the population and is very much application oriented. The performance of each structures of string is evaluated according to its fitness, which is defined as a non-negative figure of merit to be maximized. It is directly associated with the objective function value [18] in the optimization. GA treats the problem as a black box in which the input is the structure of the string and the

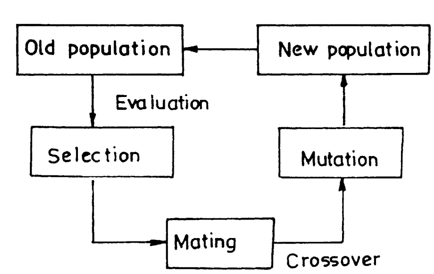

Fig. 1. The basic genetic algorithm cycle.