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Optimal Placement of Capacitors in Radial Distribution System to Minimizes the Losses at Variable Load Levels

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Abstract: This paper presents an efficient approach for optimal placement of capacitor in radial distribution system, with an objective of improving the voltage profile and reduction of power loss. Distribution system is a link between high voltage transmission system and the low voltage end users, so it's very essential to keep the system healthy and with minimum losses. The present work is devoted to determine the optimal locations and sizes of capacitors with different load levels using a genetic algorithm. Implementation of the Genetic Algorithm for its multifunction capability is one of the distinguished characteristics for optimal capacitor placement in distribution system. To verify the effectiveness of the proposed algorithm, it is tested on IEEE 33-bus radial distribution networks.

Key-Words: - - Power System, bus voltage control, Capacitor Placement, optimization techniques, load levels.

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I. Introduction

The widespread use of electrical energy by modern civilization has necessitated producing, transmitting, and distributing bulk electrical energy economically and efficiently. Electricity distribution is a final stage in the delivery of electricity to end users. A distribution network carries electricity from the transmission system and delivers it to consumers. It is the most visible part of the supply chain, About 30 to 40 % of total investments in the electrical sector go to distribution systems, but nevertheless, they have not received the technological impact in the same manner as the generation and transmission systems. The loss minimization in distribution systems has assumed greater significance recently since the trend towards distribution automation is to improve their reliability, efficiency and service quality will require the most efficient operating scenario for economic viability variations. To achieve power and energy no reduction, voltage regulation and for reactive power compensation, capacitors are widely installed in distribution systems. Capacitors are commonly employed to provide reactive power compensation, improve the power factor, feeder voltage profile, Power loss reduction and increases available capacity of feeders in distribution system. Static capacitors are the cheapest and the simplest means for reactive power compensation. Therefore it is important to find optimal location and sizes of capacitors in the system to achieve the above mentioned objectives.

There are many ways for capacitor placement and determination size of capacitors in power systems. Many techniques have been developed for solving the capacitor placement problem, namely, analytical, numerical programming, heuristic and artificial based techniques [1]. Duran et al. [2] consider the capacitor sizes as discrete variable and employed dynamic programming, whereas, Grainger and Lee [3] were expressed the location and capacity of capacitor as continues variable based on non linear programming. Maxwell [4] suggests there are several benefits of capacitor placement which include: (i) Reduced I^2R losses and energy losses. (ii) Reduced regulation cost. (iii) Reduced kVA input to feeder. (iv) Reduced I^2X losses. (v) Increased revenue as result increased voltage levels. Salama M.M.A. et al [5] in their work assume a fixed load condition and a uniform feeder. A concentrated load at the end of the feeder is dealt with separately.

In solving optimal capacitor placement problem heuristic based techniques have been widely used. Abdel- Salam [6] in their paper uses heuristic technique for reactive loss reduction in distribution network. The capacitor rating is determined by differentiating the system losses with respect to the load connected to that node. M. Masoum et al. [7] Fuzzy logic has been applied to solve the capacitor placement problem in which the constraints are fuzzified and the alpha cuts are used to direct the search process to ensure that the objective function is improved at each iteration process. In 2007 Haghifam and Modares in [8] developed an efficient Genetic Algorithm with a new coding as two rows of chromosome used for optimization in simultaneous allocation of fixed and switchable capacitors. Genetic Algorithm (GA) is an effective tool in solving the optimization problem especially in case of capacitor location in radial distribution system [9]. Pushpendra [10] in their paper uses concept of ant colony search with limits and improvement technique is use along with GA to search the proper mutation operator to accelerate searching out the global solution.

To improve quality of power and its stability and voltage regulation shunt compensation are basically used in transmission system [11]. By reactive power compensation shunt capacitor maintains the voltage level in power line, Series compensation is used to control the impedance of

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power line. While by reactive power consumption shunt reactors reduce the overvoltage.

The placement and sizing of capacitors should be modelled simultaneously in the form of an optimization problem. Otherwise, the power system will not be optimal.

This paper is organized as follows: section II discussed the proposed Genetic Algorithm, section III gives the problem formulation, section IV presents result of the proposed problem and section V outlines conclusion.

II. Genetic Algorithm

Genetic algorithm is a *population-based search* method. GA is the main paradigm of evolutionary computing. GAs is inspired by Darwin's theory about evolution **"survival of the fittest". Means select the best discard the rest.**
Genetic Algorithm (GA) was first introduced by John Holland of Michigan University in 1970's. Genetic algorithms are procedures based on the mimetic of mechanics of natural selection and genetics. A simple GA is an iterative procedure, which maintains a constant size population of candidate solutions. During each iteration step, 3 genetic operators (1) reproduction (2) crossover (3) mutation, are performing to generate new population, & the chromosome of new populations have evaluated via the value of the fitness, which is related to cost function. According to the evolutionary theory, only the most suited elements of a population can survive and generate offspring, thus transmitting their biological heredity to new generations. Based on these genetic operators & the evaluations the better new populations of candidate solutions are formed. If the search goal has not been achieved, again GA creates offspring stings through above 3 operators & the process is continued until the search goal is achieved. They compute a set of individuals, a population, i.e., evolving through a set of biologically inspired operators constituting the reproduction scheme. In this way, new individuals are generated from parents. The heredity is enclosed in the chromosomes of individuals represented in an optimization problem by a specific numerical code. The suitability of each element according to the optimization problem under consideration is evaluated via a fitness value directly derived from the objective function.
Steps involved determining the optimal parameters of the controller using genetic algorithm are given below.
Step 1. Start: Create random population of n chromosomes
Step 2. Fitness: Evaluate fitness of each chromos in the population
Step 3. New population:
a. Selection: Based on fitness function
b. Recombination: Cross-over chromosomes
c. Mutation: Mutate chromosomes

d. Acceptation: reject or accept new one
Step 4. Replace: old with new population and the new generation
Step 5. Test: Test for problem criterion
Step 6. Loop: Continue step 2-5 until criterion is satisfied.

III. Problem Formulation

Electrical power loss is an important issue in power system. Various ideas have been proposed for reduction of such losses. The location and size of capacitor in distribution system is to be determined by using Newton Raphson load flow analysis to compute the power losses. For identifying the size and location of capacitor meta-heuristic algorithm i.e. Genetic Algorithm is used.
Power flow equations:
Power flow equations of distributed system are computed as [12].

Objective function
Minimization $= \sum_k^N P_{LOSS,k}$
P_k = Real power flowing out of bus k.
Q_k = Reactive power flowing out of bus k.
P_k' = Real power flowing out of bus k after reconfiguration.
Q_k' = Reactive power flowing out of bus k after reconfiguration.
P_{Lk+1} = Real power flowing out of bus k+1.
Q_{Lk+1} = Reactive power flowing out of bus k+1.
$P_{T,LOSS}$ = Total power loss of the feeder
V_k = Voltage at bus k.

$$P_{k+1} = P_k - P_{LOSS,k} - P_{Lk+1} \qquad (1)$$
$$= P_k - \frac{R_k}{|V_k|^2} \{P_k^2 + (Q_k + Y_k|V_k|^2)^2\} - P_{Lk+1}$$

$$Q_{k+1} = Q_k - Q_{LOSS,k} - Q_{Lk+1} \qquad (2)$$
$$= Q_k - \frac{X_k}{|V_k|^2} \{P_k^2 + (Q_k + Y_{k1}|V_k|^2)^2\} - Y_{k1}|V_k|^2 - Y_{k2}|V_k|^2 - Q_{Lk+1}$$

$$|V_{k+1}|^2 = |V_k|^2 + \frac{R_k^2 + X_k^2}{|V_k|^2}(P_k^2 + Q_k^2) - 2(R_kP_k + X_kQ_k)$$
$$= |V_k|^2 + \frac{R_k^2+X_k^2}{|V_k|^2}(P_k^2 + (Q_k + Y_k|V_k|^2)^2) - 2(R_kP_k + XkQkYkVk2) \qquad (3)$$

The power loss in the line connecting k and k+1 may be computed as

$$P_{LOSS(k,k+1)} = R_k \frac{(P_k^2 + Q_k^2)}{|V_k|^2} \qquad (4)$$

Power loss equation:
$$P_{T,LOSS} = \sum_{k=1}^n P_{LOSS}(k,k+1) \qquad (5)$$

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IV. Result

As energy and power losses are reduced and power factor improves, so there is a net profit in installing the capacitors. After the compensation of system there is a considerable improvement in voltage profile. It satisfies the voltage constraint. Result obtained in paper is by using 51 iterations and 20 population size in GA toolbox in MATLAB software. As a result of capacitor placement reactive power is compensated, power factor of the system improves. So both energy loss & power loss reduces. Data is obtained from load flow programme on MATLAB are carried on a computer with Intel core i-3, 2.50 GHz, and 2.0 GB RAM.

S No.	Capacitor location (Bus No)	Capacitor value (MVar)	Losses (MW)
1.	No capacitor	---	0.4653
2.	30	0.91	0.3489

Table 1 capacitor location, capacitor value, & losses

Table 1 shows the capacitor location, value and losses after and before placing of the capacitor. When the capacitor is not placed in distribution system the losses are 0.4653MW. Here the result is obtained after 40 runs in GA toolbox and each run completed in 113 seconds, get capacitor location at bus number 30, of value 0.91Mvar, minimum power loss is 0.3489MW; power loss reduction is about 25% after placing the capacitor at optimal location and of proper size.
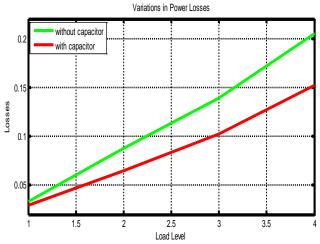

Fig 1 Graph represents variation in power losses

Fig 1 represents graphical view of power losses with respect to variable load level by using GA. Here without using capacitors losses are high, and by placed capacitor optimally at variable load level losses get minimized. Location and size of capacitor is an important aspect to reduce the power losses of system.
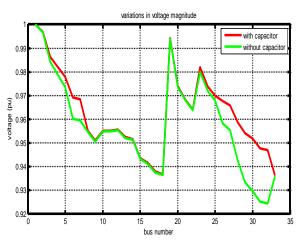

Fig 2 .Graph representation of Voltage Magnitude

The voltage profile curves of all load conditions are shown in Fig. 2, respectively. The shapes of voltage profiles at all three load levels are almost the same except minor change in voltage magnitude. Voltage rise by help of capacitor placement, here result obtain better after placing capacitor. Results are obtained for radial 33 bus distribution system, considering the optimal tie lining for the system.

V. Conclusion

An approach incorporating the use of Genetic Algorithm has been presented in this paper to determine the optimal locations and size of capacitors to place in a distribution system at dynamic load level. To reduce the power losses solution is been obtain in IEEE 33 bus radial distribution system. Here by using Genetic Algorithm get the optimal location and size of the capacitor which reduces the power losses approximately 25% at variable load levels. If the location and size of capacitor is not appropriate then solution obtained may be far from real circumstances. The motive of the study is to minimize the power losses and enhance the efficiency of distribution system.

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