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# Optimal Location and Size of Capacitor on Distribution: Improve Voltage Profile and Active Power Loss

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*Abstract*--**This paper presents a GA approach to determine the optimal location and size of capacitor on distribution systems to improve voltage profile and active power loss. Capacitor placement and sizing are done by loss sensitivity analysis and GA. Power Loss Sensitivity factor offer the important information about each section in a feeder. This factor is determined using load flow study. In a feeder, Sections with highest power loss sensitivity are selected to installation the capacitor. GA with a multi-purpose goal function for simultaneous reduction of the losses and the improvement of the voltage profile detects the optimal size of capacitor in each candidate section. The results of the application of this method are compared with the results obtained from the installation of capacitors by DIGSILENT software.**

*Index Terms*--**shunt capacitors, voltage profile, Loss reduction, power loss sensitivity factor, Genetic algorithm**

## 1. INTRODUCTION

The distribution networks are radial networks in which the resistance ratio to the line reactance is high and at the same time the voltage level in these networks is low resulting in a very high current. Besides, the distribution systems are often unbalanced and as a result of the above factors it leads to an increase in power losses in the distribution networks related to the transmission networks and at the same time results in unfavorable variations in the voltage profile.

By changing the load specifications or the system, today it is possible to change the amount of losses and simultaneously improve the voltage profile. For example, by installing a series capacitor in the line, it is possible to change the characters of the line. It is also possible to change the rate of passing reactive power in the line to improve the losses and the voltage profile by inject the reactive power with use of shunt capacitors. In the programming of reactive power two parameters of locating and exploitation are studied. For placement, the determination of type, size, and the place of new sources of reactive power are discussed and are also considered in exploitation and optimization exploitation adjustment from available sources. In the selection of capacitors for a systems three basic parameters that is, size, location of installation, and type are considered. Today, different methods for the optimized termination of these three parameters are presented. For example, by using Tabu Search one can select Buses with higher sensitivity as the candidate places for the installation of the capacitors [1,2], or by employing graph search algorithm one can determine the optimized place for the installation of capacitor [3]. It is also possible to determine the place for the installation of the capacitors by employing metal melting simulation method [4]. In most methods the goal function is a unify-purpose function, while by using the genetic algorithm one can employ a multi-purpose function without any limitations in search spaces. In most articles the application of capacitors with switching capabilities are recommended, while in most spaces the use of these capacitors is not feasible. In this article for determination the power loss sensitivity of each section the calculation are done in the pick of the load. We then consider the determination of the required optimized size of the capacitor in the minimum load by genetic algorithm. By using this method the increase of voltage due to phase lead of the system in the minimum load is prevented. In order to prove the efficiency of this method, the results of capacitor placement by this method are contrasted with those obtained from DIGSIENT software.

## 2. Candidate Sections Base on Sensitivity Factors

A new methodology is used to determine the candidate section for placement of capacitor using power loss sensitivity factor And voltage drop in each section. Consider a distribution line connected between ‘p’ and ‘q’ buses in Fig. 1.

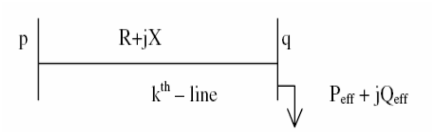


Fig . 1.A distribution line

By employing the feeder impedance matrix and the specifications of the available loads and distributing the load by a reciprocal method, the amount of passing current in each section in the load pick is determined. By using the amount of the obtained current in $k^{th}$ and equations (1), (2) and (3) we precede the calculation of the rate of active power losses, reactive power losses and voltage drop in each section [4].

$$P_{lineloss}[q]=[I_k]^2\cdot R[k]=\frac{\left(P_{eff}^2[q]+Q_{eff}^2[q]\right)R[k]}{(V[q])^2} \quad (1)$$

$$Q_{hineloss}[q]=\frac{\left(P_{eff}^{\;2}[q]+Q_{eff}^2[q]\right)X[k]}{(V[q])^2} \quad (2)$$

$$\text{Voltage drop}=I(R\cos\theta+X\sin\theta) \quad (3)$$

Now, both the loss sensitivity factors can be obtained as shown in equation (4) and (5).

$$\frac{\partial P_{lineloss}}{\partial Q_{eff}}=\frac{(2Q_{eff}[q]R[k])}{(V[q])^2} \quad (4)$$

$$\frac{\partial Q_{lineloss}}{\partial Q_{eff}}=\frac{(2Q_{eff}[q]X[k])}{(V[q])^2} \quad (5)$$

where:

$P_{eff}[q]$: total effective active power supplied beyond the node ‘q’.

$Q_{eff}[q]$: total effective reactive power supplied beyond the node ‘q’.

## 3. Capacitor Placement Algorithm

With regard to the presented subjects about the selection candidate Buses for the installation of capacitors and genetic algorithms, the method of capacitor placement are performed on the basis of the following stages.

1- Formation of the initial population on the basis of candidate buses.

2- Evaluation of each of the chromosomes as follows:

2–1 - Installation of the capacitors specified by each of his chromosomes on the candidate buses.

2–2 - Performing load distribution operations by a reciprocal method.

2–3 - Calculation of power fall rate and voltage profile

2–4 - Assigning a specific amount as the rate of chromosome competence to it.

3- Construction of a new population on the basis of transmits operations, crossover, and mutation.

4- Repetition of stages 2 and 3 until reaching the stoppage parameter which can be the maximum number of repetition.

5- Decoding each of the chromosomes and determining the required capacitor rate.

The capacitor placement algorithm is show in Fig. 2.

## 4. Simulation results

In order to show the specifications of the presented methods, we first start with the use of the above method for placating capacitors in a distribution feeder depicted in Fig. 3. We then start the operations of capacitor placing on this feeder by DIGSILENT software. The intended feeder with the name of a radial feeder is very long with great voltage and power drop. Its physical and electrical specifications are presented in Tables I and II.

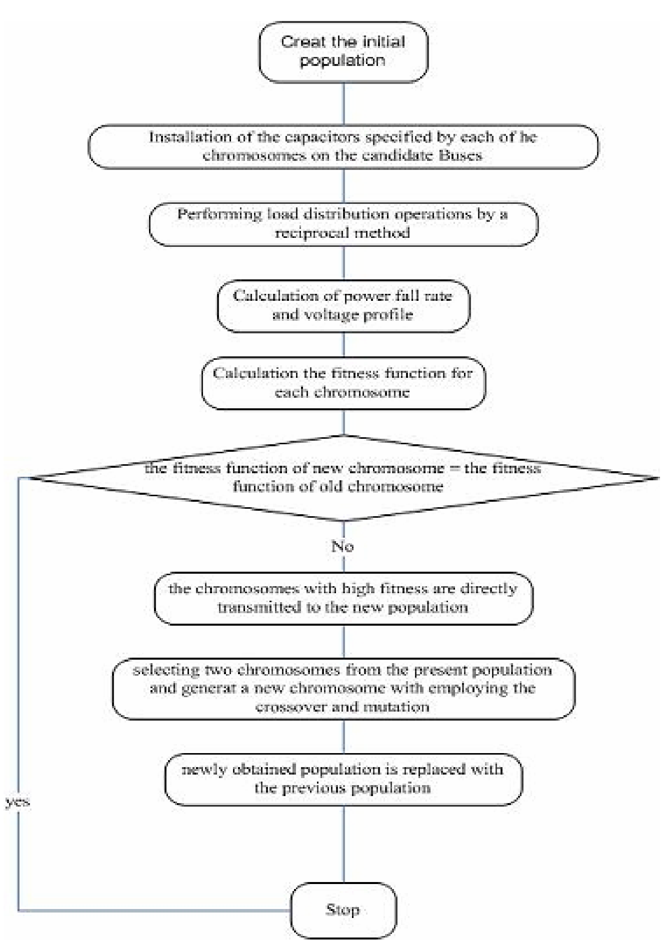


Fig. 2. Capacitor placement algorithm

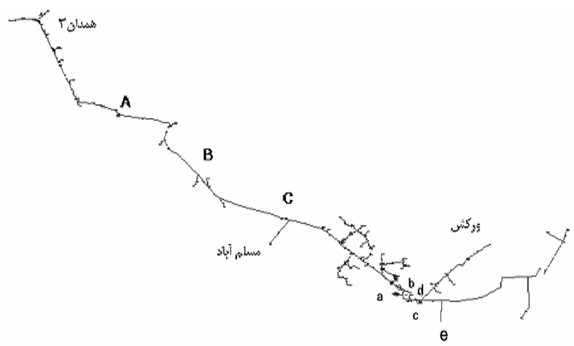


Fig.3. Geographical diagram of NASHER feeder

TABLE I

Physical specifications of NASHER feeder

| Name | NASHAR |
|---|---|
| length | 87050 |
| length of right way | 46135 |
| number of section | 186 |
| number of indoor transformer | 0 |
| number of outdoor transformer | 87 |

After capacitor placing with GA in NASHER feeder and Performing load distribution operations by a reciprocal method and calculate power fall rate and voltage profile and detected the critical points with regard to losses and voltage drop. The critical sections in this feeder are A, B, C. The determined capacitor amounts for each of the places with aim of GA and amount of power losses in each critical section before and after capacitor placement are presented in Table III. The base unit capacitor in each bank is 125 KVar.

TABLE III

The capacitor size required in each section

| Section Name | Capability of Installed Capacitor (KVar) | Power Losses before Capacitor Placement in Each Section (KW) | Power Losses after Capacitor Placement in Each Section (KW) |
|---|---|---|---|
| A | 125 | 27.78 | 18.25 |
| B | 250 | 69.89 | 46.49 |
| C | 750 | 49.3 | 33.95 |

By simulation of NASHER feeder in DIGSILENT software and definition of the capacitors with the capacities of 130, 250, 480, 1000, and 30 KVar and the performance of capacitor placing operations, this software specified the places for a, b, c, d, and e. The determined capacitor amounts for each of the places are presented in Table IV.

TABLE IV

The size of the suggested capacitor for each section by the software

| Section Name | Capability of Capacitor (KVAR) |
|---|---|
| a | 1000 |
| b | 480 |
| c | 250 |
| d | 130 |
| e | 30 |

By exercising the results of the algorithm and the software as well as installation of the specified capacitors in the specified and critical sections by the software, we will witness changes in the feeder parameters according to Table V. In Figs. 4, 5, and 6 the voltage profile before and after placing the capacitors in the two methods are depicted.

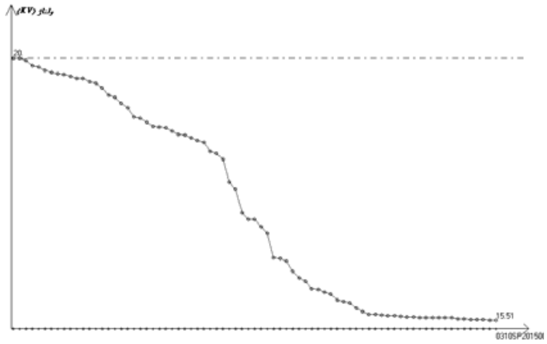

Fig. 4. The NASHER feeder voltage profile before placing the capacitor

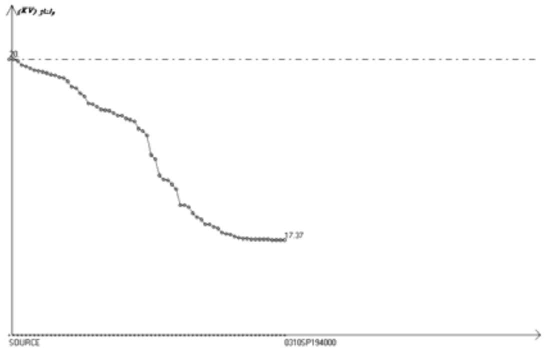

Fig. 5. NASHER voltage feeder profile after placing the capacitor by intelligent method

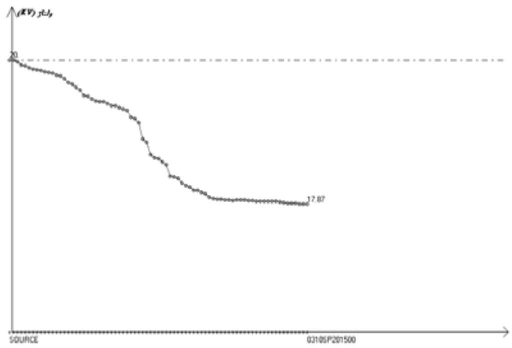

Fig. 6. NASHER feeder voltage profile after placing the capacitor by DIGSILENT software

TABLE V

The specification of the feeder before and after capacitor placing

| Specification | Before Placing the Capacitor | After Placing the Capacitor by Intelligent Method | After Placing the Capacitor by DIGSILENT Software |
|---|---|---|---|
| current in head of feeder (A) | 149.27 | 119.64 | 116.31 |
| voltage (KV) | 15.509 | 17.3 | 17.87 |
| power factor | 0.809 | 0.991 | 0.982 |
| power losses in feeder (KW) | 577 | 391 | 347 |

## 5. Conclusion

One of the useful methods with precise calculation capabilities and without any approximation such as linearization, limitation in the search space, and goal function is the genetic algorithm. In this article a multi-purpose goal function has been employed for the simultaneous improvement of several parameters in the determination of the size of capacitor by genetic algorithm. The place for the installation of the fixed capacitor was also obtained by a fast load distribution method that is, a reciprocal method. This algorithm was executed on a very long radial feeder and noticed considerable reduction of losses and a relative improvement of voltage profile and the quality of the power. With the reduction of the losses we noticed that a part of the line capacity became free and ultimately we had a reduction in the expenses for the expansion of new sources. Additionally, with the relative improvement in the quality of voltage profile, the quality of the power was also increased. Comparing the results of placing capacitors by intelligent method and DIGSILENT software, we notice that the method of presentation has economically higher advantages than the software method, because while the software creates more improvements in the rate of losses and voltage profile, but it uses more capacitors which are not economical.

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