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Improving Reliability and Reducing Power Loss in Power Distribution Network by Determining Optimal Location and Size of Capacitor Banks

Mohammad Nadjafi[1*] and Mohammad Hajivand[1,2]

1. Aerospace Research Institute (Ministry of Science, Research and Technology); Department of Aerospace Management, Law and Standards; Tehran, P.O.B 14665-834, Iran

2. MSc. Electrical Engineering (Power Systems), Islamic Azad University, Young Researchers and Elite Club, Boroujerd Branch, Boroujerd, Iran

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Abstract

The use of capacitor banks in distribution system has many well-known benefits that include improvement of the system power factor, voltage profile, and reliability besides the reduction of losses due to the compensation of the reactive component of power flow. These benefits depend greatly on how capacitors are placed in the distribution system. Hence, in order to achieve the high reliable construction, switching capacitor has been placed to improve the main challenges of the network designing (reliability and reduce power loss) in the radial distribution system. As regards, the importance of the reliability and power losses are ignored in the distribution networks; the aim of this paper is primarily to establish an objective function for the parallel optimization of these aforementioned parameters. For this purpose, three reliability indices: System Average Interruption Frequency Index (SAIFI), the System Average Interruption Duration Index (SAIDI) and the Cost of Energy Not-Supplied (CENS) along with the power loss reduction parameter have been improved based on the proposed GSO algorithm. Then, the developed technique has been used on the IEEE standard distribution network as a problem-solving system and the best and worst placement of the capacitors banks are investigated.

Keywords: Capacitor placement; Reliability improvement; Power loss reduction; Group search optimization algorithm; Distribution system;

Nomenclature and Units*

BFOA	Bacterial Foraging Optimization Algorithm
CENS	Cost of Energy Not Supplied
COA	Cuckoo Optimization Algorithm
DE	Differential Evolution
DN	Distribution Network
DRDLF	Dimension Reducing Distribution Load Flow
GA	Genetic Algorithm
GSO	Group Search Optimization
LSI	Loss Sensitivity Index
OF	Objective Function
RCGA	Real Coded Genetic Algorithm
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
VSI	Voltage Stability Index
UC	Unit Commitment
λ_i	Failure Rate
θ_{ij}	Admittance Angle
δ_i	Phase Angle
$L_{i(\alpha)}$	Average Load
N_i	Number of Networks
P_{di}	Active Power Generation
P_{gi}	Active Power Loads
P_{ij}	Active Power from *i* to *j* bus
Q_C	Active Bus Loads
Q_{di}	Reactive Power Generation
Q_{gi}	Reactive Power Loads
Q_L	Reactive Bus Loads
r_S	Average Time Duration Outage
U_S	Annual Average Duration Outage
V_i	Measured Voltage
Y_{ij}	Bus Matrix Admittance

1. Introduction

Capacitors are widely installed in distribution systems for reactive power compensation in order to indirectly reduce the real power loss, release voltage regulation and system capacity. However, the installation of shunt capacitors in primary distribution systems can also effectively reduce peak power and energy losses[1]. Most useful tools and techniques have been developed in order to optimize these parameters,

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[*] Corresponding author: M. Nadjafi, PhD, Assistant Professor in Aerospace Engineering; E-mail address:m.nadjafi@ari.ac.ir

which are: evolutionary algorithm, analytical-mathematical techniques, heuristic method and the hybrid approach. Evolutionary algorithms have been used to solve the problem. A new technique for finding the optimal values of the fixed and switched capacitors in the distribution networks with above properties based on the Real-Coded Genetic Algorithm (RCGA) is presented in[2]. Also, an efficient method for simultaneous allocation of fixed and switchable capacitors is presented with uncertainty and time-varying loads in radial distribution systems[3]. As well as, an efficient methodology for the optimal location and sizing of fixed and switched shunt capacitors in radial distribution systems is presented using GA[4]. Along with Differential Evolution (DE) Algorithm, Dimension Reducing Distribution Load Flow (DRDLF) is used to find optimal location and size of the switching capacitor [5]. In this context, a genetic algorithm based on a fuzzy multi-objective method is proposed to determine the optimal values of the shunt and switching capacitors in order to improve the voltage profile and minimize power losses. The superiority of the pre-existing fuzzy technique has been proven by experiment on a 69-bus standard test system and the definition of three levels of load on this network [6].

In order to improve the power quality in the network, some research and study have been done to find the location and determination of the optimal capacity of the shunt capacitor. To this end, the new target function is used to solve the target function (which is a function of the cost of power losses, energy losses and capacitor bank charges), and the constraints (voltage range, number and capacity of installed capacitors). The simulations results are compared with another version of the genetic algorithm [7]. On the other hand, function-based functions on capacitor cost to minimize power and energy losses and improve the voltage profile have proposed[8]. Also, a novel algorithm based on a genetic algorithm is used to solve this problem by considering the voltage stability limit. The 34-bus standard test system is used as a sample network and simulation results are provided by different scenarios. A new long-term scheduling for optimal allocation of a capacitor bank in the radial distribution system with the objective of minimizing power loss of the system subjected to equality and inequality constraints with Bacterial Foraging Optimization Algorithm (BFOA) is proposed. The Loss Sensitivity Index (LSI) and Voltage Stability Index (VSI) are included in the target function. In the proposed model, load variations from low frequency (50%) to high (160%) on a distributed network of 34 and 85 IEEE bus is performed[9] and the same is done by the with the Cuckoo Optimization Algorithm (COA)[10].

The analytical-mathematical techniques are the second approach that has been used. Two new approaches for the determination of the direction of switched capacitor banks as well as an efficient technique for estimating the distance of switched capacitors from the monitoring location in distribution systems is described [11]. Two fundamental signatures of shunt capacitor bank switching transient phenomena from which one can accurately determine the relative location of an energized capacitor bank whether it is upstream or downstream from the monitoring location [12] in which deals with the analysis of transients initiated by the switching of shunt capacitors in power networks. These transients will propagate through the network along the transmission elements and will, accordingly, be felt at other locations far from the capacitors, such as load terminals[13]. In this field, a computationally efficient methodology is proposed for the optimal location and sizing of static and switched shunt capacitors in radial distribution systems[14]. Similar work has been performed in order to the improvement of the voltage stability index by optimal capacitor location using an analytical technique that is strongly sensitive to voltage collapse in distribution networks[15]. The proposed technique is accomplished and has been tested on the 34 and 69 IEEE standard test system in[16]. Accordingly, two optimization models are proposed for obtaining optimal capacitor locations for maintaining the voltage profile in distribution networks. First, the problem of locating the element as a power transmission problem is correlated with an innovative mathematical representation of the formation of the voltage profile. Then, the problem of the location of the capacitor is modeled and solved. Ramos and his colleagues focused on the optimal location of capacitor banks based on the average curve of daily load variations in the unbalanced distribution network[17]. The simulation results are implemented on IEEE standard networks and compared to the results in the background [18], two main goals are the calculation of the reactive power demand and minimization of the cost.

Another suggested class of analysis methods is the Meta-heuristic techniques. Heuristic search strategies are used to determine the optimum capacitor placement and ratings for distribution systems[19]. In the heuristic approach, a practical solution technique is proposed for the capacitor placement problem that is easy to implement[20]. The proposed approach uses a graph search algorithm. An efficient heuristic algorithm is presented in [21] in order to solve the optimal capacitor placement problem in radial distribution systems. Finally, in these classes of analysis methods, hybrid techniques have been employed to solve switching capacitor placement. To this end, a fuzzy-reasoning method is presented for optimum shunt capacitor placement and sizing for the radial distribution systems [22]. Accordingly, by considering the problem of optimally placing fixed and switched type capacitors is proposed in a radial distribution network[23].

Based on studies done, the use of capacitor banks in distribution system has many well-known benefits that include improvement of the system power factor, voltage profile, and reliability besides the reduction of losses due to the compensation of the reactive component of power flow. These benefits depend greatly on how capacitors are placed in the distribution system. Hence, in order to achieve the high reliable construction, switching capacitor has been placed to improve reliability and reduce power loss in the radial distribution system. The optimality of the two parameters of power loss and reliability is one of the main challenges for network designers. As regards, the importance of the reliability and power losses are ignored in the distribution networks; this paper primarily focuses on the parallel optimization of these parameters. The two parameters of the System Average Interruption Frequency Index (SAIFI) and the Cost of Energy Not Supplied (CENS) as a measure of reliability improvement have been investigated. Since the GSO is part of the latest particle intelligence techniques, this paper has been used as a problem-solving technique and a study on the IEEE standard distribution network with scenario-based designs based on the number of capacitor banks has been accommodated.

The remainder of this paper is structured as follows: Section 2 presents the theoretical basics about reliability and losses in distribution networks. Formulating Structure for objective function and constraint relations are proposed in section 3. The concept of the proposed GSO algorithm has been presented in section 4. Based on the proposed algorithm, the simulation results are provided in Section 5 and the last part is about the conclusion and future work.

2. Theoretical Basics

A distribution network (DN) as the last section of a power system in each country has the widest variety of equipment and the most extensiveness, both of which may lead to many problems in the system. Using a wide variety of equipment in a great number increases the probability of failures and power outage which decreases the system reliability. Since DNs are directly connected to the consumers with no mediates, the current value is high and the voltage value is low and in case the network is excessively extended the high current will rise even more. Therefore, resistive losses (or RI^2 losses) is very high in DNs, especially in Iran's power grid. The mentioned problem will be doubled when the DN is designed in form of a radial topology. The DN designers do not have various choices to solve and/or reduce the resistive losses because economic and environmental issues should also be taken into account while improving and solving the technical problems. Thereby, most of the network designers suggest using capacitor banks to overcome the dominant problems of DNs [24].

2.1. Distribution Network Reliability

Regarding that the proposed objective function in this paper consists of reliability parameters, at first, the importance of reliability in power systems, especially in DNs, is addressed. The following are the importance of risk studies in a DN [25]:

The dominance of calculating risk index in a DN is not less than that of generation and transmission networks because the distribution section has a considerable share on the power outage. Also, reconstruction of power systems is added to this issue (calculation of losses). In a reconstructed environment, the economic factors play a noticeable role and are not less important than technical factors.

The aims of studying reliability in DNs include: Determination of network's reliability and the level of customers satisfaction that contains the frequency of short-term and long-term outages, outage duration, and the number of interrupted customers; Reliability improvement; A basis for development and design of the network; Determining the characteristics of the implementation of operation-based regulations; and Maintenance scheduling and Unit Commitment (UC) or resource allocation.

On the other hand, the reliability of a DN is expressed in terms of reliability indices. The reliability evaluation results of DNs are presented in the form of load nodes or overall system indices. Reliability indices of load nodes include the average rate of failure occurrence λ (failure/year), the average time duration of outage r (hour), and the annual average duration of outage U (hour/year) [26]:

$$\lambda_s = \sum_{i \in A} \lambda_i \, (failure/year) \tag{1}$$

$$U_s = \sum_{i \in A} \lambda_i . r_i \, (hour/year) \tag{2}$$

$$r_s = \frac{U_s}{\lambda_s} (failure/year) \tag{3}$$

Where λ_i is the rate of failure occurrence at the i-th mode, and r_i is the required time for supply restoration to the considered load nodes after a failure occurs at the i-th mode.

In order to complete the required equations in reliability analysis of the distribution networks, the following three indices are utilized in this paper to evaluate the reliability improvement trend. First, the System Average Interruption Frequency Index (SAIFI); this index is defined to obtain information on the average number of system interruptions for each customer in a specific area:

$$SAIFI = \frac{\sum_{i=1}^{n} U_i}{\sum_{i=1}^{n} N_i} \tag{4}$$

Second, the System Average Interruption Duration Index (SAIDI); this index commonly addresses the number of minutes the customers are interrupted, and it is used to avoid the information employed regarding the average interruption duration of each customer.

$$SAIDI = \frac{\sum_{i=1}^{n} N_i U_i}{\sum_{i=1}^{n} N_i} \tag{5}$$

The third index is Cost of Energy Not-Supplied (CENS); this index expresses the amount of energy not supplied with respect to all the customers. First, the index is a combination of the probability of event occurrences and their consequences, and second, it allows for the calculation of the cost of energy not supplied. Hence, there are many applications for this index compared to other choices for operation and development of the system.

$$CENS = \frac{\sum_{i=1}^{n} L_{i(a)} U_i}{\sum_{i=1}^{n} N_i} \tag{6}$$

$L_{i(a)}$ is the average load connected to the loading place.

2.2 Distribution Network Losses

One of the important parameters in a power system is the system losses, which determines the optimality, efficiency, and long-term operating costs of the system. Energy loss is obtained, in fact, from the summation of the instantaneous values of power losses and is the difference between the generated power and the consumed power by the customer. That part of the electrical energy is not converted to useful work is called *losses*, therefore the losses formed due to the low efficiency of power equipment is also included in this part of the energy. Two topics in the field of losses that are worth mentioning are [24]: First, the losses from the electrical energy distribution companies' point of view; this power loss is the difference between the delivered energy and the output energy. If the power loss is studied from an economic standpoint, then it is the difference between the purchased and sold energies. As a result, only the occurred losses in the power systems are important from standpoint of these companies. However, if the power loss is also taken into account as a factor in these companies' policy, then the economic price of the losses should be considered in the calculations as well. Second, the imposed costs by power losses; the high value of the annual costs a distributor suggests that the loss reduction leads to considerable benefits. This value should be annually calculated for every distribution company. Although the removal of all the losses is impossible, the removal of a part of the annual losses cost may result in a dramatic cost saves to justify the investments for improving the efficiency of networks.

3. Formulating the Proposed Method

In this section, in order to improve the reliability of the system and reduce power loss in the radial distribution system, required equations and relationships based on Object Function (OF)and constraints are separately derived and proposed which are discussed bellows.

3.1Objective Function

The proposed objective function includes the reliability indices and distribution network losses. Object Function (OF) has been formulated based on minimizing power loss and improving three reliability indices; Reliability Indices of System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) are improvement indices from the viewpoint of costumes and Cost of Energy Not Supplied (CENS) is from the viewpoint of distribution company. Thus OF is formulated as:

$$OF = \sum_{k=1}^{ny} \left\{ \frac{SAIFI_k}{SAIFI_0} + \frac{SAIDI_k}{SAIDI_0} + \frac{CENS_k}{CENS_0} + \frac{Loss_k}{Loss_0} \right\} \tag{7}$$

Where, ny is the system lifetime, $Loss_0$, $SAIFI_0$, $SAIDI_0$, and $CENS_0$ are indices values before placement. By this technique values of four indices are normalized.

3.2Constraint Functions

Conditions of the problem are mainly the limitations of utilization and the problems that must be considered in relation to power quality. Our problem involves a series of equal and unequal constraints. The unequal constraints are related to the bus voltage, power-flow and the maximum injection power to each bus which should be within a certain range. Equivalence also involves load flow equations, which must be true for all variables in the system. In the following, each of these constraints will be investigated along with the corresponding equations.

Load Flow Constraint: Load flow is the first step in optimal capacitor placement. However, the observance of the load flow in solving power system problems is obvious, but its expression is indicative of its importance. The load flow relations for active power and reactive power are formulated as follows[27]:

$$P_{gi} - P_{di} - V_i \sum_{j=1}^{N} V_j Y_{ij} \cos(\delta_i - \delta_j - \theta_{ij}) = 0 \quad (8)$$

$$Q_{gi} - Q_{di} - V_i \sum_{j=1}^{N} V_j Y_{ij} \sin(\delta_i - \delta_j - \theta_{ij}) = 0 \quad (9)$$

P_{gi}, Q_{gi}: Active and Reactive power generation in *i* bus.

P_{di}, Q_{di}: Active and Reactive loads in *i* bus.
V_i, δ_i: Measuresand the Voltage phase angle of *i* bus.
Y_{ij}, θ_{ij}: Bus Matrix admittance and admittance angle.

Voltage and Power Constraints: With the location, the value of the voltage of each bus should be changed within a reasonable range, the bus voltage below the lowest defined voltage means the ineffectiveness of the proper distribution of capacitor banks, in terms of size and capacity, and between the bus and the value Most of the voltage above the defined threshold creates overvoltage problems. Voltage change in a reasonable range, as one of the objectives of the capacitor location, is specified as follows[28]:

$$V_i^{min} \le V_i \le V_i^{max}; i = 1,2,\dots,N \quad (10)$$

Where V_i is the *i*-th bus voltage.

The range of losses between the bus and the distribution network is calculated from the Equation (11):

$$P_{ij}^{min} \le P_{ij} \le P_{ij}^{max}; i = 1,2,\dots,N \quad (11)$$

$P_{ij}$is the active power from bus *i* to *j*.

Installed Capacity Constraint: The maximum capacity of the installed capacitor should be less than or equal to the reactive load in the network, which means that the installed capacitor must not be so large that the network goes from the self-to-capacitive mode and shows capacitive behavior. This concept is given by[29]:

$$Q_C^{Total} = \sum_{i=1}^{N_C} Q_i \ ; \ Q_C^{Total} \le Q_L \quad (12)$$

Q_C^{Total}, the VAR connected loop by capacitor banks for radial distribution network; and Q_L is the Reactive loads in the redial distribution network.

4. Proposed GSO Algorithm

In this section, the proposed optimization algorithm is introduced based on the group search technique. The population of the GSO algorithm is called a group and each individual in the population is called a member. Suppose*n*-dimensional search space, the *i*th member at the *k*th searching bout (iteration) has a current position: $X - i^k \in R^n$;and head angle: $\phi_i^k = (\phi_{i1}^k, \phi_{i2}^k, \dots, \phi_{i(n-1)}^k) \in R^{n-1}$; that the search direction of the *i*th member is a unit vector $D_i^k(\phi_i^k) = (d_{i1}^k, d_{i2}^k, \dots, d_{i(n-1)}^k) \in R^n$ can be calculated from ϕ_i^k via a polar to Cartesian coordinate transformation [30, 31].

$$d_{i_1}^k = \prod_{q=1} \cos\left(\phi_{i_q}^k\right) \quad (13)$$

$$d_{i_1}^k = \sin\left(\phi_{i_{(j-1)}}^k\right) . \prod_{q=1} \cos\left(\phi_{i_q}^k\right); \quad (j = 2, \dots, n-1) \quad (14)$$

$$d_{i_1}^k = \sin\left(\phi_{i_{(j-1)}}^k\right) \quad (15)$$

In GSO, a group consists of three types of members: producers and scroungers whose behaviors are based on the Particle swarm (PS) model; and dispersed members who perform random walk motions. For the convenience of computation, we simplify the PS model by assuming that there is only one producer at each searching bout and the remaining members are scroungers and dispersed members. The simplest joining policy, which assumes all scroungers will join the resource found by the producer, is used. In optimization problems, unknown optima can be regarded as open patches randomly distributed in a search space. Group members, therefore, search for the patches by moving over the search space. It is also assumed that the producer and the scroungers do not differ in their relevant phenotypic characteristics. Therefore, they can switch between the two roles. In the following, the tasks and equations of each member of the algorithm are described.

4.1Producers Members

The producer scans three points around it to find a better position. At the *k*th iteration, let the producer's position denoted by the $X_p^k = (X_{p1}^k, X_{p2}^k, \dots, X_{pn}^k)$. First, the producer scans a point in front of it:

$$X_Z = X_p^k + r_1 l_{max} D_p^k(\phi^k) \quad (16)$$

Second, it scans a point on its right-hand side:

$$X_r = X_p^k + r_1 l_{max} D_p^k\left(\phi^k + \frac{r_2 \theta_{max}}{2}\right) \quad (17)$$

Third, it scans a point on its left-hand side:

$$X_l = X_p^k + r_1 l_{max} D_p^k \left(\phi^k - \frac{r_2\theta_{max}}{2}\right) \tag{18}$$

where, r_1 is a random number normally distributed with mean 0 and standard deviation 1, r_2 is a random number uniformly distributed in[0,1].The θ_{max} is maximum pursuit angle, and the l_{max} is max-pursuit distance as follows:

$$l_{max} = \|U_j - L_j\| = \sqrt{\sum_{j=1}^{n}\left(U_j - L_j\right)^2} \tag{19}$$

Where, U_j and L_j are the upper bound and lower bound of the search range for the jth dimension. If the producer finds that the best position in the three points is better than its current position, it moves to the best position and change its head angle as Eq.(20),where α_{max} is the max-turning angle.

$$\phi^{k+1} = \phi^k + r_2\alpha_{max} \tag{20}$$

Otherwise, it stays at original position. If the producer fails to find a better point in a iterations, it scans front again as Eq.(21):

$$\phi^{k+\alpha} = \phi^k \tag{21}$$

Where, α is a constant given by round ($\sqrt{n+1}$).

4.2Scrounger Members

In the computation, most of the members are chosen as scroungers. In each iteration, a number of group members are selected as scroungers. The scroungers will keep searching for opportunities to join the resources founded by the producer. If the ith member is chosen as a scrounger at the kth iteration, it moves toward the producer with a random distance,

$$X_i^{k+1} = X_i^k + r_3\left(X_p^k - X_i^k\right) \tag{22}$$

Where, $r_3 \in R^n$ is a random sequence that uniformly distributed in the range (0,1).

4.3 Ranger Members

The rest members in the group are rangers. If the ith member is chosen as a ranger at the kth iteration, it turns its head to a random angle as Eq.(20), and calculates the search direction using Eqs. (13-14), then moves to that direction with a random distance as the following:

$$l_i = a.r_1.l_{max} \tag{23}$$

4.4 Solving the Problem by Proposed GSO Algorithm

So far, the concept of optimal capacitor placement problem, distribution network functions and relations, and the GSO algorithm has been presented. In the following, the capacitor placement problem solution by GSO algorithms discussed.

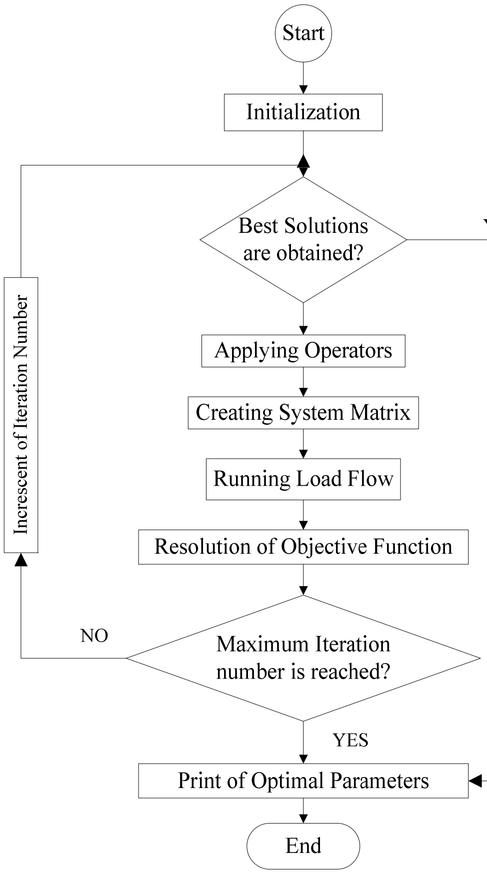

Fig.1. Determining Optimal Location and Size of Capacitor Banks Based on Improving Reliability Indices

In this algorithm, initially, by entering the system information, the load flow program was done by considering the constraints of the load flow problem. Then, using the sensitivity analysis presented in Eq. (11), the candidate buses for determining the capacitor are determined. Finally, the values of the objective function, including reliability indices and loss based on the candidate buses, are calculated.Fig.1shows the proposed flowchart of optimal capacitor placement solution by the GSO algorithm in order to find the capacitor placements in which improves the reliability indices and reduces power loss in power distribution network.

5. Simulation Results

In this section, based on the proposed algorithm for finding the best capacitor placements with the aim of increasing reliability and reducing power losses rates, the simulation results will be presented. It should be noted that the simulation code has been prepared in the MATLAB® program setting, and simulations have been performed on capacitor elements in accordance with IEEE standard test system. Accordingly, the capacitor bank on 14-step has been considered[32]. The corresponding data on this type of capacitor bank is presented in Table 3.

Table 3. Capacity and cost of each capacitor bank[32]

Step	Capacity (kV.Ar)	Cost ($)
1	25	57.73
2	50	81.64
3	100	115.47
4	125	129.10
5	150	141.42
6	200	163.20
7	250	182.57
8	300	200.00
9	400	230.94
10	500	258.19
11	650	294.39
12	800	326.59
13	1000	365.14
14	1200	400.00

Also, system power is divided into ten load levels which value of each load level and corresponding duration have been listed in Table 4. In the study process, the number of capacitor banks starts from one and continues the capacitor is economic justification.

Table 4. Load level and duration of capacitor bank

Step	Load Level (kV.Ar)	Duration (y)
1	0.1391	0.0486
2	0.1101	0.1692
3	0.0609	0.2584
4	0.1304	0.1979
5	0.1130	0.6057
6	0.1014	0.8237
7	0.0841	0.8106
8	0.0812	0.8022
9	0.1014	0.7081
10	0.0783	0.8594

5.1Optimal Values

Based on simulations, the optimal values of capacitor placement in the 34 bus IEEE distribution system are shown in Table 5. In the study process, five parameters have been compared: SAIFI (*f/y*), CENS (*$*), power losses (*kW*) and objective function functions (without unit).The first column of the table represents capacitor installation states. By considering results of the table, in the case of no capacitor installation, the SAIFI, SAIDI, CENS and power losses are high value and in the case of one, two, three, and four capacitors, these values are decreasing, respectively. The bulk of these parameters are better when installed in four capacitors than in other states. Generally improving reliability from one to four capacitors is considerable while by installing the fifth capacitor, the system parameters can be worse destruction. This trend continues in the presence of six capacitor banks.

Table 5.Optimal values of capacitor placement

No.	Power losses	CENS	SAIDI	SAIFI	OF
0	221.4904	241784918	16.7245	23.9344	4.0000
1	68.8941	1173629	8.1684	11.6678	1.9488
2	62.4402	11406418	7.9234	11.3299	1.8922
3	59.1447	1140627	7.9059	11.3021	1.8888
4	63.6595	126575	7.8557	11.2410	1.8749
5	69.5618	1317411	8.7583	12.4030	2.1049
6	62.6449	1304123	9.4429	13.4716	2.2297

This indicates that the system is saturated in the presence of five banks and the reactive power capacitor capacitance is much more. In the presence of at least one capacitor bank, the aim of the network is reduced by more than half.

5.2. Optimal Location & Size of the Installed Banks

Fig 2. shows the optimal location and size of the placed capacitor banks on a standard system. In each bank, the first number is the number of capacitor bank and the second is the size of the capacitor bank. Due to the Fig. 2, its can claimed that buses 14 and 18 are the most likely location to install a capacitor. In bus 11, in the presence of six capacitor banks, two banks have been installed which it is a Weakness for six capacitors placement. Most capacitor bank capacity is 650 *kVAr*.

5.3Steps change of the placed capacitor banks

Changes Steps capacitor banks for placement of units are provided in Fig 3. As shown, the placements of the capacitor banks are arranged from one to six units. Demonstrated results show that the maximum range of step change is related to the sixth capacitors, and the maximum local capacitor steps obtain in the second and sixth load level. Based on the Fig 3, whenever the capacitor step changes are smooth and flexible, the best placement of capacitor is attained. On the contrary, if these changes are suddenly and sharp, the worst placement of capacitor is attained. Accordingly, the capacitor 6 is the worst case in this distribution network; hence, it has the maximum range of changes in capacitor step.

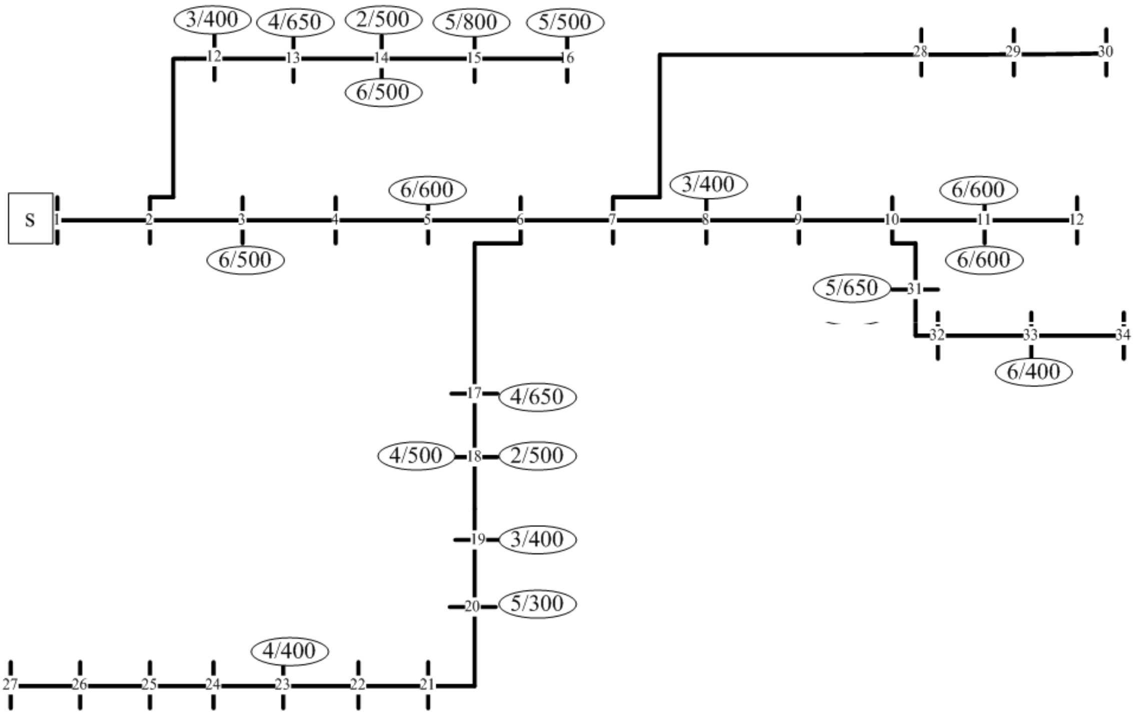

Fig.2. Single Line Diagram of the Test System

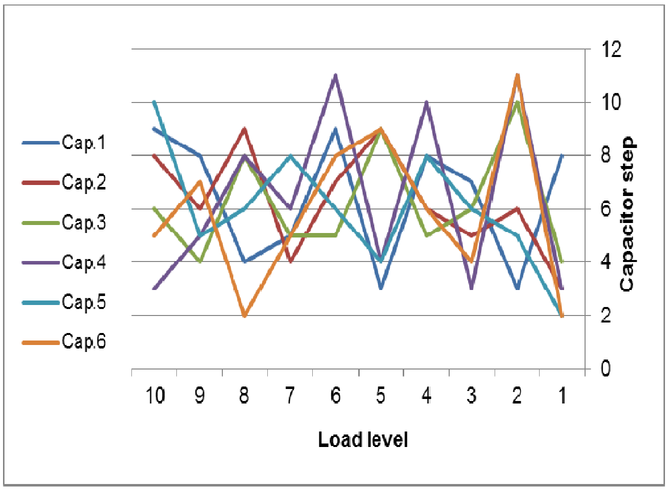

Fig.3. Placement of six capacitors and steps change of the placed capacitor banks

6. Conclusions and Future Work

Shunt capacitor banks installation in distribution systems leads to; energy (power) loss reduction, increasing the available capacity of feeders, voltage profile improvement and power factor correction. Main problem in installing capacitor banks is finding optimal location and size so that annual cost of system minimized. In this paper, in order to optimization aforementioned problem, two main challenges related to the distribution network in stalling capacitor banks are: the improvement of reliability (due to the variety and number of equipment, the structure of the entity and the close relationship with consumers) and the minimization of power losses (due to the high level of current flow in the distribution network) are considered. To achieve this goal, we introduce an objective function for GSO algorithm implemented on the 34-bus IEEE standard that could cover either the reliability indices or the power loss parameter. The simulations results show the placement of four capacitors present the best solution and, in the worst case the six capacitor bank have been installed in one bus. These results indicate that the increasing the number of capacitors not only increase reliability and reduce power losses, but also increase the cost and complexity of the network distribution structure. In the future work, the authors try to use of enhanced GSO algorithm, to improve the capabilities of the GSO algorithms. Hence, Coordinate Distributed Generation (DG) placement with capacitors is overlapping in terms of minimizing power losses and improving network reliability will be considered since it is one of the topics of interest to network designers.

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