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Research Paper

Optimal Capacitor placement and Sizing based on Capacitor cost, voltage stability Index, loses and different loading used GOA algorithm

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Abstract - The paper provides a new index in order to determine optimal size and location of Capacitor units, minimize system power loses and Capacitor cost, optimize voltage profile and increase voltage stability margin. A multi- objective optimization method is used in order to size and allocate Capacitor; Optimized Improve GOA algorithm is used for this aim. The load variations effects on optimal capacity are studied in this paper. The load variations effects on voltage profile, voltage stability and loses are determined after bus and capacity identification. Linear load variations are considered from 50 to 150% of base load (with 10% steps). Present constraints are system voltage, feeders flow and C capacity limitations. Offered method is used for 34 bus experimental system. All experiments are simulated in MATLAB software. The simulation results show considerable effects of system loses, voltage profile improvement and increased voltage stable margin through expending the least cost.

Keywords: Capacitor location and sizing; GOA Algorithm; cost index; voltage stability index; voltage profile improvement; voltage stability margin; minimize active power loses.

1- There are three main objectives in the operation of the distribution system:1- Electricity delivery to consumers in their places of consumption
2- Lowest possible cost of reaching the first objective 3. To provide the appropriate levels of reliability, the distribution system must be powered by electric feeders with Suitable capacity for consumers. In recent years, the debate has focused on the implementation of smart grids and the transformation of traditional power networks from a centralized structure to distributed production structures to take advantage of various benefits such as economic benefits, reliability, environment, and so on[1,2,3]. The purpose of this structure is to distribute the unilateral distribution network to an active distribution network and to use renewable sources as scattered resources. However, this was not the case in traditional distribution systems [4,5]. The use of distributed generation resources within the distribution system will provide major benefits to planners and users of power systems. One of the main advantages of using this new type of system

is the activation of a large part of the production capacity within the distribution system, which increases reliability [5,6]. At the level of operation or dynamics, taking into account the existence of telecommunication substrates, it is necessary to change the power of their output, which transmits the commands sent from the central control system through the monitoring of the entire network information and analysis [7].

One of the important effects of C installation includes earned economic effects and advantages of installations and consumers that result in tendency to Capacitor usage; it must be considered as an important factor.

Load variations of distribution systems must be considered as certain event in long- and short- term planning.

2- Proposed objective function

2-1- Voltage profile optimization objective function:

Equation 1 applies to voltage profile optimization where Vrated=1pu is optimal voltage and expressed as below [1].

$$f_1 = \sum_{i=1}^{N} (|V_{rated} - V_i|)^2 \qquad (1)$$

2-2- Power loses objective function of distribution systems:

Total active losses of network with N nodes will be obtained from equation 2 [2].

$$f_2 = P_{Loss} = \sum_{i=1}^{N}\sum_{j=1}^{N}\left[\alpha_{ij}(P_iP_j + Q_iQ_j) + \beta_{ij}(Q_iP_j - P_iQ_j)\right] \qquad (2)$$

Where $\alpha_{ij} = \frac{r_{ij}}{V_iV_j}\cos(\delta_i - \delta_j)$ and $\beta_{ij} = \frac{r_{ij}}{V_iV_j}\sin(\delta_i - \delta_j)$. $V_i \angle \delta_i$ is voltage of ith bus and $Z_{ij} = r_{ij} + jx_{ij}$ is impedance of two i and j BusBars. Also, Pj and Pi are injected power of ith and jth BusBars.

2-3- Capacitor cost objective function

Capacitor cost is considered as objective function in order to limit Capacitor cost that must be minimized. Capacitor cost is divided into three sections [2].

2-3-1- Maintenance cost:

(4)

Maintenance cost is for one year. Maintenance cost of planning period is as below:

$$CM = CM_1 \times \sum_{t=1}^{T}\left(\frac{1+InfR}{1+IntR}\right)^t \qquad (5)$$

Where T is operation period, InfR is inflation rate and IntR is interest rate. Current value is installed Capacitor maintenance cost.

2-3-3- Operating cost:

$$CPV(C_2) = C_2 \times \sum_{t=1}^{T} \left(\frac{1 + InfR}{1 + IntR} \right)^t \quad (7)$$

Capacitor economic data for 10 years is used from Table 1.

Table1: c economic information [2].

parameter	Unit	value
c installation cost	MW/$	31800
c operation cost	MW h/$	29
c maintenance cost	MW h/$	7
Inflation rate	%	9
Interest rate	%	12
Planning period	Year	10

2-4- Objective function of voltage stability index in radial distribution system

Voltage stability concept is defined as power system capability in order to maintain network all buses in allowed range after turbulence. In fact, the main reason of instability is system inability in providing sufficient reactivity [2].

Simple power distribution method [2] is introduced in order to extract voltage stability index in radial distribution systems. Extracted stability index is as below:

$$f_3 = C_{RES} = C_1 + CM + CPV(C_2) \quad (8)$$

The index has two advantages, including: the need for load distribution implementation for all VSIs calculation and proper velocity for real time calculations. Whole system voltage stability can be assessed after obtaining voltage stability index of all groups. In this case, a node of minimum VSI corresponds to the most sensitive node.

Now, a new index is defined as total index for distribution network voltage stability as below:

$$OVSI = \sum_{m=2}^{NB} [VSI(m)] \quad (9)$$

The higher OVSI, then network voltage stability will be higher and vice versa.

3- Modeling Capacitor in power distribution studies

C unit capacity is lower compared to conventional power plants, then it is offered that C to be modeled as PQ constant bus in order to load distribution analysis in model distribution systems. A modeled C unit acts as constant PQ bus like negative load in load distribution analysis[1]. In this paper, C is considered and modeled as negative load.

4- Multi-objective fuzzy

Since the study objective functions are more than one objective function, multi- objective methods must be used in order to solve multi- objective optimization. We must find a method in order to get an interstitial response of these functions, since optimization of one objective function worsens other functions. The fuzzy method is used in this study. Accordingly, maximum and minimum of each objective function is calculated separately; that is, problem is solved separately for each objective function and maximum and minimum of each objective function will be obtained. Then, any of them is introduced for fuzzification in order to optimize these functions simultaneously

$$\mu_k(f_i) = \begin{cases} 1 & f_i \le f_{i\,min} \\ \dfrac{f_i - f_{i\,min}}{f_{i\,max} - f_{i\,min}} & f_{i\,min} \le f_i \le f_{i\,max} \\ 0 & f_i \ge f_{i\,max} \end{cases} \tag{10}$$

New objective function after normalization is maximum normalized objective functions minimization; that is, each vector fitness of Imperialist Competitive Algorithm at each repetition will be equal to the greatest normalized objective function among four normalized objective functions. Each vector with smaller objective function is determined as the best identified position [10]. Therefore, the final objective function of this study is defined as a new objective function in order to minimize active power loses and C cost, maximize voltage stability margin index and improve voltage profile simultaneously.

$$F = min\left(max\left(\mu(f_1), \mu(f_2), \mu(f_3), \mu(f_4)\right)\right) \tag{11}$$

Its constraints include:

The Busbar voltage must not be more or less than allowed range [2]:

$$V_i(min) \le V_i \le V_i(max)\ , i = 1, \dots, NB \tag{12}$$

We will have below equation for radial distributive system stability performance [2]:

$$VSI(m) > 0, m = 2,3, \dots, NBr \tag{13}$$

Selected capacity of each source must be standard value and below offered capacity:Lines capacity must not be more than identified allowed range [2]:

$$I_{max} \le 520A \tag{15}$$

5- Capacitor placement and sizing method

Partical GOA Algorithm is a new evolutionary algorithm where optimization technique begins with initial population (G). Some countries are selected as imperialist with minimum cost function and other countries are divided among them as colony. Each colony moves towards its G and tries to get the best position. Some Capacitor are selected as ICapacitor with minimum cost in sizing and allocating Capacitor with final defined objective function in 13 and other remained Capacitor form Capacitor and are divided among Capacitor and are optimized using algorithm of ref [1].

5-1-GOA algorithm:

The locust algorithm was published in 2017. Like other optimization algorithms, this algorithm attempts to find the optimal answer among several responses. Grasshopper optimization algorithm is considered as the most recent and one of the most powerful optimization algorithms [9,11]. The simulation of this article is complete and now you can optimize your problem by changing your target function and with very simple changes. On the other hand, due to the novelty of this algorithm, the publication of scientific articles by it and the implementation of the MATLAB project are much more convenient than other algorithms such as genetic algorithm and particle swarm

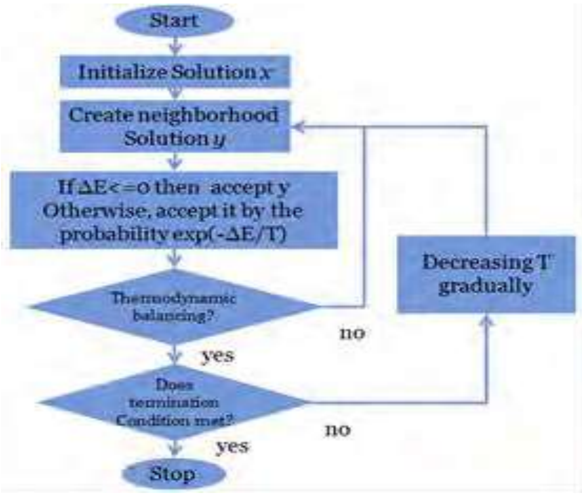

Fig 1-GOA algorithm

6- Results and discussion

In this paper, two radial distribution systems have been selected in order to implement the proposed methodology; a 34-bus radial distribution system with total demand of 637.4MW and 874.2MVAr and a 69-bus radial distribution system with total demand of 3.802 MW and 2.719 MVAr. This networks details are available in [1,2] respectively

As mentioned previously, C units can provide active and reactive power and are modeled as negative loads.

GOA algorithm is implemented and C size and optimal location are determined for each scenario.

6-1- Optimization results for three various levels in 34-bus system

The results are provided below.

Table2. Load variations scenario results without Capacitor in 34-bus system

Before C Installation			
Load Level	**0.5**	**1**	**1.5**
Active Power Loss (Kw)	52.8612	221.7498	525.4368
Reactive Power Loss (Kvar)	15.5381	65.1241	154.1615
Voltage min (pu)	0.9716	0.94169	0.90998
Voltage max (pu)	1	1	1
Voltage Profile	0.011502	0.048318	0.11465
Power Loss	52.8612	221.7498	525.4368
VSI min	0.89104	0.78615	0.6854

Table3. Load variations scenario results in presence of Capacitor in 34-bus system

After C Installation

Load Level	0.5	1	1.5
Active Power Loss (Kw)	32.5535	70.7543	126.7528
Reactive Power Loss (Kvar)	9.5232	19.3372	32.9742
Voltage min (pu)	0.98056	0.97348	0.96487
Voltage max (pu)	1	1	1
F1 Voltage Profil	0.0069913	0.010826	0.016485
F2 Loss	32.5535	70.7543	126.7528
F3 Cost	561318.1514	4288667.631	8545330.279
Installation Cost	72504	553956	1103778
Maintenance Cost	13.4688	102.9061	205.0442
Operating Cost	488800.6827	3734608.725	7441347.235
VSI min	0.92017	0.89799	0.86657

Table4. Simulation results of various three-level load scenario in 34-bus system

Load Level	0.5	1	1.5
Capacitor Size (Kvar)	692.4806	1435.6886	2154.8624
Capacitor pf	0.31331	0.77173	0.84961
Capacitor Bus	25	25	23
Active Loss Reduction	38.42%	68.09%	75.88%
Reactive Loss Reduction	38.71%	70.31%	78.61%
DeltaV	0.02%	0.06%	0.09%

According to above tables, system loses, voltage profile and system voltage stability margin as well as C cost have been optimized considerably at various load levels.

As mentioned previously, load demand varies (from 5% to 150% at 10% steps)..

According to figure 3, C optimal size varies linearly with load level.

Then, we check the effects of C on main issue based on load variations after C placement using optimal values of load based GOA algorithm

6-2 Results of C effects on voltage profile

Figure 2 shows 34 bus experimental system voltage profile under various load levels without Capacitor

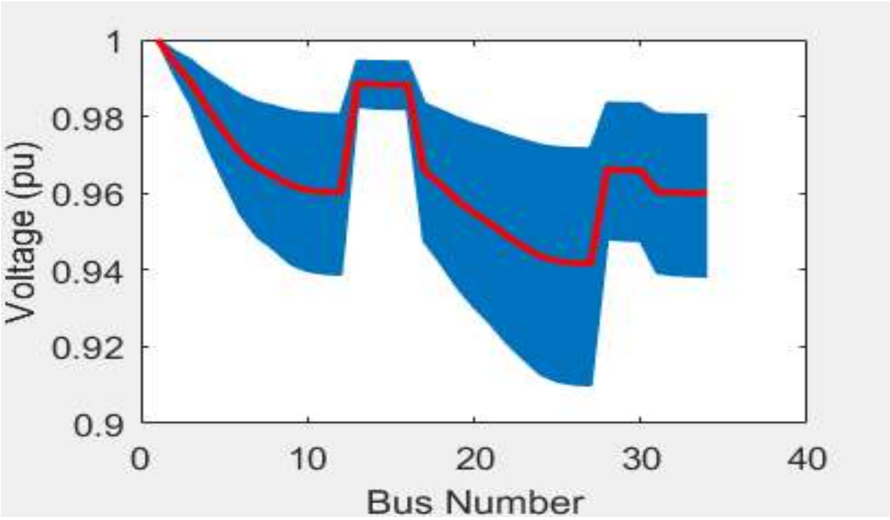

Fig2. System voltage profile at various load levels without Capacitor in 34-bus system

It is clear that reduced load affects positively network voltage profile, while load growth makes it worse.

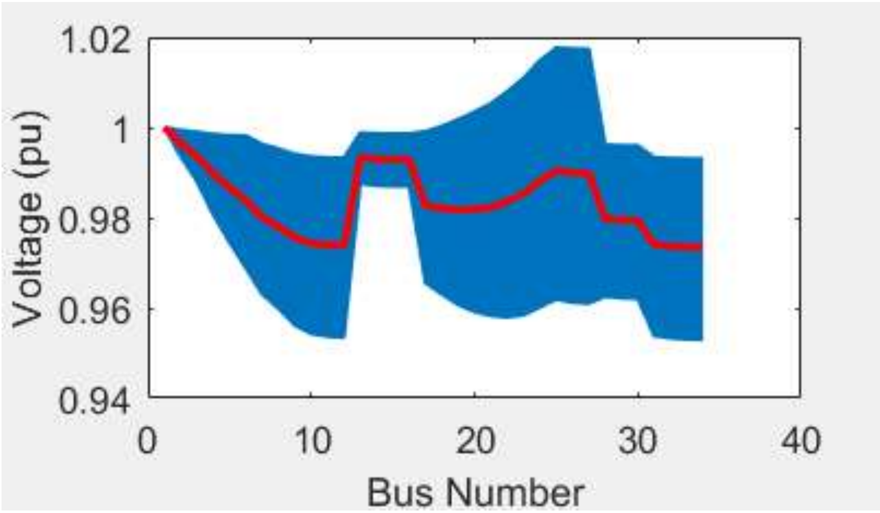

Fig3. System voltage profile at various load levels in presence of Capacitor in 34-bus system

As can be seen, voltage of busses at all levels has increased after one optimal Capacitor unit installation compared to figure 3.

6-4- Results of Capacitor effects on voltage stability

Figure 4 shows VSI curve of 34 bus distribution system at various levels of load.

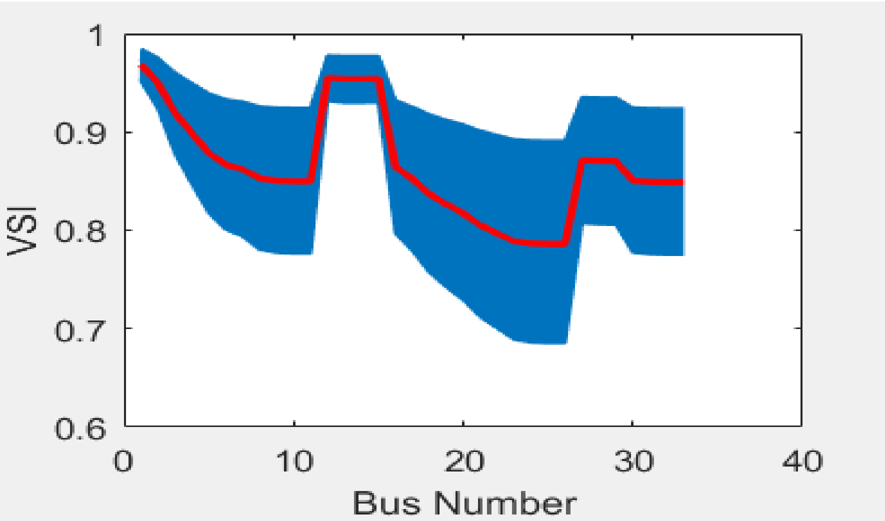

Fig4. All bus VSI at various load levels without Capacitor in 34-bus system

Considering voltage stability, bus 27 has the worst and bus 2 has the best position. Load growth reduces VSI level of all buses, especially of the weakest bus (bus 27) and increases its load.

According to figure 4, bus 27 has minimum VSI value, therefore is the weakest bus due to load position. Network buses VSI are close to limits; they must be considered in Capacitor allocation as decisive factors.

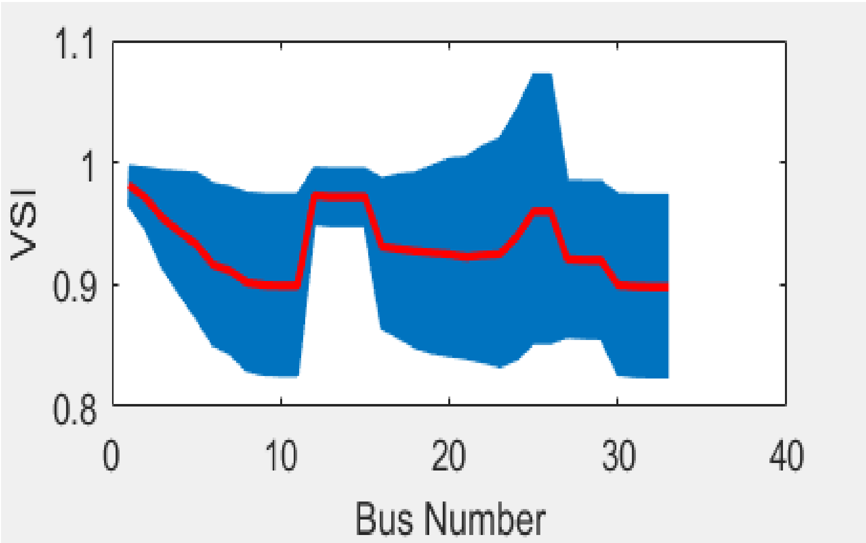

Fig5. All bus VSI at various load levels in presence of Capacitor in 34-bus system

System VSI is shown in figure5 at all load levels and after optimal Capacitor unit installation in bus 25. Comparing figures 4 and 5 shows that VSI of all buses especially the weakest bus (bus 27) is increased.

7. Conclusion

Firstly, results were obtained experimentally for Capacitor placement in load variations in order to optimize system objectives including voltage stability margin and cost profile loses. It was found that increased optimal Capacitor location and size leads to objectives variation but objectives values become the best one. The scenario is theoretpsolly responsive but practpsolly it cannot change Capacitor location and place by load variation. A solution was offered in order to select and implement optimal Capacitor location and size in nominal load using GOA algorithm and fix load variable scenarios (size and location) as well as selected Capacitor respond to voltage level parameters violation (between 95-100%), power loses (as much as possible) and total cost (including installation, operation, maintenance costs). All of mentioned objectives are acceptable in 34 systems. Results show that one optimal model must be used for Capacitor sizing and location and must respond to system power quality based on load variations. In this paper, proposed GOA optimization method is used in order to solve this problem. The results show that study concerns are solved. The long term framework can be proper tool for distribution network planning.

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