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ABC Based Solution for the Optimal Location of Capacitors in a Radial Distribution System

[1]P. Mangaiyarkarasi and [2]M. Ramesh Babu

[1]PG Scholar, Department of EEE, St. Joseph's College of Engineering, Chennai, India
[2]Professor, Department of EEE, St. Joseph's College of Engineering, Chennai, India

Abstract: The transmitting process of power from the generators to the customers encounters higher losses on the distribution system. It is common that the placement of Capacitor is easily controllable and more advantageous in reducing the losses. The overall efficiency of distribution of power is increased by reducing power loss, which constitutes active and reactive components of branch currents, in distribution systems. Power loss reduction in a system is attained by controlling the flow of reactive power. Total power losses in the system are reduced, by the optimal location of the Capacitor using various Artificial Intelligence techniques. Further, the increase in regulation of voltage and reduction of total losses, before and after installing Capacitor by using Artificial Bee Colony Algorithm at its optimal location is discussed and their performance is tested on distribution systems consisting of 33 buses and 69 buses.

Key words: ABC · Capacitor placement · Radial Distribution System · Reactive Power Compensator · Voltage Stability Index

INTRODUCTION

Reactive power compensation is a common technique, which is used for reducing the losses in the distribution system [1]. This can be done by the following methods such as Shunt Compensation, Synchronous Condensers etc. [2]. From the above, Shunt compensation is widely used [3].

The Shunt compensator used here is Capacitor. Installing shunt capacitors is more beneficial as it reduces kVA loading in generator, upgrades regulation of voltage and reduction of losses in the system [4]. Reactive power compensation is essential to avoid voltage collapse and improving the voltage profile [5].

In this work optimal positioning and sizing of capacitors are determined using ABC algorithm. This algorithm is useful for reducing losses and upgrading voltage profile [6].

Positioning Capacitors at correct place reduces the losses and upgrades the voltage profile in the system. In this work optimal positioning and sizing of capacitors are determined using ABC algorithm. This algorithm is useful for reducing losses and upgrading voltage profile.

Installation of capacitors evaluates the size and position of the same to be placed which reduces the losses and upgrades the voltage profile in the system.

Voltage Stability Index: The nodes which are more responsive to voltage collapse are identified using this factor.

$$VSI(m) = |V_l|^4 - 4\{P_m.X_{lm} - Q_m.R_{lm}\}^2$$
$$-4\{P_m.R_{lm}) + Q_m.X_{lm}\}^2.|V_l|^2$$

The point, where $VSI(m)$ has lesser value, is more likely to collapse. The current value is the lacking point where the voltage collapse starts from this node. $VSI(m)$ factor must always be maximized for avoiding any kind of collapse in voltage.

Problem Formulation: The aim is to upgrade the loss reduction and voltage profile with respect to the constraints:

Maximize

$$\{K_e(R_{lbc} - P_{lac}).Tip - \gamma[C_{ic}.N_{CB} + C_{cp}.\sum_{l=1}^{N_{CB}} Q_{c(l)}] - C_0.N_{CB}] + \rho_a \sum_{m=2}^{N} VSI(m)\} \quad (1)$$

K_e- cost of power, P_{LBC}& P_{Lac}-total original power loss before and after compensation, Tip–scheduled period, γ-deterioration factor, C_{ic}–insertion cost, N_{CS}–total buses, C_{cp}- purchase cost,

Corresponding Author: P. Mangaiyarkarasi, Department of EEE, St. Joseph's College of Engineering, Chennai, India.

$Q_{c(l)}$- amount of reactive power of installed capacitors.

Equality Constraints:

- Power Balance limits

$$P_{sl} = \sum_{i=1}^{nl} P_D(l) + \sum_{j=1}^{n} P_L(m)$$

$$Q_{sl} + \sum_{l=1}^{N_B} Q_C(l) = \sum_{l=1}^{nl} Q_D(l) + \sum_{m=1}^{n} Q_L(m)$$

P_{sl} & Q_{sl}- watt and watt less power from reference bus, $P_D(l)$ & $Q_D(l)$-watt and watt less power demand, $P_L(m)$ & $Q_L(m)$- watt and watt less power loss.

Inequality Constraints:

- Voltage Limits

$V_{l,min} \leq |V_l| \leq V_{l,max}$ l = 1, …….N

$V_{l,\ min}$- lower acceptable voltage limit, $V_{l,max}$-upper acceptable voltage limit

- Reactive Compensation Limit

$Q_{ci}^{\min} \leq Q_{ci} \leq Q_{ci}^{\max}$, ,   l = 1….. N_B

$Q_{ci}^{\min}$ & $Q_{ci}^{\max}$ - lower and upper watt less power limit

- Line Capacity Limit

$S_{lia} \leq S_{lia}^{rated}$ $i = 1\ldots\ldots n$

S_{lia} – existing line flow, S_{lia}^{rated}- existing rated line transfer capacity

Selection of Node and Sizing of Capacitor: It encloses the methodology for OCP to identify the optimal positioning and size of the capacitor. Selecting node for capacitor installation provides excellent results for reducing losses and upgrading voltage profile. Choosing the capacitor size depends upon selecting appropriate node in the system.

Capacitor size must be chosen appropriately for reduction of losses. Various kinds of methods are used to identify the size of capacitor to be installed.

List of methods that have been used to solve this problem are PSO, Tabu search, BFOA etc. From the above ABC technique is chosen to identify the size of the capacitor.

Solution Methodology: It is a very simple, vigorous and population based randomized algorithm which requires a few control parameters to be adjusted. It contains three stages: Worker Bee stage, Non-Worker Bee stage and Look-out Bee stage.

Essential Steps:

I : Worker bees are provided with the food sources initially.
II : Perform once more.
III : Pass the worker bees to their area of source and calculate their quality.
IV : Pass the non-worker bees to their area and calculate their quality.
V : Pass the look-out bees for identifying new solutions.
VI : Remember the excellent solution found so far.
VII : Up till [requisites are crossed].

The flowchart of ABC using OCP is given below:

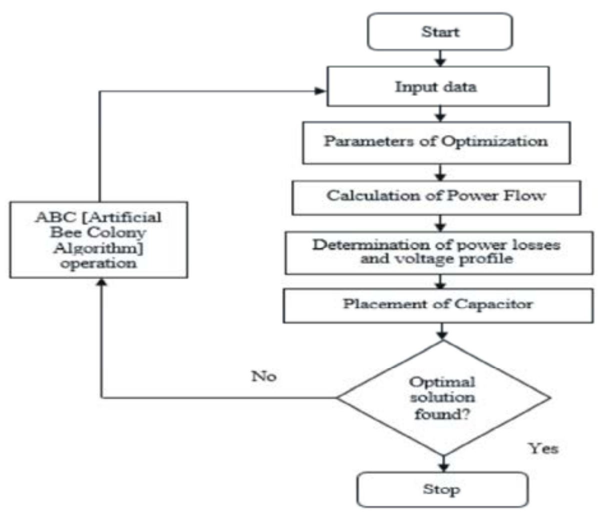

Fig. 1: Flowchart of ABC using OCP

RESULTS AND DISCUSSIONS

This is analyzed on 33 bus system and 69 bus system. The one line diagram of 33 bus and 69 bus is shown in Figure 2 and 3.

33 bus system:

33 bus system _33 buses and 32 branches
Base voltage _11kV
Base MVA _100.
Bus 1 is slack bus and other buses are PQ bus.

69 bus system:

69 bus system _ 69 buses and 68 branches
Base voltage _11kV
Base MVA _100
Bus 1 is considered to be slack bus and rest other buses are PQ bus.

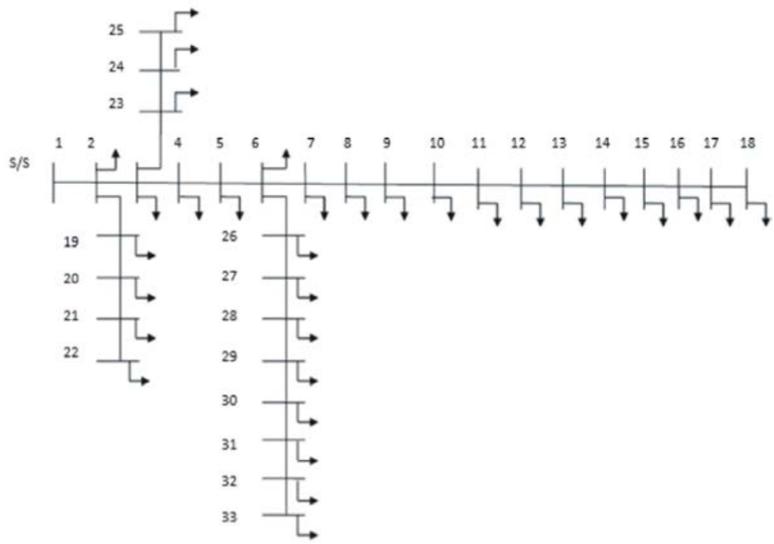

Fig. 2: 33 bus system

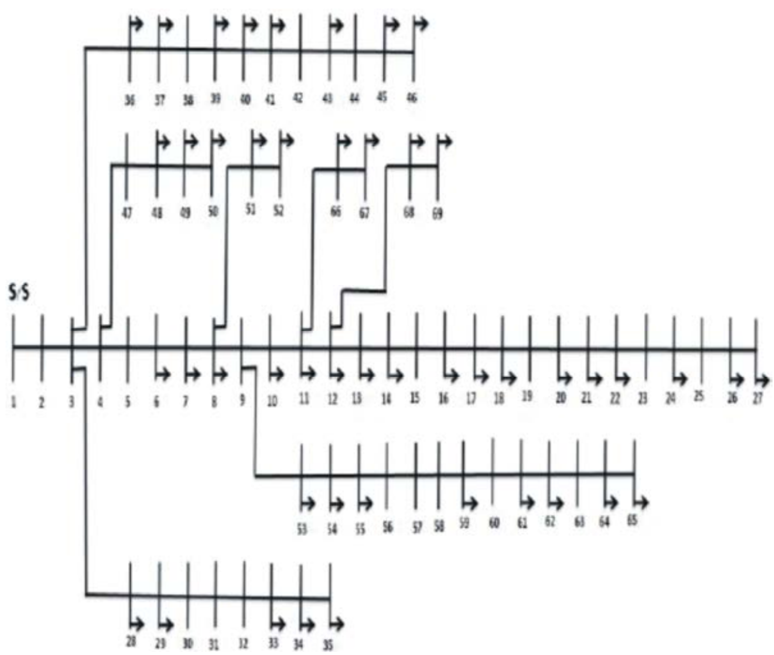

Fig. 3: 69 bus system

Analysis of 33 bus system:
Before Capacitor location:

Real and Reactive power loss before capacitor placement	=	267.42 kW [Real], 180.55 kVAR [Reactive]
Minimum system voltage	=	0.8820 p. u. (at node 15)

Voltage stability index is used to select the optimal node. The nodes 15, 31 and 30 are attained by the same.
Total Compensation provided=3142.94
Bus 31= 958.42
Bus 30=1042.85
Bus 15=1141.67

After Capacitor Location:

Real and Reactive power loss after capacitor placement	=	183.22 kW [Real], 122.62 kVAR [Reactive]
Minimum system voltage	=	0.9444 p. u. (at node 15)

Characteristicsof Convergence: This shows the characteristics for 33 bus system. Here the capacitance cost reduces with respect to the assessments, in this technique.

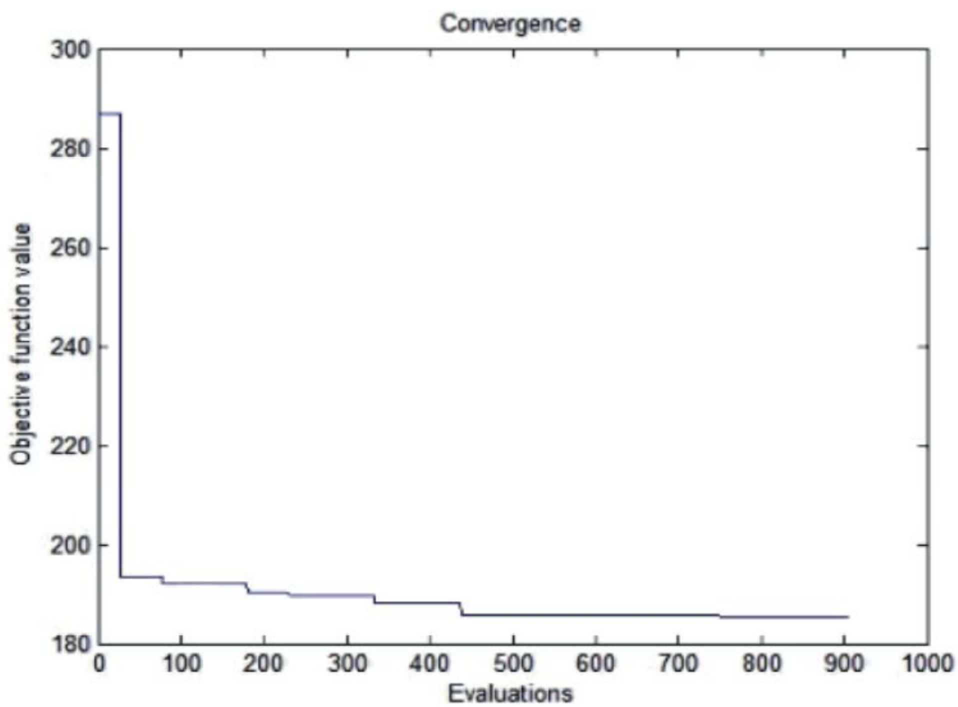

Fig. 4: Characteristics of Convergence for 33 bus system

Voltage Profile Before and after Capacitor Location:

Red line _ voltage profile before capacitor location
Blue line _ voltage profile after capacitor location

Thus, the voltage profile for the system has been enhanced and the minimum p. u. voltage has been upgraded from 0.8820 to 0.9444.

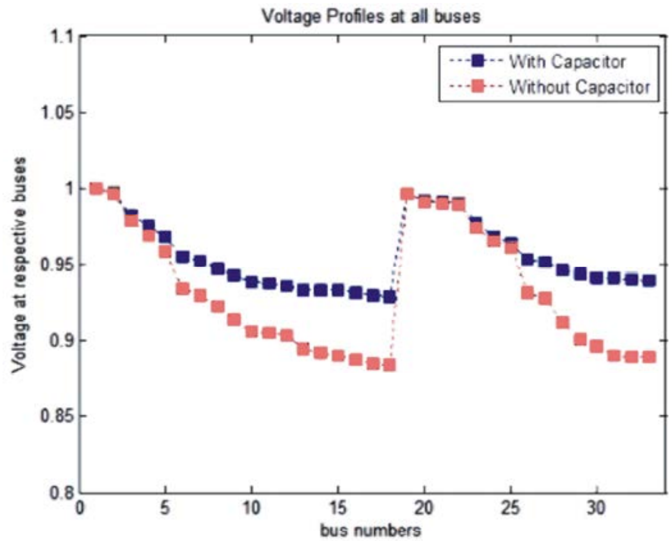

Fig. 5: Voltage profile before and after location of capacitor for 33 bus system

Analysis of 69 bus system:

Before Capacitor location:

Real and Reactive power loss before capacitor placement = 349.89 kW [Real], 155.35 kVAR [Reactive]

Minimum system voltage = 0.8724 p. u. (at node 60)

Voltage stability index method is used to select the optimal node. The nodes 15, 31 and 30 are attained by the same. Total Compensation provided=2131.63

Bus 61= 987.42

Bus 60=898.56

Bus 58=245.65

After Capacitor Location:

Real and Reactive power loss after capacitor placement = 231.77 kW [Real], 103.34 kVAR [Reactive]

Minimum system voltage = 0.9100 p. u. (at node 60)

Characteristicsof Convergence: This shows the characteristics for 69 bus system. Here the capacitance cost reduces with respect to the assessments, in this technique.

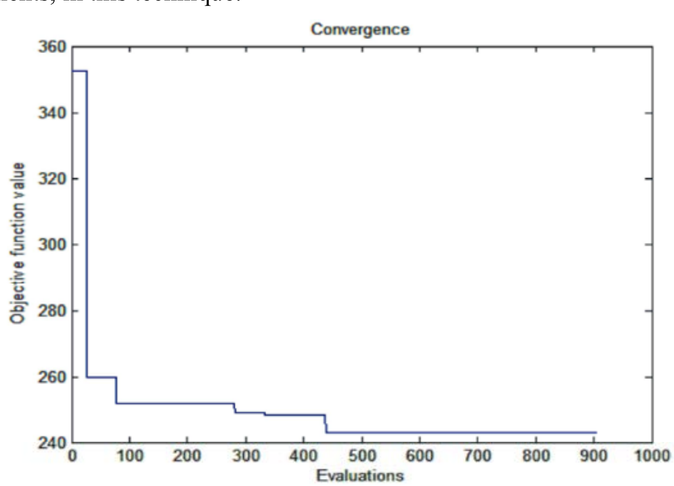

Fig. 6: Characteristics of Convergence for 69 bus system

Voltage Profile before and after capacitor location:
Red line _ voltage profile before capacitor location
Blue line _ voltage profile after capacitor location

Thus, the voltage profile for the system has been enhanced and the minimum p. u. voltage has been upgraded from 0.8724 to 0.9100.

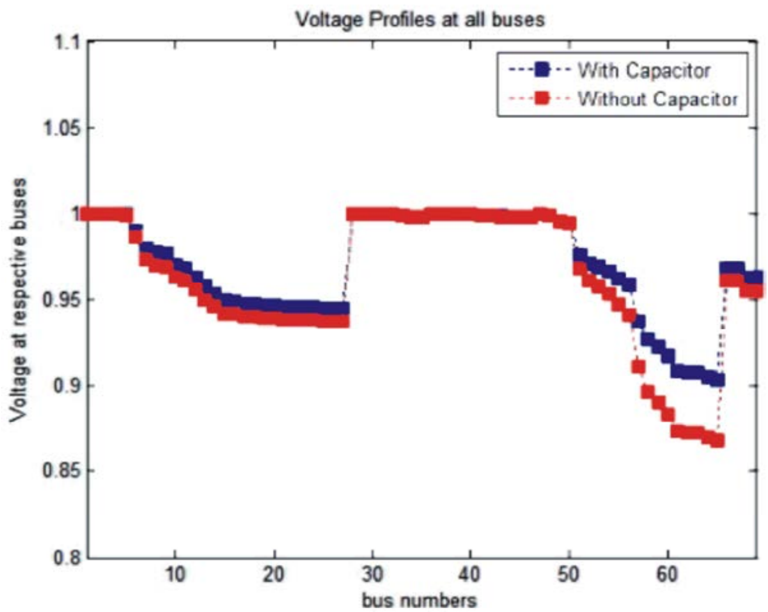

Fig. 7: Voltage profile before and after location of capacitor for 69 bus system

Thus, the capacitor injected at its optimum position, Buses 31, 30 and 15 for 33 bus network and Buses 61, 60 and 58 for 69 bus network, the Voltage Regulation has been upgraded and the total power losses are reduced.

CONCLUSION

The work was carried out to reduce the total power losses and to upgrade voltage profile using ABC algorithm in a 33 bus and 69 bus system. The objective was attained by locating capacitor at different buses. The results thus obtained were efficient and comparable with other methods.

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